Rajarata University of Sri Lanka
Mihintale

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SYMPOSIUM PROCEEDINGS



INTERNATIONAL SYMPOSIUM OF RAJARATA UNIVERSITY OF SRI LANKA

Sustainability nexus: Climate Actions, Technological Innovations and Global Collaborations

ISymRU 2026

Sustainability Nexus: Climate Actions, Technological Innovations, and Global Collaborations

International Symposium of Rajarata University of Sri Lanka

Extended Abstracts

Hosted by:

Faculty of Management Studies, Rajarata University of Sri Lanka

International Symposium of Rajarata University of Sri Lanka (ISymRU) 2026
Proceeding Book

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Page Layout by:
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We gratefully acknowledge our keynote speakers, distinguished guests, and invited speakers for honouring the symposium with their presence and for sharing their valuable insights and expertise. We extend our sincere thanks to the vice chancellor, deans of all faculties, chairperson, co-chairperson and secretaries of ISymRU 2026, advisory board, editorial board, all the committee coordinators and members of ISymRU 2026 for its invaluable guidance, encouragement, and continued support throughout the planning and implementation of the symposium.

Our heartfelt appreciation goes to the extended abstract reviewers, panel chairs and panelists, and resource persons of pre-symposium workshops and webinars for generously dedicating their time, knowledge, and expertise to ensure the academic quality and success of ISymRU 2026. We warmly thank all authors, researchers, and presenters for sharing their research findings, innovative ideas, and scholarly contributions.

Our sincere appreciation is extended to the academic and non-academic staff of Rajarata University of Sri Lanka for their unwavering commitment, cooperation, and dedication towards making this event a success. We also gratefully acknowledge the administrative and technical staff whose tireless efforts and behind-the-scenes contributions have been instrumental in the smooth coordination and successful execution of the symposium.

We further express our profound gratitude to all industry partners and sponsors who provided financial, material, and logistical support. Their generosity and collaboration have played a vital role in facilitating this important academic event and strengthening the university's research partnerships.

International Symposium of Rajarata University of Sri Lanka 2026
Introduction

The International Symposium of Rajarata University of Sri Lanka (ISymRU) 2026 represents a significant milestone in the continued commitment to advancing knowledge, promoting research excellence, and fostering meaningful academic and professional collaboration at the university. ISymRU 2026, themed under 'Sustainability Nexus: Climate Actions, Technological Innovations, and Global Collaborations', brings together researchers, academics, industry professionals, policymakers, and emerging scholars, the symposium provides an opportunity to exchange innovative ideas, share research findings, and explore solutions to contemporary challenges through interdisciplinary dialogue and scholarly engagement.

The extended abstracts were presented in this book under six different tracks: Sustainable Agriculture, Ecosystem Intelligence, Strategic Governance & Conscientious, Health Equity & One Health, Inclusive Futures, and Next-Gen Syntheses.

Beyond the presentation of research findings, ISymRU 2026 underscores the importance of strengthening partnerships among universities, industries, public institutions, and other stakeholders. Such collaboration is essential for translating research into practical solutions, enhancing innovation, nurturing entrepreneurial thinking, and ensuring that academic knowledge contributes meaningfully to society.

The publication of these proceedings serves not only as a record of the research presented at ISymRU 2026 but also as a lasting scholarly resource for academics, practitioners, policymakers, and future researchers.

As Rajarata University of Sri Lanka continues to strengthen its role as a centre of academic excellence and social contribution, ISymRU 2026 reaffirms the University's dedication to cultivating a vibrant research culture that values intellectual curiosity, innovation, inclusivity, and societal relevance.

Message from the Chancellor
Rajarata University of Sri Lanka



It is with profound pride and great satisfaction that I issue this message on the occasion of the International Symposium of Rajarata University of Sri Lanka (ISymRU 2026). Situated in the historical and culturally eminent region of Mihintale, Rajarata University has consistently striven to honor its heritage by fostering academic distinction, impactful research, and community-driven knowledge creation. The launch of ISymRU 2026 represents a landmark moment in our institutional evolution, transitioning our research tradition into a broader, globally connected academic movement.

The theme chosen for this year's symposium, ***"Sustainability Nexus: Climate Actions, Technological Innovations, and Global Collaborations,"*** comes at a critical juncture in human history. Modern societies are grappling with interconnected crises, ranging from climate vulnerability and environmental degradation to rapid technological shifts and economic uncertainties. In addressing these global challenges, higher education institutions must serve not merely as centers of teaching, but as proactive hubs of evidence-based solutions, ethical guidance, and interdisciplinary dialogue.

By bringing together international and local scholars, policy makers, industry leaders, and emerging researchers, ISymRU 2026 creates an essential space for cross-border collaboration and knowledge exchange. The academic tracks curated for this event reflect a holistic commitment to societal well-being, driving research that directly supports sustainable development goals and national priorities.

I extend my heartiest congratulations to the Vice Chancellor, the Dean and faculty members of the Faculty of Management Studies, the Symposium Committee, track chairs, reviewers, and student volunteers for their tireless efforts in bringing this international event to fruition. I also express my gratitude to all the authors, keynote speakers, and participating institutions for enriching this symposium with their intellectual contributions.

May ISymRU 2026 spark transformative ideas, cultivate lasting international partnerships, and inspire research that meaningfully serves humanity. I wish the symposium outstanding success.

Rev. Eathalwetunuwewe Gnanathilaka Thero
The Chancellor
Rajarata University of Sri Lanka, Mihintale

Message from the Vice Chancellor
Rajarata University of Sri Lanka



It gives me immense pleasure to extend a warm welcome to all participants for the International Symposium of Rajarata University of Sri Lanka (ISymRU 2026).

ISymRU 2026 represents the flagship university-wide academic gathering of Rajarata University of Sri Lanka, embodying our steadfast commitment to expanding intellectual horizons and advancing multi-disciplinary research on a global scale. Building on the solid foundation and momentum established by previous editions of the symposium, ISymRU 2026 continues to serve as an enduring international platform for rigorous scholarship, evidence-based inquiry, and transformative ideas.

The theme of ISymRU 2026, ***"Sustainability Nexus: Climate Actions, Technological Innovations, and Global Collaborations,"*** underscores the urgency of integrating digital capabilities with environmental stewardship and international partnerships. Through our six multidisciplinary tracks, the symposium addresses the multifaceted nature of contemporary global challenges. By adopting a hybrid format on October 29, 2026, we ensure that geographical boundaries do not limit scholarly participation or the dissemination of high-impact research findings.

A university's core mission is to generate knowledge that transforms communities and industries. ISymRU 2026 exemplifies this mission by bridging the gap between theoretical frameworks and empirical applications. I commend the Faculty of Management Studies and the organizing committee for their visionary leadership in steering this prestigious event. I also convey my deep appreciation to our keynote speakers, session chairs, reviewers, paper presenters, industry partners, and sponsors for their invaluable contributions.

I trust that the insights, debates, and networks developed during ISymRU 2026 will inspire innovative solutions and strengthen academic-industry partnerships for years to come. I wish all participants a productive and memorable experience at ISymRU 2026.

Prof. PMB Jayathilake
Vice Chancellor
Rajarata University of Sri Lanka, Mihintale

Message from the Dean
Faculty of Management Studies



On behalf of the Faculty of Management Studies at Rajarata University of Sri Lanka, it is an absolute honour and privilege to welcome you to the International Symposium of Rajarata University of Sri Lanka (ISymRU 2026).

Since our faculty initiated the National Research Symposium of Management (NRSM) back in 2017 under the theme "Exploring Business Insights", we have remained dedicated to nurturing a vibrant research culture among undergraduates, academics, and industry practitioners. Over the years, our symposiums have navigated diverse global and national economic shifts, from exploring "*Wisdom for Sustainability*" and "*Building Resilience*" in times of crisis, to understanding "*The BANI World*" and "*Merging Talent and Technology for Transformation*". Today, as we host ISymRU 2026, we proudly build upon that foundation, broadening our scope to embrace complex global sustainability challenges.

The overarching theme for ISymRU 2026, ***"Sustainability Nexus: Climate Actions, Technological Innovations, and Global Collaborations,"*** reflects the pressing reality of the modern business and social environment. Sustainable development can no longer be viewed in isolation; it requires a strategic convergence of technological advancement, climate-conscious governance, economic inclusivity, and multi-sectoral collaboration. The six thematic tracks curated for this symposium provide an exceptional platform for researchers to present extended abstracts, showcase empirical evidence, and debate emerging management and social paradigms.

As the host faculty, we are particularly proud of the role ISymRU plays in supporting early-career scholars and undergraduates. Providing a rigorous platform where young researchers can present their work alongside experienced international academics, receive constructive peer feedback, and publish their findings is fundamental to building future research capacity.

I express my profound gratitude to the University Administration, led by the Vice Chancellor, for their continuous guidance. My heartfelt thanks go to the Symposium Chairperson, Prof. WHMS Samarathunga, the Co-Chairpersons, Dr. SNS Dahanayake and Dr. NHK Cooray, the Symposium Secretaries, Mrs. HMRD Kularathne and Mr. TUS Senarath, as well as all the other sub-committees whose dedicated efforts made this symposium possible. I also acknowledge our sponsors and national and institutional partners for their trust and generous support. I wish all researchers, session chairs, and delegates an intellectually stimulating, productive, and enjoyable symposium experience.

Prof. HMBP Ranaweera
Dean
Faculty of Management Studies,
Rajarata University of Sri Lanka, Mihintale

Message from the Symposium Chairperson



It is with great pleasure that I share this message in my capacity as Chairperson of the International Symposium of Rajarata University of Sri Lanka (ISymRU 2026). This year's theme, "Sustainability Nexus: Climate Actions, Technological Innovations, and Global Collaborations," reflects an urgent global imperative. As humanity confronts the interconnected challenges of climate change, technological disruption, environmental degradation, and socioeconomic inequalities, the need for interdisciplinary research, responsible innovation, and meaningful international collaboration has never been greater. Universities have a vital responsibility not only to advance knowledge but also to translate research into solutions that benefit communities, inform policy, and shape a sustainable future.

Hosting ISymRU 2026 in the historic setting of Mihintale adds particular significance to this mission. As a place deeply connected to Sri Lanka's cultural heritage and longstanding traditions of coexistence between humanity and nature, Mihintale reminds us that sustainability is not merely a contemporary scientific ambition but an enduring responsibility to future generations.

Against this backdrop, our ambition is to position ISymRU beyond a conventional research dissemination platform, as a catalyst for international research partnerships, interdisciplinary innovation, and evidence-informed solutions to global challenges. The symposium brings together diverse scholarly perspectives across six thematic tracks, complemented by internationally recognised keynote speakers, expert panel discussions, and interactive pre-symposium sessions. Through its hybrid format, we seek to broaden international participation and create opportunities for meaningful academic exchange.

Equally important is our commitment to nurturing emerging scholars. We envision ISymRU as an inclusive intellectual space where early-career researchers can engage with established academics, challenge conventional perspectives, develop professional networks, and discover new opportunities for collaborative inquiry. Ultimately, the true value of this symposium should be measured not only by the research presented but also by the partnerships established, ideas exchanged, and positive changes inspired beyond its conclusion.

I wish you all an intellectually stimulating, inspiring, and memorable symposium.

Prof. WHMS Samarathunga
Chairperson
International Symposium of Rajarata University of Sri Lanka 2026

Message from the Symposium Co-Chairpersons





It is a great privilege to welcome researchers, academic scholars, industry professionals, and students from across the globe to the International Symposium of Rajarata University of Sri Lanka (ISymRU 2026).

Scholarly research is a collaborative journey that grows through open dialogue, rigorous peer evaluation, and shared knowledge. The theme of ISymRU 2026, ***"Sustainability Nexus: Climate Actions, Technological Innovations, and Global Collaborations,"*** was selected to address the urgent need for integrated solutions in an increasingly interconnected world. Whether examining climate adaptation, digital transformation, ethical governance, or community resilience, our goal has been to provide a platform where high-impact research can inform policy, industry practices, and future academic inquiry.

In our roles as Co-Chairpersons, we have had the privilege of working alongside a dedicated team of academic track coordinators, editorial board members, and international reviewers. We received a significant number of extended abstract submissions from diverse research domains. Through a rigorous double-blind peer-review process, we curated technical sessions that highlight theoretical depth, methodological strength, and practical relevance. Furthermore, by organizing the event in a hybrid format, we have ensured seamless participation for both local attendees in Mihintale and international delegates joining virtually.

We extend our sincere gratitude to the Vice Chancellor, the Dean of the Faculty of Management Studies, and our Symposium Chairperson, Prof. WHMS Samarathunga, for their constant leadership and support. We are equally grateful to our keynote speakers, panel experts, session chairs, and corporate sponsors whose partnerships have enriched this symposium.

Most importantly, we thank all contributing authors and presenters. Your commitment to advancing knowledge is what drives ISymRU 2026 forward. We hope that the proceedings of this conference offer valuable insights and spark long-term academic and professional collaborations.

Dr. SNS Dahanayake & Dr. NHK Cooray
Co-Chairpersons
International Symposium of Rajarata University of Sri Lanka 2026

Message from the Symposium Secretaries





It gives us immense satisfaction to convey this message on the occasion of the publication of the Proceedings and the opening of the International Symposium of Rajarata University of Sri Lanka (ISymRU) 2026.

Organising an international academic event of this scale involves months of meticulous planning, operational coordination, and collective effort. From the initial call for papers and managing abstract submissions through the editorial review process, to coordinating technical logistics for our hybrid sessions, pre-symposium webinars, and venue setup at the Faculty of Technology in Mihintale, our goal has been to deliver an inspiring and seamless experience for every delegate.

The theme of ISymRU 2026, ***"Sustainability Nexus: Climate Actions, Technological Innovations, and Global Collaborations,"*** reflects our collective ambition to advance sustainable development through actionable research. We are honoured to facilitate a platform that brings together academics, practitioners, policy makers, and student researchers from around the world.

This symposium would not have been possible without the guidance and support of many individuals. We extend our deepest gratitude to the Vice Chancellor and the Dean of the Faculty of Management Studies for their steadfast encouragement. We express our gratitude to our Symposium Chairperson, Prof. WHMS Samarathunga, Co-Chairpersons, Dr. SNS Dahanayake and Dr. NHK Cooray, and the coordinators of all the sub-committees, for their guidance and fullest support throughout this process. We also recognise the hard work of all track coordinators, sub-committee members, technical teams, administrative and non-academic staff, and student volunteers who worked behind the scenes to make ISymRU 2026 a success.

Finally, we extend our heartfelt appreciation to all keynote speakers, both national and international partners, session chairs, authors, and participants. Your scholarly engagement and shared commitment to knowledge creation are the true foundation of this symposium. We wish you an engaging, productive, and memorable experience at ISymRU 2026.

Mrs. HMRD Kularathne & Mr. TUS Senarath
Secretaries
International Symposium of Rajarata University of Sri Lanka 2026

Message from the Keynote Speaker
Vidya Jothi Emeritus Professor Sarath W Kotagama



The world has changed over the last 100 years to become a "confused" and "lost" in its future direction.

Starting from the "fossil fuel" saviour in the forties, we have achieved immense "progress" in terms of its application to become the dependent human being on that very resource. We never expected it to become the "biggest" threat contributor to our present and future. Despite the alarm calls given as way back as 1876, we did not heed to the science. Our single most desire to be the "superior being" on this planet, deterred us to look deeply in to the fundamentals of ecological and environmental sciences.

Coupled with the emergence of "economics" as a distinct social science in **1776** with the publication of Adam Smith's seminal book, *An Inquiry into the Nature and Causes of the Wealth of Nations* a subject that touched the hearts with powerful message for "self-indulgence" in benefits even at the expense of the majority – "profiteering". This has resulted in a society totally "polarised and radical". In order to attain "self-sustaining" benefits, it has caused our actions to make human kind a extremely selfish and destructive being. Coupled with numerous "artificial" products our quest for superiority had no bounds.

The wakeup call, resulting from the 1970 "Earth Day programme" resulted in a plethora of terminologies, which themselves has provided a convenient cover to scrumptiously continue the disaster in the guise of "development". To achieve the status of the "rich" we agreed to transfer the strategies of the "developed" to the un-developed or Under developed countries – termed as "poor" in 1972. The folly was recognized in 10 years and we all agreed to move in a different pathway called "sustainable development". The primary theme of this very conference- Sustainability nexus. Yes, it is very much a nexus, yet the most fundamental question is - have we understood sustainability?

Other developments in the "sciences and technological applications" have equally progressed in the last couple of years. It is causing deep concern with regards to "Climate Action" – why must this be the case?, followed by "technological innovations" such as "Artificial Intelligence or AI". Despite these advances we are still stuck with the basic question. We are not ready to understand and respond to them, so that our concerns can be reversed. Have we recognized the difference between "NEEDS and- WANTS", which is the primary factor that is driving our minds to continue the situation, through our actions of the present"

Prof. S W Kotagama
Vidya Jothi Emeritus Professor
Department of Zoology and Environment Sciences
University of Colombo

Message from the Keynote Speaker
Dr. Asha de Vos



I am deeply honoured to deliver the keynote address at the International Symposium of Rajarata University of Sri Lanka (ISymRU) 2026, under the timely theme, "Sustainability Nexus: Climate Actions, Technological Innovations, and Global Collaborations."

My journey in marine science, conservation, and storytelling has been long, challenging, and immensely fulfilling. What began as a childhood fascination with adventure and science evolved into a lifelong commitment to the ocean, particularly to unravelling its mysteries, sharing its stories, and protecting it. Through my pioneering research on blue whales in the Northern Indian Ocean, I was able to show the world how little we know, even of the largest animal that has roamed our planet and highlight the role of tropical ecosystems like ours in the lives of these giants. This work has advance scientific knowledge but also demonstrate that groundbreaking discoveries can emerge from places and communities often overlooked in global scientific discourse.

Yet, my journey has taught me that scientific discovery alone is insufficient. Our success hinges on how equitable and inclusive we are in the process of our scientific and decision-making processes. My strong desire to ensure that, across the world, marine science and conservation are conducted in an inclusive and equitable manner has required continued advocacy for dismantling archaic colonial models that have limited the capacity and opportunities of many in our parts of the world. While this has been a personal quest for over a decade, I built Oceanswell to showcase new models of scientific partnership.

I firmly believe that the future of science must be collaborative, inclusive, and locally empowered. Global partnerships should strengthen local scientific capacity rather than perpetuate dependency. This principle resonates strongly with the symposium's emphasis on sustainability, innovation, and international collaboration.

Through this journey, I have remained immensely proud to be Sri Lankan and to showcase the capacity of our people and region to contribute to global scientific advancement. I hope my experiences will encourage researchers, particularly emerging scholars, to challenge conventional boundaries, pursue their passions with courage, and recognise that meaningful global change can begin with a curiosity about your own backyard.

I look forward to sharing my journey and engaging with the ISymRU 2026 community.

Dr. Asha de Vos
Marine Biologist and Ocean Educator
Founder and Executive Director, Oceanswell
Adjunct Research Fellow, University of Western Australia Oceans Institute
Member, United Nations Secretary-General's Scientific Advisory Board

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Department of Biochemistry, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka.

Prof. K. Weerakoon
Department of Parasitology, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka.

Prof. W.P. Wijewardena
Department of Accountancy and Finance, Faculty of Management Studies, Rajarata University of Sri Lanka.

Prof. N. Wickramasinghe
Department of Community Medicine, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka.

Prof. P. N. Yapa
Department of Biological Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka.

Dr. R.K. Ahinsa
Department of Chemical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka.

Mr. A.A.D.P. Bandara
Department of Accountancy and Finance, Faculty of Management Studies, Rajarata University of Sri Lanka.

Dr. M.M.K. Bandara,
Faculty of Technology, Rajarata University of Sri Lanka

Dr. N.H.K. Cooray
Department of Marketing Management, Faculty of Management Studies, Rajarata University of Sri Lanka.

Dr. S.N.S. Dahanayake
Department of Tourism and Hospitality Management, Faculty of Management Studies, Rajarata University of Sri Lanka.

Dr. H.A.N. Dharmagunawardhane,
Department of Materials Technology, Faculty of Technology, Rajarata University of Sri Lanka

Dr. D.M.D. Disanayake
Department of Plant Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka.

Dr. U. Ekanayake
Department of Physical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka.

Dr. J. Fernando
Department of Agricultural Engineering and Soil Science, Faculty of Agriculture, Rajarata University of Sri Lanka.

Dr. W.A. Gunarathne
Department of Physical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka.

Dr A. Hettiarachchi
Department of Community Medicine, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka.

Dr. A.L.M. Jameel
Department of Accountancy and Finance, Faculty of Management Studies, Rajarata University of Sri Lanka.

Dr. N. Jayaratna
Department of Chemical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka.

Dr. R.A. Jayarathna,
Department of Materials Technology, Faculty of Technology, Rajarata University of Sri Lanka

Dr. D. Jayasundara
Department of Microbiology, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka.

Dr. Y. Kalyani
Department of Information & Communication Technology, Faculty of Technology, Rajarata University of Sri Lanka

Dr. S.M.C.B. Karalliyadda
Department of Agricultural Systems, Faculty of Agriculture, Rajarata University of Sri Lanka.

Mr. E.J. Kosgollegara
Department of Agricultural Engineering and Soil Science, Faculty of Agriculture, Rajarata University of Sri Lanka.

Mrs. H.M.R.D. Kularathne
Department of Human Resource Management, Faculty of Management Studies, Rajarata University of Sri Lanka.

Dr. H. Kulathilake
Department of Computing, Faculty of Applied Sciences, Rajarata University of Sri Lanka

Dr. J.D.T. Madhusanka
Department of Marketing Management, Faculty of Management Studies, Rajarata University of Sri Lanka.

Dr. J.K. Mallika
Department of Business Management, Faculty of Management Studies, Rajarata University of Sri Lanka.

Mr. P.G. Munasinghe
Department of Information Systems, Faculty of Management Studies, Rajarata University of Sri Lanka.

Mr. H.P.K. Pathirana
Department of English Language Teaching, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka.

Dr. K. R. E. Padmathilake
Department of Plant Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka

Ms. T.D.C. Priyadarshani
Department of Plant Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka

Mr. N.M.K.C. Premarathne
Department of Agricultural Systems, Faculty of Agriculture, Rajarata University of Sri Lanka.

Mr. R.M.G.H.N. Ratnayake
Department of Information Systems, Faculty of Management Studies, Rajarata University of Sri Lanka.

Mrs. K.A.K.S. Rathnakara
Department of Human Resource Management, Faculty of Management Studies, Rajarata University of Sri Lanka.

Dr. L.P. Rupasena
Department of Agricultural Systems, Faculty of Agriculture, Rajarata University of Sri Lanka.

Mr. T.M. Siriwardana
Department of Archeology, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka

Ms. T.M.C. Senarathna
Department of Social Sciences and Humanaties, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka

Dr. S. Senevirathne
Department of Chemical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka.

Dr. A.N.L.M. de Silva
Department of Social Sciences, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka.

Dr. U.G.A.I. Sirisena
Department of Plant Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka.

Dr. P. Siriwardhana
Department of Social Sciences, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka.

Dr. W.W.A.N. Sujeewa
Department of Human Resource Management, Faculty of Management Studies, Rajarata University of Sri Lanka.

Dr. G. Thilakarathna
Department of Animal and Food Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka.

Dr. N. Thilakarathna
Department of Information & Communication Technology, Faculty of Technology, Rajarata University of Sri Lanka

Dr. Y.M.W.G.P.K. Udurawana
Department of Marketing Management, Faculty of Management Studies, Rajarata University of Sri Lanka.

Dr. E. Wiligas
Department of Tourism and Hospitality Management, Faculty of Management Studies, Rajarata University of Sri Lanka.

Dr. W.M. T.B. Wijepala
Department of Archaeology and Heritage Management, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka.

Mr. W. Wickramaarachchi
Department of Information & Communication Technology, Faculty of Technology, Rajarata University of Sri Lanka

Dr. A. Wijegunawardhana
Department of Bioprocess Technology,
Faculty of Technology, Rajarata University of Sri Lanka, Mihintale

Mr. N. S. Weerakoon,
Department of Computing, Faculty of Applied Sciences, Rajarata University of Sri Lanka

Mr. G.A.K.N.J. Abeyrathne
Department of Economics, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka.

Dr. M.I.M. Shuja
Department of Physiology, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka.

Mr. A.I.Y. Lankapura
Department of Agricultural Systems, Faculty of Agriculture, Rajarata University of Sri Lanka.

Mr. M. Mohomed
Department of Physical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka.

Dr. H. Fernandez
Department of Biological Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka.

DR. N. Prasangini
Department of Information & Communication Technology, Faculty of Technology, Rajarata University of Sri Lanka

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Department of Agricultural Biology, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

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Department of Marketing Management, Faculty of Commerce and Management Studies, University of Kelaniya.

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Faculty of Social Sciences and Languages, Sabaragamuwa University of Sri Lanka.

Prof. A. Shanthaarachchi
Professor in Economics, Department of Economics and Statistics, Faculty of Social Sciences and Languages, Sabaragamuwa University of Sri Lanka.

Prof. B. Wanninayake
Department of Marketing Management, Faculty of Commerce and Management Studies, University of Kelaniya.

Prof. R.A.S. Weerasiri
Department of Marketing Management, Faculty of Commerce and Management Studies, University of Kelaniya.

Dr. D. N. Jayarathne
Associate Professor, School of International Education, Jiangxi Science and Technology Normal University, China.

Dr. S. Bandara
Department of Marketing Management, Faculty of Commerce and Management Studies, University of Kelaniya.

Mrs. T. Dissanayake
Department of External Affairs Coordinator, Faculty of Business Studies and Finance, Wayamba University of Sri Lanka.

Dr. M. Fernando
Department of Marketing Management, Faculty of Commerce and Management Studies, University of Kelaniya.

Mr. N. Gunawardena
Department of Marketing Management, Faculty of Commerce and Management Studies, University of Kelaniya.

Dr. S. Gunathilake
Department of Chemistry, Faculty of Science, University of Peradeniya.

Dr. S.K. Illangarathna
Librarian, Bhiksu University of Sri Lanka.

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Department of Computer Science, Faculty of Science, University of Jaffna.

Dr. D.W.M.M.M. Kumari
Department of Biosystems Technology, Faculty of Technology, University of Sri Jayewardenepura.

Dr. M.J.M.S. Kurera
Department of Biotechnology, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka.

Dr. M.M.M. Mufassirin
Department of Computer Sciences, Faculty of Applied Sciences, South Eastern University of Sri Lanka.

Dr. S. Patabendige
Department of Marketing Management, Faculty of Commerce and Management Studies, University of Kelaniya.

Dr. K. Prabhashini
Department of Mass Media, Sri Palee Campus, University of Colombo, Wewala, Horana, Sri Lanka.

Dr. N.R. Perera
Department of Marketing Management, Faculty of Commerce and Management Studies, University of Kelaniya.

Ms. R.M.U.R.K. Rathnayaka
Department of Marketing Management, Faculty of Management Studies, University of Peradeniya.

Mr. D.T. Ratnayake
Department of Marketing Management, Faculty of Management Studies and Commerce, University of Sri Jayewardenepura.

Dr. M. Rathnayake
Department of Sinhala, Faculty of Arts, University of Peradeniya.

Dr. N. Rodrigo
Department of Mathematics, Faculty of Science, University of Peradeniya.

Dr. A. Rukshan
Department of Marketing Management, Faculty of Business Studies, University of Vavuniya.

Dr. D. Sandaruwan
Department of Oceanography, Ocean University of Sri Lanka.

Dr. S. Somasiri
Department of Marketing Management, Faculty of Management Studies and Commerce, University of Sri Jayewardenepura.

Dr. D.K. Thilina
Department of Marketing Management, Faculty of Commerce and Management Studies, University of Kelaniya.

Dr. C.N.R. Wijesundara
Faculty of Management Studies, Sabaragamuwa University of Sri Lanka.

Dr. B. Wijesundara
Department of Marketing Management, Faculty of Commerce and Management Studies, University of Kelaniya.

Ms. S. Wijenayake
Department of Marketing Management, Faculty of Commerce and Management Studies, University of Kelaniya.

W. A. G.K. Wickramainghe
Department of Physical Sciences, Faculty of Applied Sciences, South Eastern University of Sri Lanka.

Ms. K.D.M.K. Weeratunge
Department of Marketing Management, Faculty of Management Studies, University of Peradeniya.

Mr. T. Arudchelvam
Department of Computing and Information Systems, Faculty of Applied Sciences, Wayamba University of Sri Lanka.

Mrs. R.P.T.H. Gunasekara
Department of Computing and Information Systems, Faculty of Applied Sciences, Wayamba University of Sri Lanka.

Dr. D.S. Vithanage
Department of Information and Communication Technology, Faculty of Technology, University of Ruhuna.

Mr. C. Dissanayake
Department of Technology, Faculty of Indigenous Health Sciences and Technology, Gampaha Wickramarachchi University of Indigenous Medicine.

Dr. R.H.G.R. Wathsala
Research Fellow, University of Bologna, Italy.

Mr. M. Withanage
Fish Nutritionist, National Aquaculture Development Authority of Sri Lanka.

Dr. S. Jayawardana
Senior Research Scientist, Food Technology Section, Industrial Technology Institute, No. 503/A, Halbarawa Gardens, Thalahena, Malabe.

Dr. D. Munasinghe
Senior Scientist and Chartered Town Planner, National Building Research Organisation (NBRO).

Dr. K. Kumari
National Institute of Fundamental Studies, Hanthana Road, Kandy.

Mr. N De Silva,
Geophysicist, Director Mineral Exploration, Geological Survey and Mines Bureau

Table of Content

Oral presentations

Sustainable Agriculture: Advancing Climate Resilience, Food System & Livelihoods

Integrated Effect of Urea–*Gliricidia* Nutrient Management on Nitrogen Use Efficiency and Productivity of Maize in Southern Sri Lanka 3
Liyanage A.

Sustainable Agricultural Practices in Indigenous Communities: A Case Study of Henanigala South Indigenous (Vedda) Village, Sri Lanka 9
Jayarathne S.M.C.D. and Chandrasekara C.M.K.N.K.

Predatory Efficiency of *Coccinella transversalis* and *Micraspis discolor* on Different Developmental Stages of Whitefly (*Aleurodicus rugioperculatus*) 14
Jayakody S. and Vinobaba M.

Productivity Change and Resource Use Efficiency in Sri Lanka Inland Fisheries: Evidence From a DEA–Malmquist Index Analysis 18
Sandaruwan W.H.A., Kesavamoorthy V., Wickramanayaka D.G.A.M. and Bandaranayka P.W.S.M.C.

Determinants of Participation of Smallholder Tea Farmers in Organised Green Leaf Marketing Channels: Evidence From the Southern Province of Sri Lanka 22
Pradeep M.U., Kuruppu I.V., Nanayakkara G.L. and Dharmasiri P.G.T.M.

An Investigation into the Development of Agriculture in Thirukkural 26
Sindhuja K.

Climate-Resilient Coconut Production: Evaluating Girdle Micro-Sprinkler Irrigation Under Dry Zone Conditions 28
Nusrath H.F., Warnasooriya W.M.R.S.K., Piyarathne P.N.M.S., Gunasekara M.A.P. and Sandamali G.G.A.

Effect of Cooking Methods on the Quality of Purple-Fleshed Sweet Potato Flour (*Ipomoea batatas* L.) 33
Sudasinghe I.U., Weerakoon W.M.S.U., Wijesundara W.M.N.M. and Arachchige M.P.M.

Stochastic Frontier Analysis of Dairy Farm Production Efficiency in the Baddegama and Balapitiya Veterinary Ranges, Galle District 37
Gajasinghe P.P., Hitihamu H.M.S.J.M, and Magamage M.P.S.

Assessing the Future of Paddy Cultivation in Gampaha District Through Production Trends and Farmers' Perceptions 41
Athukorala K.A.D.R.Y., Bandara A.L.J. and Herath H.M.L.K.

Native *Trichoderma asperellum* Against Rice Brown Leaf Spot Pathogen *Bipolaris oryzae*: A Dual Culture Study 45
Karunarathna U.G.D.S., Mudugama M.V.S.S., Bandara G.A.S.D.P., Priyadarshani T.D.C. and Egodawatta W.C.P.

Technical Efficiency of Tea Smallholders in Mid Country Wet Zone (MW2b), Sri Lanka 49
Rupasinghe E.K.W.G.P.L., Bandara A.L.J. and Herath H.M.L.K.

An Intelligent Multi-Agent Architecture for Climate Risk Assessment and Decision Support 53
Masood A.

Ecosystem Intelligence: Exploring Innovations for a Green Planet through Applied Sciences

The Use of Triglycerides-Producing Marine Photosynthetic Microorganisms for Laboratory-Scale Biodiesel Production 58
Rathnayaka S., Muhandiram A., Ambepitiya H., Jayathilake C., Somasiri M., Basnayaka C., Ekanayake L., Edirisinghe R., Yapa N. and Fernando E.

On the Firefly Algorithm Modification to the Step-Fixed Charge and Facility Location Problem 62
Ekanayake E.M.D.B. and Rodrigo W.N.P.

Extraction, Metal Chelation and Characterisation of Soil-Derived Humic Acid 68
Senanayaka S.R.H.B. and Herath A.C.

Electrochemical Characterisation of Sulfur Dioxide–Benzoic Acid System in Acetonitrile 73
Nisfer I. and Herath A.C.

Laboratory-Scale Establishment of an Enhanced Biological Phosphorus Removal Bioreactor System for Enrichment of Polyphosphate-Accumulating Organisms 78
Herath H.M.H.M., Arachchi V.D.J., Karunarathne W.A.D.C., Somasiri B.M.C., Jayathilake C.M., Muhandiram P.M.A.C., Rathnayaka R.M.S.L.B. and Fernando E.Y.

Photodynamic Action of 5,10,15,20-Tetrakis(4-Carboxyphenyl) Porphyrin (H_2TcPP)–Au Nanocomposite Against Pathogenic *Aspergillus niger* and *Rhizopus* sp. 84
Wannige A.S. and Herath A.C.

VLF Investigation of Shallow Conductive Structures Associated with the Wahawa Geothermal Field, Sri Lanka 89
Chathurya K.A.D.D., Harankahawa S.B., Weligepola W.K.G.V., Navodya T.M.D., Wijewardane H.O., Dahanayake U. and Samaranayake S.A.

Development of Omega-3-Enriched Mayonnaise Using Coconut, Rice and Flaxseed Oil 94
Dissanayake H.M.N.S., Edirisinghe E.M.R.K.B. and Senarath H.P.S.

Strategic Governance & Conscientious: Transforming Business for Sustainability in the Digital World

Digital Minimalism and Employee Job Performance: Evidence From IT Professionals in Sri Lanka 99
Weerasinghe T.D.

Attitudinal Responses to Artificial Intelligence in Sustainable Purchasing Context: A Generation Z Perspective 106
Jayasinghe U.H. and Maphosa V.

Impact of Online E-Commerce on Online Purchase Intention: The Mediation Role of Brand Trust; Electrical Building Material Sector, Sri Lanka 110
Ranjith H.K.M.P., Hendeniya H.M.U.S. and Ranjith H.K.D.S.

Digital Communities in Shaping Female Beauty Standards: A Netnography Study 115
Hendeniya H.M.U.S. and Ranjith H.K.M.P.

Work-Life Balance and Employee Performance in Trincomalee Budget Hotels 120
Namasivayam V. and Dassanayake D.M.C.

Impact of User-Generated Content on Brand Evangelism: The Mediating Role of User Emotion 125
Deshika K.L.I. and Adhikari A.M.S.I.

French Tourists' Pre-Visit and Post-Visit Perceptions of Sri Lanka as a Tourist Destination 129
Premarathna P.G.C.R. and Adhikari A.M.S.I.

Factors Affecting Taxpayers' Satisfaction in Sri Lanka 133
Prathiraja P.A.N.S. and Sameera V.G.N.

Digital Governance and Financial Accountability: A Critical Analysis of Cyber Vulnerabilities in Sri Lanka's Public Finance System 137
Ganegama K. and Fernando R.

The Impact of Mindfulness on Anti-Consumption Behaviour: The Mediating Role of Authenticity 142
Rathnayaka V.A.S. and Madhusanka J.D.T.

Impact of Algorithmic Facebook Ad Personalisation on Unplanned Buying Behaviour: The Mediating Role of Customer Engagement 146
De Silva D.A.D.M. and Madhusanka J.D.T.

Impact of Self-Brand Congruence on Compulsive Buying Behaviour: The Mediating Role of Brand Attachment 150
Wijesuriya D.C.H. and Iroshana M.W.U.K.

Impact of Excessive SNS Usage on Brand Avoidance: The Mediating Role of Social Media Fatigue 154
Aregoda T.M.K.N. and Iroshana M.W.U.K.

Impact of Short Video Marketing on Purchase Intention: Mediating Role of Perceived Value in Sri Lankan Bakery Industry 158
Sewwandi P.G.N. and Adhikari A.M.S.I.

Impact of Brand Experience on eWOM: Mediating Effect of Brand Love in Real Estate, Sri Lanka 162
Rohanadeera S.D. and Adhikari A.M.S.I.

The Impact of Brand Romance on Brand Attachment With the Mediating Effect of Brand Trust in the Smartphone Industry of Sri Lanka 166
Fernando W.C.I. and Adhikari A.M.S.I.

Digital Dreams: Women Entrepreneurs Thriving Through Social Commerce in Central Province, Sri Lanka 170
Kuruppu K.A.D.T.D., Senevirathne Y.Y. and Fernando T.S.S.

A Study on the Problems Affecting the Sustainable Development of the One-Day Fishing Industry 176
Imesha W.K.H.C.

The Impact of Live Streaming Marketing by Online Influencers on Consumer Purchase Intentions: The Mediating Role of Brand Trust in the Fashion Industry in Kandy, Sri Lanka 182
Manusha P.W.A.N. and Wasana K.M.L.K.

Investigating Idiosyncratic Deals on Employee Retention: The Mediating Role of Hedonic Motivation – Evidence From Fashion Stores in Uva Province, Sri Lanka 186
Siromiya S.S.

Exploring Digital Sincerity in TikTok Branding: Understanding Brand Believability in Aesthetic Clinics of Sri Lanka 191
Ranasinghe H.A.D.S. and Hendeniya H.M.U.S.

The Impact of Multisensory Marketing on Customer Loyalty in Badulla District's Food and Beverage Industry 195
Manike R.M.P.P. and Wasana K.M.L.K.

The Effect of Visual Merchandising on Impulsive Buying: The Mediating Role of Customer Emotions with Special Reference to the Apparel Stores 199
Nisansala A.H.C.C. and Wasana K.M.L.K.

Self-Identity and Students' Tuition Class Choice in Ratnapura, Sri Lanka 203
Sewwandi H.A.S. and Cooray N.H.K.

Volatility Dynamics and Forecasting Accuracy of the Sri Lankan Rupee Exchange Rate 207
Vithanage P.T., Bandara A.L.J. and Herath H.M.L.K.

Exploring Entrepreneurial Leadership Styles and Opportunity Identification Among Micro-Entrepreneurs in the North Central Province 213
Maddumage M.O.W. and Cooray N.H.K.

The Impact of Sustainable Packaging on Brand Loyalty With Special Reference to the Food and Beverage Industry in Ampara District, Sri Lanka Among Generation Z 217
Jowdath Aadhil M.Z. and Wasana K.M.L.K.

Exploring Spatial Vulnerability in Public Transportation Spaces 221
Thathsarani M.M.D. and Cooray N.H.K.

The Impact of Social Media Influencers' Reputation Signals on Consumer Purchase Intention: The Mediating Role of Parasocial Relationships With Influencers in the Context of Beauty Brands in the Western Province of Sri Lanka 225
Jayawardhan J.G.H.B. and Hendeniya H.M.U.S.

The Impact of Product Placement Advertising on Consumer Purchase Intention of Gen Z With the Mediation of Brand Recall: Special Reference to the Automobile Industry in the Western Province, Sri Lanka 229
Kumari R. and Hendeniya H.M.U.S.

The Psychological Impact of Using AI Chatbots to Discuss Mental Health among State University Students 234
Werellagama W.M.R.A.U. and Senarath T.U.S.

Determinants of the Privacy Paradox in Cloud Storage Usage among Sri Lankan Undergraduates 239
Dewmini A.M.T. and Ratnayake R.M.G.H.N.

User Acceptance of Passenger Information Systems Among Daily Train Commuters in Western Province 243
Pathirana K.P.R.S. and Bandara K.M.P.G.A.J.

Managing the Negative Impacts of Overtourism Through Sustainable Tourism Practices: A Case Study of Ella 247
Dilshan M.M.G.A. and Dayangana K.T.L.U.S.

Community Readiness, Participation and Challenges in Tourism Development in Loolkandura: Towards a Community-Based Integrated Approach 251
Kavindi G.J.O. and Abeywickrama K.T.N.P.

Influence of Video Gaming Behaviour Among Adolescents 256
Wickramasinghe W.G.L. and Gamini V.K.N.

Health Equity & One Health: Strengthening Global Well-being and Systemic Resilience

Importance of Learning Histology and Embryology in the Medical Curriculum: Student Perspectives on Future Careers 261
Magamage S.D., Muthunayaka M.B.N., Wijesinghe A.G.K.R., Hakmanage N.M. and Kumarasinghe N.

Knowledge, Attitude and Practice of MDI Technique Among Asthmatic Patients Attending the Respiratory Clinic, Teaching Hospital Anuradhapura 265
Ahamed M.F., Bandara B.A.A.S., Anuththara W.A.S., Akshara T., Bahji S.A., Ahamed A.A.A., Bandara M.M.T.C. and Shuja M.I.M.

Localised Non-Traumatic Ocular Nodules of Potential Trematode Aetiology in Children: A Clinico-Epidemiological Study From Anuradhapura, Sri Lanka 270
Kodithuwakku P., Weerakoon H., Wijayasiriwardana W., Asanthi J., Gam Hewage P.G., Widanage G.J.N., Wickramasinghe S., Silva A. and Weerakoon K.

Enterobiasis Among Primary School Children in Anuradhapura District, Sri Lanka 274
Jayakody N., Gordon C., Collinson N., Silva A., Wickramasinghe N., Wickramasinghe S., Wijayasekara A., Karunarathne C., De Silva N. and Weerakoon K.

Utility of Early White Blood Cell Parameters as a Predictor of Snakebite-Induced Acute Kidney Injury 279
Dilrangi T., Mendis V., Waiddyanatha S., Chathuranga U., Isbister G.K. and Silva A.

Methodological Lessons from Developing a Community-Based Intervention to Improve Healthcare-Seeking in Cutaneous Leishmaniasis 283
Gunasekara S.D., Agampodi T.C., Agampodi S.B., Fernando M.S., Weerakoon K.G. and Wickramasinghe N.D.

Menstrual Health-Related Practices among Female Garment Factory Workers in Anuradhapura District, Sri Lanka 287
Weerasinghe D.W.G.K., Senarathna L. and Wickramasinghe N.D.

School-Based Health Promotion Intervention to Improve Adolescent Physical Activity in Anuradhapura District 291
Jayawardena H.S.C., Gunathilake S. and Senarathna L.

Inclusive Futures: Social Science and Humanities for Sustainability and Versatile Future

Employee Retention Motives and Retention Intention: Examining the Moderating Role of Job Embeddedness in Sri Lanka's Apparel Sector 297
Ramesh A.R. and Manjula S.

Exploring Motivational Factors in English Language Learning Among Certificate in English (Extension) Programme Students at Rajarata University of Sri Lanka 302
Nandarathna B.G.D.S., Wehella D.A., Nizam A.A.M. and Pathirana H.P.K.

Algorithms as Cultural Gatekeepers: Social Media Recommendations and Aesthetic Diversity in Sri Lankan Youth Cinema 306
Ranathunga R.M.N.A.

AI-Assisted ESL Pedagogy in Sri Lankan Higher Education: Opportunities, Challenges, and Sustainability 309
Kuruppuarachchi M.T.K.

Impact of Artificial Intelligence-Based Mobile Applications on Second Language Writing Development: A Study Among BAMS Students Learning English as a Second Language 313
Gunarathne D.T. and Dissanayake S.A.R.R.P.

Digital Diplomacy and Soft Power Projection: A Comparative Study of Sri Lanka and Singapore 318
Jayarathna I.

"English as the Icing on the Cake": Exploring the Role of English in the Professional Lives of a Selected Group of Lawyers 322
Wickramasinghe W.M.C.A.

Sustainability Deferred: An Interpretative Phenomenological Analysis of Savings and Financial Survival Under Economic Uncertainty in Pakistan 326
Ajmal M.M., Salman S. and Ali T.

Preparing Humanities and Social Sciences Graduates for the AI Era: A Critical Review 331
Silva H.D. and Weerawansa S.R.S.D.K

Communication Strategies for HIV/AIDS Awareness Programmes in Sri Lanka: A Narrative Review (2015–2024) 336
Perera S.T. and Jayasinghe R.A.N.M.

Exploring the Implementation of Inclusive Education Policies: A Case Study of a Disabled Girl 340
Sanjeewanie R.B.A.

Consecutive Interpreting and Inclusive Communication: Perspectives from Professional Interpreters in Sri Lanka 344
Subangan P.

The Rhythm of Regional Realities: Pitch and Plurality in the Uragasmanhandiya Dialect 348
Rev. Uparathana G., Kumari K.P.P.S., Rev. Chandrasiri O, Dissanayake W., Abeyrathne A., Millagahathenna H., Dayananda N., Rev. Anuruddhasiri K., Wanninayake W.M.R.S.K., Wakista M. and Mathammana D.

Shifting Roles of Religious Populism in Sri Lanka: A Comparative Study of the Mahinda Rajapaksa Era and the Anura Kumara Dissanayake Government 350
Pathiraja K.A.D.M.M.K.

Monetising the Intangible Cost of Cutaneous Leishmaniasis: Patients' Perceptions from Anuradhapura District, Sri Lanka 354
Lalani J.M.G., Agampodi T.A., Prasanna R.P.I.R., Agampodi S.B. and Wickramasinghe N.D.

Strengthening Legal Protection for Tourists in Sri Lanka: Towards a Dedicated Tourist Harassment Offence and Fast-Track Tribunal 358
Kithmini M.N. and Samarathunga W.H.M.S.

Shaping the Context for Social Engagement: How a Business School Mentoring Programme Cited Dominant Discourses to Enable Critical Performativity 361
Racz M.

Next-Gen Syntheses: Converging ICT, Biosystems, and Engineering Technologies for Global Sustainable Development

Diffusion-Guided Semantic Embedding Model for Topic Modelling Using SEDiff-Gen Framework 367
Reddy Ch.N., Gandla D., Sunkara S., Jakku M. and Sankepally S.R.

Development and Characterisation of Starch-Based Biopolymer Films Derived from Ambul and Cavendish Banana Corms 377
Jayasekara G.O.G.P.P.B., Kulathunga K.A.R.R., Liyanawalage T.S., Polkotuwa P.W.C.L.K., Weerasinghe W.D.C. and Yasassri M.A.H.

Transforming Hospitality Feedback into Decision Support Insights Using Fine-Tuned Transformers and Zero-Shot Inference 382
Alagarathnam N. and Krishnamenan R.

A Cost-Effective Real-Time Driver Drowsiness Detection System Using Facial Landmarks and Eye Aspect Ratio 386
Gunathilake M.D.C.J. and Amirthalingam S.

Brain Tumour Segmentation Using Multi-Modal MRI: A Modality Ablation Study with 2D U-Net 391
Jayasekara D.L.P., Wijewardane H.O. and Samaranayake S.A.

Effect of Thermal Pre-Treatment and Acid Leaching on the Electrochemical Characterisation of Pulmoddai Zircon Mineral 396
Sewwandi R.M.N.M., Dharmagunawardhane H.A.N. and Herath H.M.A.M.C.

Green Synthesis of *Syzygium cumini*-Derived Copper Nanoparticles for Selective CO and H_2 Adsorption Towards Syngas Separation 400
Weerawansha G.D., Senevirathne S.A. and Jayaratna N.B.

Poster presentations

Sustainable Agriculture: Advancing Climate Resilience, Food System & Livelihoods

Study of Characterisation of *Kithul* (*Caryota urens* L.) Pith Flour as a Functional Food Ingredient in Matara District in Sri Lanka 407
Jayamanne V.S. and Karunaratne K.A.P.N.

Govi Mithuru: A Smart Farming Mobile Application to Empower Small-Scale Farmers in Sri Lanka 410
Jayathissa T.M.I.M., Layassruthy S. and Johanan I.S.E.

IoT-Based Multi-Sensor and Image Processing Early Warning System for Elephant Intrusion to Mitigate Human–Elephant Conflict in Sri Lanka 414
Silva W.J.K.C. and Yuvanraj S.

Factors Affecting the Adoption of Commercial and Self-Prepared Poultry Feed: Evidence From Kurunegala District, Sri Lanka 419
Kumara L.A.K.G., Kuruppu I.V. and Guruge T.P.S.R.

Economic and Crop Losses From Seasonal Flooding on Paddy Yield and Farmers' Livelihoods in Polonnaruwa District, Sri Lanka 426
Wimalasekra D.R., Bandara A.L.J. and Herath H.M.L.K.

Qualitative and Quantitative Assessment of Cellulase Activity in Endophytic Fungi Associated With *Aquilaria crassna* 429
Navodika K.U.I.S., Wickramasinghe J.A.A.N., Chandrasekera T.V., Withana W.T.G.S.L. and Athapaththu A.M.M.H.

Ecosystem Intelligence: Exploring Innovations for a Green Planet through Applied Sciences

Investigation of Natural Radioactivity Distribution at Wahawa Geothermal Field 435
Navodya T.M.D., Harankahawa S.B., Weligepola W.K.G.V., Chathurya K.A.D.D., Wijewardane H.O., Dahanayake U. and Samaranayake S.A.

Physicochemical Characterisation of Honey Produced by Different Bee Species in Sri Lanka 439
Wijesinghe T., Karunanayake C., Perera N., Daulagala H. and Perera A.

Determination of Crude Total Polyphenols From Sri Lankan Marine *Sargassum ilicifolium* Using Folin–Ciocalteu Assay 443
Fernando H.

Investigation of the Photovoltaic Performance of Dye-Sensitised Solar Cells Consisting of Mn-N Co-Doped TiO_2 Photoelectrodes 446
Silva W.H.H., Thotawatthage C. and Jaseetharan T.

An Incremental Look-Ahead Artificial Bee Colony (ILA-ABC) Algorithm for the Travelling Salesman Problem 452
Akthar M.N.H., Kellar S.S. and Ekanayake E.M.U.S.B

A Hybrid Artificial Bee Colony Algorithm Incorporating Exact Cycle-Cancelling for Capacitated Transshipment 456
Kellar S.S., Akthar M.N.H. and Ekanayake E.M.U.S.B.

Green Synthesis of Silver Nanoparticles Using *Azadirachta indica* for the Adsorptive Separation of Syngas 462
Bandara H.M.H.S., Jayaratna N.B. and Senevirathne S.A.

Strategic Governance & Conscientious: Transforming Business for Sustainability in the Digital World

Digital Socialisation in Consumer Behaviour: A Systematic Literature Review of Theories, Measurements and Consumer Outcomes 467
Ranjith H.K.M.P., Hendeniya H.M.U.S. and Ranjith H.K.D.S.

The Impact of Gamification on Brand Equity: The Mediating Role of Brand Engagement 473
Jayasingha J.M.P.M. and Madhusanka J.D.T.

Advertising Creativity and Footwear Purchase Intention: The Mediating Role of Attitude Toward Advertising 477
Perera W.L.A.L. and Madhusanka J.D.T.

Impact of AI Marketing on Purchase Intention: The Mediating Role of Perceived Value 481
Ududdumbara U.D.A.S. and Madhusanka J.D.T.

Impact of Brand Anthropomorphism and Brand Personality on Brand Loyalty among Fast-Food Consumers 486
Ranasinghe J.A.D.L. and Madhusanka J.D.T.

The Impact of Brand Nostalgia on Brand Attachment: The Mediating Role of Consumer Emotions in Sri Lanka's Television Industry 491
Upeksha L.A.S. and Adhikari A.M.S.I.

Visual and Informational Drivers of TikTok Concert Engagement in Sri Lanka 495
Suraweera S.P.W.G.D. and Hendeniya H.M.U.S.

Advertising Avoidance and Customer Decision-Making on YouTube: The Mediating Role of Perceived Value 499
Siriwardhana S.S.S. and Wasana K.M.L.K.

The Impact of Information Overload on Consumers' Purchase Intention With Special Reference to the Online Fashion Industry in the Eastern Province, Sri Lanka 503
Penuja S. and Wasana K.M.L.K.

The Impact of Electronic Word of Mouth (e-WOM) on Green Cosmetic Purchase Intention: Evidence From Consumers in the Western Province, Sri Lanka 507
Dissanayake D.M.T.D., Gunarathne A.G.D.L.K. and Jayasekara L.M.S.

Social Media Adoption and Its Effect on Sustainability Performance of SMEs in Kurunegala District 512
Gunathilaka M.D.S.V., Disanayaka H., Jayathilaka D. and Mendis O.

Impact of Short-Form Video Consumption on Cognitive Functions of Sri Lankan Undergraduates 518
De Jayathunga A., Subasinghe G.P. and Senarath T.U.S.

Health Equity & One Health: Strengthening Global Well-being and Systemic Resilience

Siddha *Dinacharya* and Health Promotion: Integrating Traditional Wisdom With Modern Science 524
Karunya S., Saruja N., Sivagajendran S. and Sathiyaseelan V.

Levels and Patterns of Smokeless Tobacco Use Among Manual Cleaning Workers in a Workplace Setting in Sri Lanka 528
Meewaddana L.W.R.M.R., Warnasekara Y.P.J.N. and Senarathna L.

Prevalence and Patterns of Body Image Concern Among School Adolescents: Findings From a School-Based Study 531
Thennakoon T.M.G.H., Senadheera S. and Fernando M.

Determinants of Processed Food Consumption Among Grade Nine Adolescents in a Selected School, Anuradhapura, Sri Lanka 535
Subhashini D.T.A.K. and Parween Reyal H

Digital Health Literacy and Socio-Demographic Correlates Among Elderly Patients in a Rural Tertiary Hospital 539
Dasanayaka D.R.G.V., Chinthaka A.K.A.U., Dasanayaka D.M.R.T., Dasanayaka D.M.W.G.J.K., Dissanayaka P.P.P., Dissanayake D.M.N.K. and Abeyrathne D.M.P.L.K.

Impact of Tube Type and Delayed Analysis on Serum C-Reactive Protein (CRP) 543
Koggalage D.N., Lakshini K.G.T., Nethmini M.K.G.M.M., Vidanapathirana D.M., Ranasinghe R.D.S. and Majitha S.I.

Prevalence of Anaemia among Adolescents in Jaffna District 547
Sivakaran M., Arasaratnam V. and Surenthirakumaran R.

Inclusive Futures: Social Science and Humanities for Sustainability and Versatile Future

Users' Perceptions and Experiences of Jogging Paths: A Case Study of Madiwela Jogging Path 551
Weerakoon W.M.T.S. and Rajapaksha R.M.S.P.

Burnout Among School Counsellors: A Narrative Review of Theoretical Perspectives, Antecedents, Consequences, and Prevention Strategies 555
Liyadipita H. and Herath S.

Digital Transformation in Museum Management: Challenges and Opportunities in Sri Lanka 560
Priyangana T.D.S.G.

Labour Market Conditions and Graduate Human Capital Utilisation: Evidence From Sri Lankan Commercial Banks 565
Lankathilaka L.S.P.

Anuradhapura Beyond Pilgrimage: Branding a Sacred Heritage City Through Stakeholder Perspective 569
Weerawansa S.R.S.D.K. and Hewage T.U.

Next-Gen Syntheses: Converging ICT, Biosystems, and Engineering Technologies for Global Sustainable Development

Perceived Usefulness and Trust in AI-Supported Learning: Evidence From Sri Lankan Undergraduates 574
Wasalthilake W.T.P. and Munasinghe P.G.

An Explainable Multi-Agent System for Agricultural Decision Support in Rice Yield Prediction 578
Udayangani H.K.N., Ekanayake E.M.U.W.J.B., Suriyagoda B.M.L.D.B. and Bandara R.M.U.S.

Ensemble Deep Learning Approach for Categorising Synthetic and Original Gems 582
Kularathne A.M.R.M., Kumara B.T.G.S., Wanniarachchi D.N.S. and Dilshan B.T.

Combined Assessment of HER2/CEP17 Gene Status and TNF-α Expression: A Retrospective Analysis 586
Dissanayake E., Hewagama N., Jeyakumaran T., Seneviratne B. and Jeewandara T.M.

The Impact of User Experience Quality on Customer Satisfaction in Mobile Commerce Applications: Evidence From Sri Lankan Users 591
Kalpani K.A.P. and Munasinghe P.G.

Molecular Identification of *Microbacterium schleiferi* From Black Rot-Symptomatic Cabbage From the Badulla District, Sri Lanka 595
Ranasinghe N., Rajan K. and Ranaweera D.

A Comparative Parametric and Non-Parametric Regression Analysis of Factors Influencing South Asian Carbon Dioxide Emissions 601
Samaranayake K., Ekanayake E.M.U.S.B. and Atapattu M.S.

Identifying AI-Generated Human Portraits and Applying Invisible Watermarks for Source Verification 605
Dasanayaka I.M., Bandara S.H., Divisekara C.K., Jayarathna S.P., Karunarathna D.K., Jayasinghe D.S. and Wickramaarachchi W.U.

TinyML-Based Edge AI System for Human–Elephant Conflict Mitigation in Rural Sri Lanka 609
Senanayake S.M.B.L. and Herath H.M.D.S.

Oral Presentations

Sustainable Agriculture

Advancing Climate Resilience, Food System & Livelihoods

ISymRU 2026

"Sustainability Nexus: Climate Actions, Technological Innovations, and Global Collaborations"

Integrated Effect of Urea–*Gliricidia* Nutrient Management on Nitrogen Use Efficiency and Productivity of Maize in Southern Sri Lanka

Liyanage A.[1,2,*]

[1]*Department of Agricultural Biology, Faculty of Agriculture, University of Ruhuna, Mapalana 81000, Sri Lanka,* [2]*Institute of Future Environments, Queensland University of Technology, Brisbane, QLD 4000, Australia*

*Corresponding author (email: anuga@agri.ruh.ac.lk)

Introduction

Maize (*Zea mays* L.) is, after rice and wheat, one of the most important crops for food and feed security in Sri Lanka. National maize production in 2022 was about 62,800 t, grown on about 33,500 ha, with an average yield of 1.87 t ha^{-1} (Department of Agriculture Sri Lanka, 2023). This is substantially lower than the global average of 5.8 t ha^{-1} reported by the Food and Agriculture Organization (FAO) for 2022 and the regional averages in South and Southeast Asia (3.5–5.0 t ha^{-1}). The growing poultry, dairy and animal feed sectors have caused a sharp rise in national maize demand in recent decades and a persistent demand–supply gap in the country. To meet this demand, Sri Lanka imported on average around 350,000 t of maize annually (Department of Census and Statistics, 2022), which placed a strain on foreign exchange reserves. Collectively, these data show a strong need to improve maize production at the local level through better nutrition and agronomic management. Nitrogen (N) is the major nutrient in tropical maize systems, but low N use efficiency (NUE) (30–40% of applied urea N) causes economic losses for smallholder farmers and environmental concerns in areas such as Matara District. The use of synthetic urea is limited by economic considerations; consequently, application rates are sub-optimal, compromising soil health (Senadheera et al., 2019) and NUE (Ichami et al., 2019). With the reduction of subsidised fertilisers following the agricultural crisis after 2021, there is a greater demand for affordable organic N sources to support smallholder farmers (Weerahewa et al., 2022).

Gliricidia sepium is a fast-growing leguminous tree that is common in the humid lowlands of Sri Lanka and is extensively used in agroforestry and home gardens. It produces abundant nitrogen-rich leaf biomass that decomposes rapidly, which is desirable for tropical soils. The leaf biomass contains 3.0–4.5% total organic carbon (TOC) on a dry weight basis and has a favourable C:N ratio (8–12:1), which favours rapid decomposition and N mineralisation (Sileshi et al., 2008) and improves soil properties under tropical conditions (Mafongoya et al., 2006; Sangakkara et al., 2004). However, studies on its use in conjunction with urea to enhance NUE in maize cultivation have yielded mixed results, which have been attributed to soil variability and other factors. Moreover, there is limited literature on this aspect in the uplands of southern Sri Lanka, which is the focus of this study. Earlier studies were also concerned with biomass production rather than standardised measures of NUE, and empirical data to guide policy on integrating *Gliricidia* biomass with mineral N sources were a concern. This lack of knowledge is especially pronounced in the humid lowland zone of Sri Lanka. It was hypothesised that a reduced dose of urea combined with *Gliricidia* green manure would enhance NUE and

maize grain yield in the Ultisols of southern Sri Lanka, compared with sole urea at the recommended rate, by increasing N availability and synchrony. This study aimed (i) to assess the productivity of maize as influenced by different combinations of urea and *Gliricidia*; (ii) to evaluate the N use efficiency of the tested urea–*Gliricidia* combinations using the indices N uptake efficiency (NUpE), N utilisation efficiency (NUtE) and physiological N use efficiency (NUE); and (iii) to determine the best of the tested urea–*Gliricidia* nutrient management approaches for site-specific maize farming by smallholders in the southern region of Sri Lanka.

Methodology

The experiment was conducted at the experimental farm of the Faculty of Agriculture in Mapalana, Sri Lanka, which receives an annual rainfall of 1,850 mm and has a short dry season. The soil is a loamy sand with a pH of 5.8, organic carbon content of 1.2%, total nitrogen of 0.09%, available phosphorus (Bray-1) of 14.3 mg kg^{-1} and exchangeable potassium of 0.18 $cmol_c$ kg^{-1}. A 100 m^2 randomised complete block design (RCBD) with five nitrogen management treatments and three replications was used, with a plot size of 5 m × 4 m (20 m^2). The treatments were T1, an unfertilised control (0 kg N ha^{-1}); T2, sole urea at 120 kg N ha^{-1} (261 kg urea ha^{-1}); T3, sole *Gliricidia* leaf biomass at an N equivalent of 120 kg N ha^{-1} (approximately 13,793 kg fresh leaves ha^{-1} at 3.48% N, dry weight basis); T4, urea 75% (90 kg N ha^{-1}) + *Gliricidia* 25% (30 kg N ha^{-1}); and T5, urea 50% (60 kg N ha^{-1}) + *Gliricidia* 50% (60 kg N ha^{-1}). *Gliricidia* leaf biomass (freshly harvested; 3.48% N on a dry weight basis, verified by Kjeldahl analysis) was incorporated by shallow tillage (10 cm depth) 21 days before planting to allow mineralisation. Urea was applied in two equal doses, 50% at planting and 50% at the V6 growth stage. All plots received a uniform application of phosphorus (60 kg ha^{-1} as triple superphosphate) and potassium (60 kg K_2O ha^{-1} as muriate of potash) at planting.

Maize hybrid MI5 was planted on 15 June 2024 at a spacing of 75 cm × 25 cm (53,333 plants ha^{-1}), and weeds were managed manually. During dry periods, the crop was irrigated as required, and edge effects were avoided by omitting border rows from sampling, so that data were collected only from plants in the net harvest area. At physiological maturity (R6 stage, about 110 days after planting), ears were harvested from the net plot area (12 m^2) and shelled, and the grain was dried to 14% moisture content. Five representative plants per plot were harvested for above-ground biomass (grain + stover), which was oven-dried at 70 °C to constant weight, finely ground and analysed for total N using the micro-Kjeldahl method. The following NUE indices were calculated as described by Dobermann (2007):

$$\mathrm{NUpE} = \frac{U_f}{N_{app}}$$

$$\mathrm{NUtE} = \frac{GY}{U_f}$$

$$\mathrm{NUE} = \mathrm{NUpE} \times \mathrm{NUtE} = \frac{GY}{N_{app}}$$

$$\mathrm{AE}_N = \frac{GY_f - GY_0}{N_{app}}$$

where NUpE is the nitrogen uptake efficiency, NUtE the nitrogen utilisation efficiency, AE_N the agronomic nitrogen use efficiency, U_f the total above-ground N accumulation in the fertilised crop (kg ha^{-1}), N_{app} the total N applied (kg ha^{-1}), GY the grain yield, and GY_f and GY_0 the grain yields of the fertilised and unfertilised plots, respectively. Analysis of variance (ANOVA) was performed in SAS v9.4 (SAS Institute, 2019). Tukey's honestly significant difference (HSD) test was used to separate means at α = .05. Pearson correlation analysis was used to determine the relationships between yield and the NUE indices.

Results and Discussion

ANOVA indicated that treatment effects were highly significant ($p < .001$) for all variables measured, and more than 96% of the total variation in all response variables was explained by the treatment effects (Table 1). The combined urea–*Gliricidia* treatments (T4 and T5) significantly improved grain yield and all NUE indices compared with the urea-alone and *Gliricidia*-alone treatments (Table 2). The maximum grain yield (6.47 ± 0.22 t ha^{-1}) was recorded in T5 (urea 50% + *Gliricidia* 50%), which was 11.4% higher than that of sole urea (T2: 5.81 t ha^{-1}) and 26.4% higher than that of sole *Gliricidia* (T3: 5.12 t ha^{-1}). The unfertilised control (T1) produced the lowest grain yield (3.42 t ha^{-1}), which indicates strong nitrogen limitation under local soil conditions.

Table 1

Analysis of Variance Summary of Grain Yield and Nitrogen Use Efficiency Indices of Maize Under Nitrogen Management Treatments

Source of variation	df	Grain yield MS (*F*)	NUpE MS (*F*)	NUtE MS (*F*)	NUE MS (*F*)	AE_N MS (*F*)
Replication	2	0.031 (0.72)^{ns}	0.001 (0.48)^{ns}	0.82 (0.41)^{ns}	1.14 (0.52)^{ns}	0.31 (0.28)^{ns}
Treatment	4	4.782 (112.4)**	0.018 (67.3)**	93.4 (46.7)**	83.6 (38.2)**	67.2 (43.9)**
Error	8	0.043	0.0003	2.00	2.19	1.53
Total	14					
R^2		0.984	0.971	0.959	0.966	0.961

Note. MS = mean square; df = degrees of freedom; NUpE = nitrogen uptake efficiency; NUtE = nitrogen utilisation efficiency; NUE = nitrogen use efficiency; AE_N = agronomic nitrogen use efficiency. ** Significant at $p < .001$; ns = not significant. Degrees of freedom for total = 14 (3 replications × 5 treatments − 1).

Table 2

Treatment Means of Grain Yield and Nitrogen Use Efficiency Indices of Maize Grown Under Five N Management Strategies in Matara, Sri Lanka

Treatment	N input (kg N ha^{-1})	Grain yield (t ha^{-1})	NUpE (kg kg^{-1} N)	NUtE (kg grain kg^{-1} N uptake)	NUE (kg grain kg^{-1} N input)	AE_N (kg grain kg^{-1} N)
T1 – Control (0 N)	0	3.42 ± 0.18^{c}	–	–	–	–
T2 – Urea 100% (120 kg N ha^{-1})	120	5.81 ± 0.23^{b}	0.41 ± 0.03^{b}	34.6 ± 2.1^{b}	48.4 ± 3.0^{b}	19.9 ± 1.4^{b}
T3 – *Gliricidia* 100%	120 (organic)	5.12 ± 0.21^{c}	0.38 ± 0.03^{c}	30.1 ± 2.4^{c}	42.7 ± 2.8^{c}	14.2 ± 1.1^{c}
T4 – Urea 75% + *Gliricidia* 25%	120	6.09 ± 0.19^{ab}	0.47 ± 0.02^{ab}	37.2 ± 1.9^{ab}	50.8 ± 2.6^{ab}	22.3 ± 1.6^{ab}
T5 – Urea 50% + *Gliricidia* 50%	120	6.47 ± 0.22^{a}	0.52 ± 0.02^{a}	41.8 ± 2.0^{a}	53.9 ± 2.4^{a}	25.4 ± 1.5^{a}
SEM		0.21	0.03	2.0	2.8	1.4
p-value		< .001	< .001	< .001	< .001	< .001
CV (%)		5.8	6.1	7.4	6.9	7.2

Note. Values are means ± standard error of the mean (SEM). NUpE = N uptake efficiency; NUtE = N utilisation efficiency; NUE = N use efficiency; AE_N = agronomic N use efficiency; CV = coefficient of variation.

The superior NUE of T5 (53.9 kg grain kg^{-1} N) relative to T2 (48.4 kg grain kg^{-1} N) was associated with significantly higher NUpE (0.52 vs. 0.41 kg kg^{-1} N) and NUtE (41.8 vs. 34.6 kg grain kg^{-1} N uptake). The results indicated that the microbial decomposition of *Gliricidia* leaves produced a progressive release of N, which decreased the peak concentrations of inorganic N in the soil during early vegetative growth and allowed a more continuous supply of mineral N during the grain-filling period, consistent with the theory of synchrony between N supply and crop demand (Sangakkara et al., 2004). Sole *Gliricidia* (T3) had the lowest NUE (42.7 kg grain kg^{-1} N) among the fertilised treatments, probably owing to incomplete mineralisation of the organic N during the crop growth period under the prevailing soil moisture conditions of the *Yala* season at Matara. The AE_N of T5 (25.4 kg grain kg^{-1} N) was significantly higher than those of T2 (19.9 kg grain kg^{-1} N) and T3 (14.2 kg grain kg^{-1} N), which substantiates the agronomic benefit of the 50:50 ratio. These results are similar to those of Mafongoya et al. (2006), who recorded NUE values of 45–52 kg grain kg^{-1} N in maize grown under mixed organic–inorganic fertilisation in sub-humid tropical conditions, and Jayasundara et al. (2019), who observed strong increases in NUE when *Gliricidia* was included in upcountry Sri Lankan maize production systems. The results are also in line with the general agronomic concept of combining a quick-release inorganic N source with a slow-release organic N source to provide a more balanced N supply to the plant, thus minimising gaseous and leaching losses of nitrogen and maximising its uptake by the plant.

Conclusions and Implications

The highest grain yield, nitrogen uptake efficiency (NUpE), agronomic efficiency (AE_N) and physiological nitrogen use efficiency (NUE) were obtained with the integrated nitrogen management treatment (T5), which combined 50% mineral urea with 50% *Gliricidia sepium* leaf biomass, compared with the other treatments tested. This combination performed better under the humid lowland conditions of Matara, Sri Lanka, because of the synchronised release of organic and inorganic nitrogen, resulting in reduced losses and better plant recovery. Two other ratios (75% urea:25% *Gliricidia* and 50% urea:50% *Gliricidia*) were tested, but the 50:50 ratio was the best of the treatments evaluated, indicating that the optimum ratio has not yet been determined. The results support integrated nitrogen management in maize production and highlight the need to evaluate different substitution ratios for their economic feasibility under different climate scenarios and soil conditions in southern Sri Lanka.

***Keywords*:** Integrated nutrient management, maize productivity, nitrogen use efficiency, southern Sri Lanka

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Sustainable Agricultural Practices in Indigenous Communities: A Case Study of Henanigala South Indigenous (Vedda) Village, Sri Lanka

Jayarathne S.M.C.D.* and Chandrasekara C.M.K.N.K.
Department of Geography, University of Colombo, Sri Lanka
*Corresponding author (email: jayarathne.smcd@gmail.com)

Introduction

Agriculture is not merely a means of producing food; it is a practice of culture, identity and ecological knowledge that has developed over thousands of years among indigenous peoples. Indigenous knowledge, refined over thousands of years through oral tradition, plays a role in management spanning crop selection, land preparation, harvesting and pest control (Dei et al., 2025). Indigenous agricultural systems can serve as models of sustainable agroecology, especially in light of current environmental crises, offering critical lessons that mainstream agriculture needs to learn from and integrate (Abdo et al., 2024).

This deep connection between indigenous identity and agricultural sustainability is exemplified by the Vedda of Sri Lanka, who are genetically linked to their original 6th century BC Neolithic population (Nahallage & Ananda, 2022). Historically, they engaged in *chena* farming, clearing small areas of forest to be hand-hoed, and used this practice as a supplement to hunting and gathering (Wijesinghe, 2017). Large-scale development interventions such as the Mahaweli Development Project (1970s–1990s) displaced Vedda communities from their traditional *chena* farming, and centuries of ecological knowledge were replaced by modernised irrigation agriculture (Epa, 2025). One such case is the Henanigala South Indigenous (Vedda) Village. The community's knowledge of local ecosystems, learned through experience and reinforced through ritual, is still applied today in sustainable resource-use strategies such as crop rotation, water management and fire control, and this indigenous knowledge has been inherited across generations within the community (Jayarathne et al., 2026). This paper discusses the sustainable agricultural practices of this community in order to highlight the challenges and opportunities in preserving traditional ecological knowledge and integrating it into mainstream agricultural and environmental policies.

Accordingly, the research has one main objective and several specific objectives. The main objective is to examine and analyse sustainable agricultural practices in the Henanigala South Indigenous (Vedda) community of Sri Lanka, with a focus on local knowledge, ecological adaptation and long-term resource management. The specific objectives are (1) to identify the traditional agricultural practices used by the Henanigala South Indigenous (Vedda) community; (2) to examine how local knowledge contributes to sustainable farming and environmental conservation; and (3) to assess the challenges the community faces in maintaining sustainable agricultural practices in the context of modernisation and external influences.

Methodology

A mixed-methods research design was used, incorporating both qualitative and quantitative methods. The main objective was to identify the sustainable agricultural practices used in the Henanigala South Indigenous Village and their social and environmental values. Both primary and secondary data were used. A semi-structured questionnaire survey and semi-structured interviews were used to collect primary data on the traditional agricultural knowledge and practices of the members of the indigenous community engaged in agricultural activities in the Henanigala South Indigenous Village. Research articles, books and previous studies were used as sources of secondary data. A purposive sampling method was used to select the sample: 75 indigenous people engaged in agricultural activities were selected, comprising both male and female community members. The sample represents individual respondents from households actively practising traditional agriculture within the community. Descriptive statistical methods were used to analyse the quantitative data, and thematic analysis was used for the qualitative data. The major themes identified include traditional agricultural methods, environmentally friendly practices and linkages with livelihoods. The research also used the Relative Importance Index (RII) method to assess the constraints faced by the Indigenous (Vedda) community in sustaining their traditional agricultural practices, calculated as follows:

$$\text{RII} = \frac{\sum W}{A \times N}$$

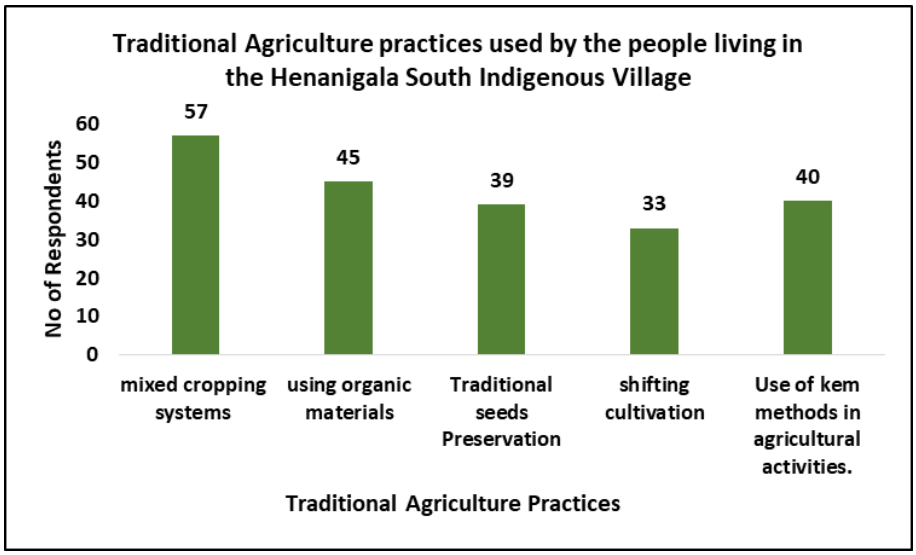
where ΣW is the total weight given to each factor by the respondents, A is the highest weight on the scale (5) and N is the total number of respondents. Higher RII values indicate greater importance.

Results and Discussion

As Figure 1 shows, the Vedda community of Henanigala South practises a range of traditional agricultural methods. The most common practice was mixed cropping, with 76% (n = 57) of respondents growing maize, millet, manioc, pumpkins and vegetables, a practice that enhances food security and maintains soil health through polyculture, reducing the need for chemical inputs (Abdo et al., 2024). Soil amendment practices were applied by 64% (n = 48) of respondents, who used leaf litter, animal manure, ash and compost as substitutes for chemical fertilisers, an approach that enriches soil organic matter and supports long-term soil fertility (Dei et al., 2025). Many respondents (52%; n = 39) preserved traditional seeds, ensuring a seed stock for consecutive planting seasons.

Figure 1

Traditional Agricultural Practices Used by the Vedda Community



Note. Data are based on responses from community members regarding traditional agricultural practices used in the Henanigala South Indigenous Village.

Of the respondents, 44% (n = 33) practised shifting cultivation (*chena*), periodically rotating their cultivation plots within the local forest environment to allow natural land recovery and support biodiversity conservation. Importantly, 72% of respondents (n = 54) reported relying on seasonal rainfall patterns and natural ecological signals rather than modern forecasting technologies. Moreover, *Kem* methods (indigenous ritual-based farming practices) were practised by 40 respondents, highlighting the extent to which cultural beliefs shape agricultural decision-making regarding planting dates, crop selection and soil fertility management. An RII analysis was conducted on the responses of the 75 participants to identify the main challenges to traditional farming practices. Each challenge was rated on a Likert scale ranging from very low impact (1) to very high impact (5).

The RII analysis highlighted five key challenges to agricultural livelihoods among the Henanigala South participants. Climate variability ranked first (RII = 0.89), as irregular rainfall and weather changes severely affect agricultural production through drought, heavy rains and floods. Youth disinterest in farming ranked second (RII = 0.84), posing a long-term threat to the intergenerational transmission of traditional agricultural knowledge and practices. Dependence on chemical inputs ranked third (RII = 0.81), with the overuse of fertilisers and pesticides degrading soil quality and harming ecosystems. Land access restrictions ranked fourth (RII = 0.76), encompassing both legal and cultural constraints that hinder agricultural development and sustainability. Finally, lack of financial support ranked fifth (RII = 0.69), as limited access to credit and agricultural investment restricts the ability to purchase inputs and adopt appropriate technologies.

Collectively, these findings indicate that the agricultural sustainability of the Henanigala South Indigenous people is threatened by urgent environmental, economic and social pressures that require integrated policy responses.

The findings of this study reveal that the Henanigala South Indigenous (Vedda) community of Sri Lanka maintains a range of traditional agricultural practices rooted in indigenous ecological knowledge. The high prevalence of mixed cropping (76%), organic soil amendment (64%) and traditional seed preservation (52%) reflects an inherited understanding of agroecological principles that aligns with the broader literature on sustainable indigenous food systems (Abdo et al., 2024; Dei et al., 2025). The practice of shifting cultivation (*chena*) by 44% of respondents, involving the rotational movement of plots to allow land recovery, demonstrates an adaptive land management strategy. Reliance on natural ecological indicators for seasonal planning by 72% of respondents further reflects an experiential knowledge of ecosystem dynamics consistent with sustainable land management principles (Jayarathne et al., 2026). The prevalence of *Kem* rituals among 40 respondents underscores how cultural and spiritual beliefs are embedded in resource use and farming decisions, as documented among indigenous groups across South and Southeast Asia (Weerasinghe & Somaratne, 2019).

However, the RII analysis reveals serious challenges threatening these practices. Climate variability (RII = 0.89) is identified as the most critical constraint, corroborating evidence that rural indigenous communities are disproportionately affected by climate change despite their minimal contribution to its causes (Food and Agriculture Organization of the United Nations, 2021). Youth disinterest in farming (RII = 0.84) poses a particularly formidable long-term threat, as sustainable practices are primarily transmitted through the intergenerational transfer of traditional ecological knowledge (Nahallage & Ananda, 2022). Dependence on chemical inputs (RII = 0.81), land access restrictions (both legal and cultural; RII = 0.76) and lack of financial support (RII = 0.69) further reflect the systemic socio-political exclusion of indigenous populations from mainstream development and policy processes (Epa, 2025).

These findings collectively demonstrate that the Henanigala South Vedda community exhibits both ecological resilience and cultural continuity in its agricultural systems. However, it faces cumulative and interrelated threats that require national policy frameworks formally recognising indigenous knowledge systems in agricultural and environmental governance.

Conclusions and Implications

The Henanigala South Vedda community demonstrates ecological resilience through traditional practices including mixed cropping, organic soil amendment, traditional seed preservation, shifting cultivation (*chena*) and ritual-based farming (*Kem*). These systems, grounded in indigenous ecological knowledge, align with international sustainable agriculture principles. However, they face existential threats from climate variability, youth disengagement, chemical input dependence, land access constraints and financial limitations. The formal incorporation of these traditional knowledge systems into national

agricultural and environmental management policies is essential to protect this invaluable heritage and sustain community livelihoods.

***Keywords*:** Climate resilience, environmental conservation, Henanigala South, indigenous communities, sustainable agriculture

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Predatory Efficiency of *Coccinella transversalis* and *Micraspis discolor* on Different Developmental Stages of Whitefly (*Aleurodicus rugioperculatus*)

Jayakody S.[1,*] and Vinobaba M.[2]
[1]*Eastern University, Sri Lanka, Vantharumoolai,* [2]*Department of Zoology, Faculty of Science, Eastern University, Sri Lanka, Vantharumoolai*
*Corresponding author (email: jayakodysandali@gmail.com)

Introduction

Whiteflies were recorded over 100 years ago as an agricultural pest distributed worldwide in tropical and subtropical regions (Oliveira et al., 2001). In Sri Lanka, three whitefly species have been identified on coconut: *Aleurodicus dispersus*, *Aleurodicus rugioperculatus* and *Aleurotrachelus atratus*. *A. rugioperculatus* has been recorded on 24 host plant species in 18 families (Madushani & Sirisena, 2024). Whiteflies feed on plant sap from leaves, which leads to discoloured patches. While feeding, they release toxins into the phloem, which are transmitted throughout the plant (Garcia, 2015). Synthetic pesticides can be applied to the leaves, but their use causes problems such as resistance and environmental pollution (Abubakar et al., 2022). Biological control of whitefly by the locally available parasitoid *Encarsia guadeloupae* has been investigated in Sri Lanka (Nishantha et al., 2025), and an additional predator could enhance the efficiency of whitefly control. However, studies on the biological control of whitefly (*A. rugioperculatus*) by ladybird beetles (*Coccinella transversalis* and *Micraspis discolor*) have not yet been documented. This study therefore aims to evaluate the predatory efficiency of these two ladybird beetles on different developmental stages of the whitefly *A. rugioperculatus*.

Methodology

Ladybird beetles were cultured following the procedure of Hesler et al. (2012), with a few modifications. Adults were collected from grass beds within the premises of Eastern University, Vantharumoolai, and cultured in 1 L plastic containers with nets under laboratory conditions (23 ± 2 °C and 60 ± 5% relative humidity). Water-soaked cotton was added to maintain humidity, and the adults were provided with aphids every 24 hours. For mating, adults were transferred by hand to plastic cups, which were checked for eggs twice a day, and plant twigs were provided as oviposition sites. To avoid cannibalism, egg clusters were separated into plastic cups (180 mL) or Petri dishes (9 cm diameter). Individual third-instar larvae were placed in plastic cups (180 mL) with punctured lids, and pupae were kept in a container until sclerotisation was complete.

The experimental procedure was adapted from Tavadjoh et al. (2010). Eight adults were randomly selected from the culture and placed in separate Petri dishes. After 24 hours of starvation, a single developmental stage of whitefly was added to each Petri dish, which was covered with polythene, sealed with tape and punctured with many holes for ventilation. A soaked cotton ball and a wet filter paper were placed at the bottom of each dish. Feeding rates were obtained by counting the whitefly individuals consumed after 24 hours, and each experiment was repeated five times. The developmental stages of

whitefly, namely first- to third-instar nymphs, fourth-instar nymphs and adults, were offered in separate experimental set-ups at 60, 30 and 20 individuals, respectively. Predatory efficiency was calculated following Salmah and Omar (1994) using the following equation:

$$\text{Predatory efficiency} = \frac{\text{Number of prey consumed}}{\text{Total number of prey introduced}} \times 100\%$$

The coefficient of variation (CV) was calculated in Excel 2024. Statistical analysis was performed by one-way analysis of variance (ANOVA) at a significance level of $p < .05$ in Minitab statistical software (Version 14.0, 2022).

Results and Discussion

Statistically significant differences in predatory efficiency were observed among the first- to third-instar nymphs, fourth-instar nymphs and adults of *A. rugioperculatus* for both ladybird beetle species. Between the two species, a statistically significant difference was observed only for the first- to third-instar nymphs and the fourth-instar nymphs. The predatory efficiency of *M. discolor* on first- to third-instar nymphs (60.67 ± 13.62) and fourth-instar nymphs (70.67 ± 11.65) was higher than that of *C. transversalis* on first- to third-instar nymphs (38.79 ± 12.31) and fourth-instar nymphs (60.58 ± 16.93) (Table 1). The highest predatory efficiencies of both species were observed on the fourth-instar nymphs of *A. rugioperculatus*: 70.67 ± 11.65 for *M. discolor* and 60.58 ± 16.93 for *C. transversalis* (Table 1). Direct comparison with previous studies was not possible owing to a lack of data; however, previous studies showed that *M. discolor* can be used as a biocontrol agent against the whitefly *Dialeuropora decempuncta* (Kumar et al., 2018).

Table 1

Predatory Efficiency of C. transversalis and M. discolor on A. rugioperculatus

Species of ladybird beetle	Predatory efficiency (%)		
	First- to third-instar nymphs	Fourth-instar nymphs	Adults
Coccinella transversalis	38.79 ± 12.31	60.58 ± 16.93	22.38 ± 8.40
Micraspis discolor	60.67 ± 13.62	70.67 ± 11.65	19.88 ± 5.25

The box plots show the distribution of the predation rate across treatment groups (species and stage) (Figure 1). Visual asymmetry was observed in the fourth-instar nymph groups, where the median coincides with the upper quartile boundary. The Anderson–Darling normality test confirmed that all data conformed to a normal distribution ($p > .05$). The variation in predation rate may be due to the stochastic nature of predator–prey interactions under laboratory conditions. The CV ranged from 16.49% (*M. discolor*, fourth-instar nymphs) to 37.53% (*C. transversalis*, adults) (Table 2).

Figure 1

Box Plot of Predation Rate of C. transversalis and M. discolor on A. rugioperculatus

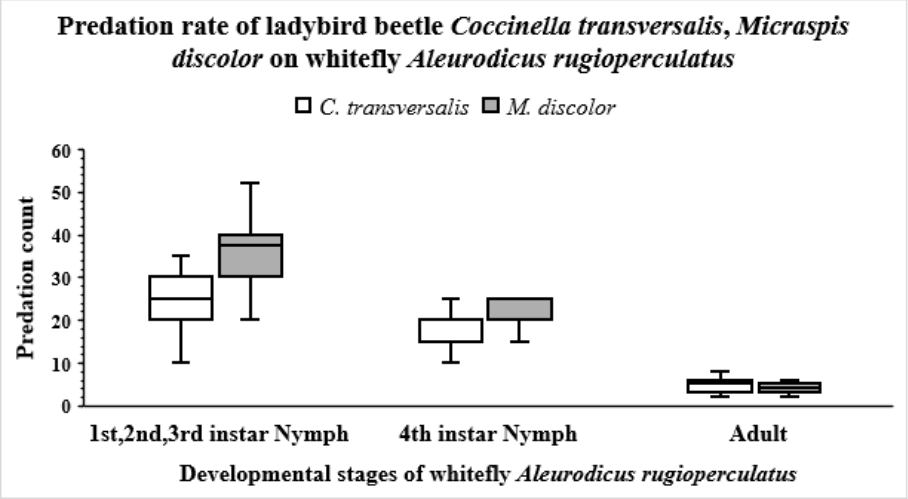


Table 2

Variability in Predation Count of C. transversalis and M. discolor

Species	Stage	CV (%)	Minimum	Median	Maximum
Coccinella transversalis	Adults	37.53	2	5	8
	First- to third-instar nymphs	31.72	10	25	35
	Fourth-instar nymphs	27.94	10	20	25
Micraspis discolor	Adults	26.41	2	4	6
	First- to third-instar nymphs	22.45	20	37.5	52
	Fourth-instar nymphs	16.49	15	20	25

Note. CV = coefficient of variation.

Conclusions and Implications

The findings of this study indicate that both *Coccinella transversalis* and *Micraspis discolor* can be used as biological control agents against the whitefly *Aleurodicus rugioperculatus*. Under the given experimental conditions, *M. discolor* is more effective than *C. transversalis* against the first- to third-instar nymphs and fourth-instar nymphs of *A. rugioperculatus*. The variation in predation rates may be due to the stochastic nature of predator–prey interactions in the laboratory set-up. Further research is recommended to determine their predatory behaviour in the field.

***Keywords*:** Biocontrol agent, ladybird beetle, predatory efficiency, whitefly

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Productivity Change and Resource Use Efficiency in Sri Lanka Inland Fisheries: Evidence From a DEA–Malmquist Index Analysis

Sandaruwan W.H.A.*, Kesavamoorthy V., Wickramanayaka D.G.A.M. and Bandaranayka P.W.S.M.C.
National Aquatic Resources Research & Development Agency (NARA), Sri Lanka
*Corresponding author (email: aravindasandaruwan4@gmail.com)

Introduction

Sri Lanka possesses substantial inland water resources, including reservoirs, perennial tanks and other freshwater bodies, which provide considerable potential for inland fish production. Over the past decades, inland fisheries have evolved from a relatively minor sector into an increasingly important component of the national fisheries industry. The expansion of reservoir fisheries, stocking programmes and fisheries management initiatives has contributed to improvements in inland fish production and has enhanced livelihood opportunities for rural fishing communities. However, production performance continues to vary considerably across districts owing to differences in resource availability, fishing intensity, infrastructure, management practices and technological adoption. Despite the growing importance of inland fisheries, empirical evidence on productivity performance and efficiency dynamics within the sector remains limited. Existing fisheries studies in Sri Lanka have predominantly focused on marine fisheries, while comparatively little attention has been given to the efficiency and productivity changes occurring in inland fisheries. Furthermore, conventional production indicators often fail to distinguish whether productivity improvements originate from better resource utilisation or from technological progress.

This study evaluates the technical efficiency and productivity dynamics of inland fisheries across the districts of Sri Lanka during the period 2016–2024. Specifically, the study aims (i) to estimate district-level technical efficiency using data envelopment analysis (DEA); (ii) to measure productivity change through the Malmquist Productivity Index; and (iii) to determine the relative contributions of efficiency change and technical change to productivity change. The findings provide important evidence for policymakers seeking to improve resource utilisation, strengthen fisheries management and promote sustainable growth in the inland fisheries sector of Sri Lanka.

Methodology

This study initially used district-level panel data covering the 25 administrative districts of Sri Lanka from 2016 to 2024. Following the production theory framework, inland fish production (tonnes) was specified as the output variable. Three input variables were considered: the number of active fishers, the number of inland fishing craft and the utilised perennial tank area (hectares). These variables represent the primary labour, capital and natural resource inputs employed in inland fish production. To evaluate productivity changes over time, the Malmquist Productivity Index (MPI) was employed using a global variable returns to scale (VRS) reference technology. The MPI measures changes in total factor productivity between two consecutive periods and decomposes productivity change into efficiency change (EC) and technical change (TC). Under the VRS specification,

efficiency change is further decomposed into pure technical efficiency change (PTEC) and scale efficiency change (SEC). The MPI is therefore expressed as follows:

$$\text{MPI} = \text{PTEC} \times \text{SEC} \times \text{TC}$$

After data validation and the exclusion of Jaffna from the balanced productivity panel, the final analysis covered 24 districts over the period 2016–2024.

Results and Discussion

The average technical efficiency scores reveal substantial regional disparities in the performance of the inland fisheries sector of Sri Lanka. Galle and Puttalam recorded frontier-level technical efficiency, while Anuradhapura (0.991) and Kegalle (0.944) also demonstrated relatively high levels of efficiency, suggesting effective utilisation of the available fisheries resources. In contrast, Nuwara Eliya (0.252), Matale (0.315), Kilinochchi (0.336) and Mannar (0.350) recorded the lowest efficiency scores, indicating significant potential for improving production through better resource allocation and management practices. The wide variation in efficiency scores across districts highlights the heterogeneous nature of inland fisheries development in Sri Lanka and suggests that district-specific interventions may be required to enhance overall sectoral performance.

Mean technical efficiency increased from 0.585 in 2016 to 0.764 in 2018, before declining to 0.627 in 2021 and recovering modestly to 0.651 in 2024, indicating persistent scope for improved resource utilisation (Figure 1).

Figure 1

Mean Technical Efficiency Trend (2016–2024)

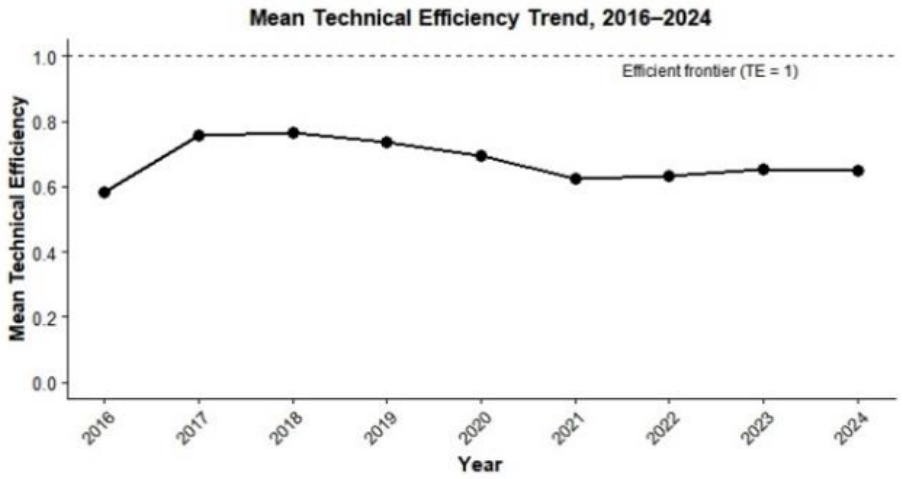


Figure 2 illustrates the temporal dynamics of productivity change in the inland fisheries sector of Sri Lanka based on the MPI, and Table 1 presents its decomposition. The Malmquist analysis revealed considerable productivity fluctuations: productivity improved during 2018–2019 (MPI = 1.043) and 2021–2022 (MPI = 1.102), while the remaining periods recorded productivity declines, the largest occurring during 2023–2024

(MPI = 0.735). These results indicate considerable temporal variation in productivity, reflecting changes in resource-use efficiency and technical conditions across districts.

Figure 2

Trend in the Malmquist Productivity Index (MPI) of Sri Lanka's Inland Fisheries Sector

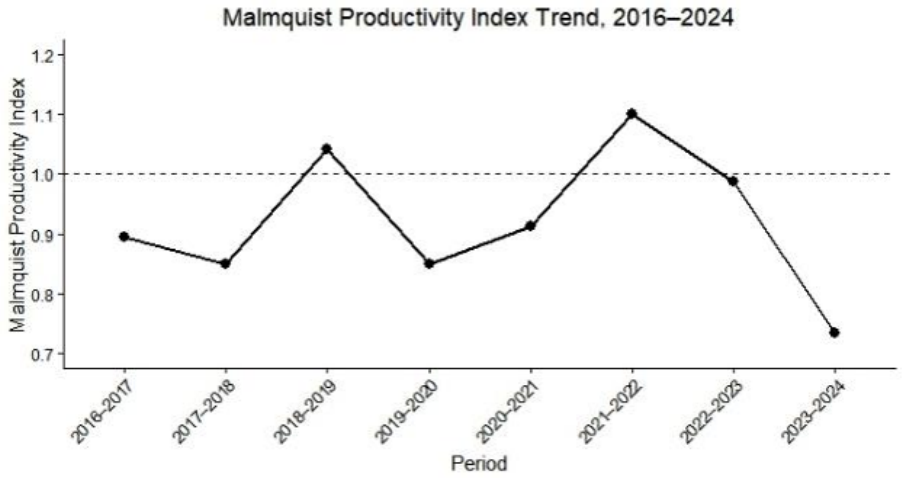


Table 1

Malmquist Productivity Index Decomposition of Sri Lanka's Inland Fisheries Sector

Time period	MPI	PTEC	SEC	EC	TC
2016–2017	0.8951	1.4796	0.9017	1.3341	0.6710
2017–2018	0.8494	1.0247	0.8821	0.9039	0.9397
2018–2019	1.0429	0.9481	1.0360	0.9823	1.0617
2019–2020	0.8483	0.8850	0.9525	0.8429	1.0064
2020–2021	0.9137	0.8920	0.9596	0.8560	1.0674
2021–2022	1.1018	1.0233	1.0177	1.0415	1.0579
2022–2023	0.9880	1.0563	0.9256	0.9777	1.0105
2023–2024	0.7347	0.9918	0.8621	0.8551	0.8592
Geometric mean	0.9150	1.0248	0.9404	0.9637	0.9495

Note. MPI = Malmquist Productivity Index; PTEC = pure technical efficiency change; SEC = scale efficiency change; EC = efficiency change; TC = technical change.
Source: Authors' calculations based on DEA–MPI analysis

The geometric mean MPI across the eight annual periods was 0.915, indicating an overall productivity decline of approximately 8.5% during 2016–2024 (Table 1). Both efficiency change (EC = 0.964) and technical change (TC = 0.949) contributed to this decline. Although pure technical efficiency improved slightly (PTEC = 1.025), this was offset by declining scale efficiency (SEC = 0.940). These findings indicate that improving resource utilisation alone is insufficient to enhance productivity, highlighting the need for technological upgrading, an appropriate scale of resource utilisation, improved fishing practices, and strengthened fisheries management and extension services.

Conclusions and Implications

This study evaluated the technical efficiency and productivity dynamics of the inland fisheries sector of Sri Lanka using district-level data for the period 2016–2024. The DEA results revealed substantial regional disparities in resource-use efficiency across districts. Galle and Puttalam recorded frontier-level technical efficiency, while Anuradhapura recorded a very high level of technical efficiency. In contrast, Nuwara Eliya, Matale and Kilinochchi exhibited comparatively low efficiency levels, indicating considerable potential for improving the utilisation of existing fisheries resources. The findings suggest that improving inland fisheries productivity requires a broader strategy that extends beyond the more efficient utilisation of existing resources. Policy interventions should focus on technological upgrading, improved fishing and harvesting practices, fisheries extension services, reservoir fisheries management and scale-appropriate resource allocation, particularly in relatively inefficient districts. Targeted investments in technological capacity and district-specific fisheries management could help reduce regional efficiency disparities and support sustainable productivity improvement in the inland fisheries sector of Sri Lanka.

***Keywords*:** Data envelopment analysis, inland fisheries, Malmquist productivity index, productivity change, technical efficiency

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Determinants of Participation of Smallholder Tea Farmers in Organised Green Leaf Marketing Channels: Evidence From the Southern Province of Sri Lanka

Pradeep M.U., Kuruppu I.V.*, Nanayakkara G.L. and Dharmasiri P.G.T.M.
Department of Agribusiness Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila (NWP) 60170, Sri Lanka
*Corresponding author (email: virajithkuruppu@wyb.ac.lk)

Introduction

Tea is a key agricultural export crop in Sri Lanka, contributing significantly to foreign exchange earnings and rural livelihoods (Sri Lanka Tea Board, 2021). Smallholder tea farmers, who cultivate less than four hectares, now account for a substantial share of the national green leaf supply, reflecting a historical shift from large estate-based to smallholder-dominated cultivation (Herath & Weersink, 2009; Tea Smallholder Development Authority, 2022). Despite their importance, smallholders continue to face significant barriers in accessing organised marketing channels, resulting in high transport costs, price uncertainty and limited bargaining power (Mohan, 2018).

In the Southern Province, particularly in the Galle and Matara districts, smallholders are central to low-income tea production, yet empirical evidence on the factors influencing their participation in organised marketing channels remains limited. Evidence from other tea-producing countries suggests that transaction costs, institutional support and trust significantly influence smallholder integration into formal value chains (Abdi & Ondabu, 2026; Mohan, 2018). However, none of these studies has specifically examined smallholder participation in organised marketing channels within the Sri Lankan tea sector. Prior research has focused largely on productivity and extension services rather than marketing channel choice (Mahindapala, 2020; Mahindapala et al., 2022; Yapa & Ariyawardana, 2010). Therefore, this study aimed to identify the key determinants of smallholder tea farmers' participation in organised green leaf marketing channels in the Southern Province of Sri Lanka, where organised marketing refers to sales through registered tea factories, cooperatives or collection centres.

Methodology

The proposed conceptual framework posited that participation in organised green leaf marketing was influenced by socio-economic factors (age, education, farming experience and land size), transaction cost factors (distance, transport cost and payment delay), institutional factors (Tea Smallholding Development Society (TSDS) membership and extension contact) and perceptual factors (trust, price uncertainty and information access).

The study was conducted from February to May 2026 among smallholder tea farmers in the Galle and Matara districts of the Southern Province; Hambantota District was excluded owing to its limited tea cultivation. A stratified random sample of 400 farmers was selected (200 per district), with stratification based on Divisional Secretariat division and farm size. The sample size was determined using Cochran's (1977) formula at a 95% confidence level ($Z = 1.96$, $e = 0.05$, $p = 0.5$), yielding a minimum of 384, which was adjusted to 400 to account for non-response. Data were collected using a structured, pre-

tested, interviewer-administered questionnaire. Transaction cost and perceptual indicators were measured on a five-point Likert-type scale (1 = strongly disagree to 5 = strongly agree), and internal consistency was confirmed (Cronbach's α = 0.754). The Likert items were aggregated into three composite scores: the transaction cost score (TC_Score), the perceptual score (Per_Score) and the institutional support score (IS_Score). Binary logistic regression (BLR) in SPSS (version 26) was used to model the probability of participation in organised marketing. The BLR model was specified as follows:

$$\ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 TC_i + \beta_2 PF_i + \beta_3 IS_i + \beta_4 AGE_i + \beta_5 EDU_i + \beta_6 EXP_i + \beta_7 LAND_i + \beta_8 GEN_i$$

where P_i is the probability that the ith farmer participates in an organised green leaf marketing channel (1 = organised, 0 = informal); TC, PF and IS denote the transaction cost, perceptual and institutional support composite scores, respectively; and AGE, EDU, EXP, LAND and GEN denote age, education, farming experience, land area and gender. The β coefficients represent the estimated effects of the predictors on the log-odds of organised market participation.

Results and Discussion

Male farmers constituted 74.0% of the respondents, reflecting the male-dominated nature of tea smallholding in the Southern Province. The largest group (32.0%) was aged 41–50 years, indicating a predominantly middle-aged farming population. In terms of education, 31.0% had completed education up to Ordinary Level, while 20.0% had no formal education (never enrolled in the formal schooling system) and 11.0% held a diploma or degree. The most common monthly tea income range was 25,001–50,000 Sri Lankan rupees (LKR) (28.0%), reflecting the modest earnings typical of smallholder tea production in the region.

Regarding farm characteristics, the majority of respondents (59.0%) cultivated less than 1 acre of tea land, confirming the smallholder character of the sample. Monthly green leaf production was most frequently in the 251–500 kg range (34.0%). A substantial proportion of farmers (74.0%) were members of a TSDS or farmer organisation, and 58.8% resided within 1 km of a processing centre. The majority of farmers (73.0%) reported receiving payment within one week of delivery, while only 8.0% received same-day payment, highlighting a prevalent cash-flow constraint in organised marketing channels. Of the 400 respondents, 215 (54%) participated in organised marketing channels, while the remaining 185 (46.0%) sold primarily through unregistered private collectors or middlemen. Table 1 presents the BLR results.

Table 1

Binary Logistic Regression Results for Participation in Organised Green Leaf Marketing

Factor	Variable	Category	*B*	*p*	OR	95% CI for OR	
						Lower	Upper
TCF	Transaction cost	1–5 Likert scale	−7.051	.001***	0.001	0.000	0.003
PF	Perceptual	1–5 Likert scale	1.771	.004**	5.875	1.783	19.362
ISF	Institutional	1–5 Likert scale	−0.149	.615	0.862	0.483	1.538
SEF	Age			.740			
		Below 30 years	0.006	.994	1.006	0.184	5.508
		31–40 years	0.445	.556	1.560	0.355	6.856
		41–50 years	0.132	.851	1.142	0.287	4.545
		51–60 years	0.780	.316	2.182	0.474	10.041
		Above 60 years (reference)	–	–	–	–	–
	Education level			.439			
		No formal education	1.056	.153	2.875	0.676	12.230
		Primary	0.718	.584	2.051	0.157	26.861
		Secondary	0.450	.540	1.568	0.373	6.595
		O/L	−0.216	.758	0.806	0.204	3.180
		A/L	0.331	.651	1.392	0.332	5.832
		Vocational	−0.001	.999	0.999	0.099	10.091
		Diploma/degree (reference)	–	–	–	–	–
	Experience			.155			
		Less than 5 years	0.003	.997	1.003	0.179	5.622
		5–10 years	0.746	.077	2.108	0.922	4.819
		More than 10 years (reference)	–	–	–	–	–
	Land area			.869			
		Less than 1 ac	−0.817	.863	0.442	0.000	4724.770
		1–3 ac	−0.533	.910	0.587	0.000	6235.414
		3–5 ac	−1.108	.818	0.330	0.000	4116.049
		More than 5 ac (reference)	–	–	–	–	–
	Gender			.380			
		Female	−0.362	.380	0.696	0.311	1.561
		Male (reference)	–	–	–	–	–
	Constant			.028	127874.556	–	–

Note. Participation status: organised, n = 215 (54%); informal, n = 185 (46.2%). Model fit: percentage correctly predicted = 92.0%; Nagelkerke $R^2 = 0.765$; $\chi^2(19) = 340.269$. B = regression coefficient; OR = odds ratio; CI = confidence interval; TCF = transaction cost factors; PF = perceptual factors; ISF = institutional support factors; SEF = socio-economic factors; O/L = Ordinary Level; A/L = Advanced Level; ac = acres. $^{***}p < .001$; $^{**}p < .01$.

The transaction cost composite score (TC_Score) was the strongest significant predictor of organised market participation ($B = -7.051$, OR = 0.001, $p < .001$). The negative coefficient and the odds ratio below one indicate that increasing perceived transaction costs substantially reduced the odds of participating in organised marketing channels. The perceptual composite score (Per_Score) was also significant ($B = 1.771$, OR = 5.875, p =

.004). Together, transaction cost barriers and channel perceptions accounted for the majority of the variation in channel choice. The institutional support composite score (IS_Score) was not statistically significant ($B = -0.149$, $p = .615$), suggesting that while TSDS membership and extension contact may create a favourable disposition towards organised marketing. Among the socio-economic variables, farming experience showed marginal significance (5–10 years: $B = 0.746$, $p = .077$), while age, education, gender and land size were non-significant, confirming that channel choice is driven predominantly by perceived transaction costs rather than by individual farmer characteristics (Abdi & Ondabu, 2026).

Conclusions and Implications

This study identified transaction cost perceptions, particularly the perceived distance to the processing centre and the appeal of the immediate cash payment offered by informal collectors, as the dominant barriers to organised market participation. Establishing closer collection points, mobile collection services and same-day payment mechanisms within formal channels are key policy interventions for improving organised market participation. Future research should assess interventions that reduce transaction cost barriers and strengthen farmer trust and information access, the two significant determinants identified in this study.

***Keywords*:** Binary logistic regression, organised markets, smallholders, tea

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An Investigation into the Development of Agriculture in Thirukkural

Sindhuja K.*
University of Kelaniya, Sri Lanka
*Corresponding author (email: sindhujasindu1020@gmail.com)

Introduction

This study investigates the conceptualisation and development of agriculture as presented in the Thirukkural. The Thirukkural is a profound cultural record reflecting the lifestyles, ethics and socio-economic structures of its time. Agriculture is not merely an occupation but the mainstay of a country's economy and the lifeblood of humanity, and Valluvar posits that it is the central force driving the entire world. Ideas related to agricultural management, water conservation and the livelihood security of farmers are deeply embedded in Tamil literature, from the Sanhamaruviya period to modern writings. The Thirukkural, which emerged during the Kalabhra period, offers timeless insights into sustainable farming practices. This study attempts to analyse and apply the knowledge generated from this classic text to highlight the historical and contemporary importance of agricultural development.

Methodology

This study adopts a qualitative approach, using ethical critical theory, social critical theory and agricultural management theories to analyse the text. The Thirukkural serves as a universal ethical benchmark. While other industries may fluctuate or face destruction, agriculture remains an indestructible foundation that sustains human life. Agricultural management theory is applied to examine how the text emphasises soil fertility, water management and crop quality as prerequisites for successful farming. Ethical critical theory is employed to evaluate how agricultural development must align with moral and righteous practices. Finally, social critical theory helps to interpret agriculture not merely as a means of food production but as a socio-economic tool capable of transforming society and ensuring national prosperity.

Results and Discussion

Agriculture is the foundational lifeblood of humanity; without it, human survival is impossible. The Thirukkural establishes that all other industries and professions are secondary to, and dependent upon, agriculture. The visionary poet Valluvar demonstrates this by stating that farmers are the linchpin of the world, as they support even those who have abandoned farming to pursue other professions (Kural 1032).

When undertaking agriculture, a farmer must possess comprehensive knowledge of soil management, water resources, fertilisation methods and crop cultivation techniques. Valluvar dedicates an entire chapter, "Uzhavu" (Chapter 104), to explaining these principles, which form the bedrock of sustainable agriculture.

In Kural 1037, Valluvar emphasises the importance of deep ploughing and soil aeration over fertilisation, stating: "If land is ploughed so that an ounce of dust dries to a quarter-ounce, it will yield abundantly without even a handful of manure." In Kural 1038, he

outlines the chronological steps of crop management: "Manuring is better than ploughing; after weeding, guarding the crop is better than watering it." This highlights that resource management and crop protection are as critical as initial cultivation. Furthermore, Kural 1039 emphasises the necessity of the landowner's direct presence and regular inspection, noting that if the farmer sits idle without visiting the field, the land will neglect him like an estranged spouse. These verses collectively demonstrate a highly advanced understanding of agricultural management that remains relevant today.

It is remarkable that such advanced scientific and social insights can be identified in a text originating from the post-Sangam era. The literature clearly illustrates that humanity thrives when agriculture is practised systematically. Valluvar integrates human labour dynamics with agricultural productivity, demonstrating how collective human effort can establish long-term sustainable development. Furthermore, the Thirukkural emphasises that, while individual, family and national progress rely on diverse commercial enterprises, it is the stability of the agricultural sector that provides the ultimate economic cushion for a nation.

Conclusions and Implications

The Thirukkural stands out as the foremost ethical and philosophical text to emerge during the Kalabhra period. It captures the historical transition in which early communal societies evolved into land-owning agrarian systems, and it precisely defines the structural value of agriculture as the foundation of human survival. By rereading, deconstructing and reconstructing the concepts of agricultural and water management contained within the Thirukkural, its unique historical value can be unlocked. Consequently, this study serves as an intellectual contribution to contemporary agrarian discourse, offering historical solutions to modern agricultural crises and paving the way for deeper field studies of heritage-based sustainable farming.

The Thirukkural is an unparalleled secular text in Tamil literature, containing universal principles applicable across all eras. The insights regarding resource management, soil preservation and labour coordination found in the text are deeply intertwined with modern ecological needs. The core implication of this study is the urgent need to bridge ancient Tamil agrarian wisdom with contemporary agricultural policies to address modern issues such as soil degradation, water scarcity and economic instability among farmers.

Keywords**:** Agricultural management, sustainable agriculture, Tamil literature, Valluvar, water management

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Climate-Resilient Coconut Production: Evaluating Girdle Micro-Sprinkler Irrigation Under Dry Zone Conditions

Nusrath H.F.[1], Warnasooriya W.M.R.S.K.[1,*], Piyarathne P.N.M.S.[1], Gunasekara M.A.P.[2] and Sandamali G.G.A.[1]

[1]*Department of Plant Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka, Anuradhapura, Sri Lanka,* [2]*Coconut Cultivation Board, Anuradhapura, Sri Lanka*

*Corresponding author (email: rasikaw@agri.rjt.ac.lk)

Introduction

Coconut (*Cocos nucifera* L.) is a vital crop contributing significantly to the Sri Lankan economy and rural livelihoods, with annual nut production estimated at 2.5 to 3.4 billion, depending on climatic and management conditions (Central Bank of Sri Lanka, 2023; Coconut Research Institute of Sri Lanka, 2024). Its yield is highly sensitive to climatic factors such as water availability and temperature (Intergovernmental Panel on Climate Change [IPCC], 2014; Panabokke, 1996). Reproductive processes, including pollen viability, pollen germination and fertilisation, are particularly vulnerable to heat and moisture stress; elevated temperatures in the dry zone have been shown to increase flower and fruit abortion while reducing pollen viability, ultimately constraining fruit set and yield (Ranasinghe, 2015).

Girdle micro-sprinkler irrigation (GMIS) is a modern irrigation system that improves water-use efficiency by improving root-zone soil moisture. It disperses water as fine droplets around the palm base, creating evaporative cooling that lowers canopy and floral temperatures and helps mitigate heat stress (Fernando et al., 2024; Liyanage et al., 2008). This study examined the impact of GMIS on canopy microclimate, pollen viability and germination, and flowering and fruiting behaviour, along with selected soil properties, in the Dry Zone of Sri Lanka.

Methodology

The research was conducted on a coconut farm equipped with a girdle micro-irrigation system in Galkulama, Anuradhapura, located in the DL1 agro-ecological region of the Low Country Dry Zone (mean annual temperature 27–28 °C; mean annual rainfall 1,200–1,400 mm), over a total study period of 6 months, with detailed climatic, pollen and fruit-set data collected during September–October 2024. Coconut palms of the CRIC 60 variety were assigned to two treatments, T1 (rainfed control) and T2 (irrigated with GMIS for 20–25 min day^{-1}, approximately 60–80 L per palm), in a completely randomised design (CRD) with ten replicates per treatment (20 palms in total; one palm = one replicate). No formal field blocking was applied, as a CRD assumes a relatively uniform experimental area; individual palms were treated as sampling units within each treatment.

Mature male flowers were collected 2–6 days after spathe opening and processed for the assessment of pollen germination and viability, following Kumarathunge et al. (2024). Pollen was incubated in a sucrose-based germination medium at 26, 28, 30 and 32 °C under 75% relative humidity for 24 h. Germination was assessed under a light microscope, a grain being considered germinated when the pollen-tube length exceeded

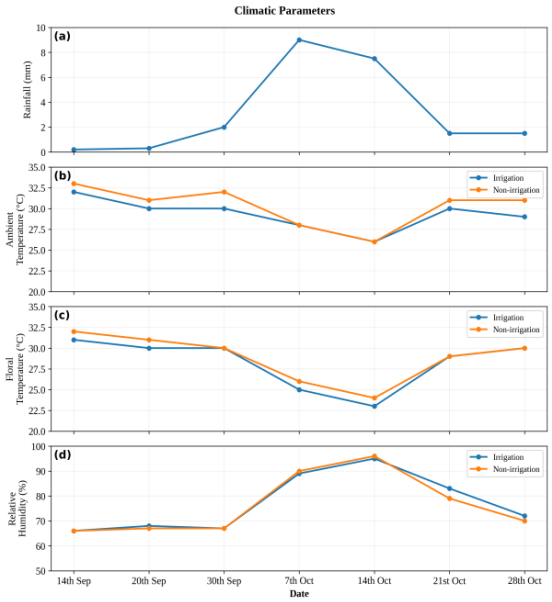
the grain diameter (Hebbar et al., 2018). Viability was assessed using 1% acetic carmine staining. Soil samples were analysed for gravimetric moisture content, pH and electrical conductivity (EC). Floral temperature, canopy temperature and relative humidity were recorded fortnightly. The number of bunches per tree, nuts per bunch and fallen button nuts per tree were recorded. Data were analysed using a mixed-effects model in RStudio, with treatment (irrigated vs. non-irrigated) fitted as a fixed effect and individual palm as a random effect to account for the repeated fortnightly measurements taken from the same ten palms per treatment; treatment effects were considered significant at $p \leq .05$.

Results and Discussion

As shown in Figure 1, ambient temperature ranged from approximately 26 to 32 °C in the irrigated plots and from 26 to 33 °C in the non-irrigated plots. Although the non-irrigated plots consistently exhibited slightly higher ambient temperatures than the irrigated plots, the differences were not statistically significant ($p > .05$), suggesting a modest cooling effect of GMIS (Figure 1b). However, canopy/floral temperature (Figure 1c) and relative humidity (Figure 1d) did not differ significantly between treatments, probably because rainfall during the study period (Figure 1a) moderated the environmental stress.

Figure 1

Variation of Climatic Parameters for Irrigated and Non-Irrigated Treatments During the Study Period



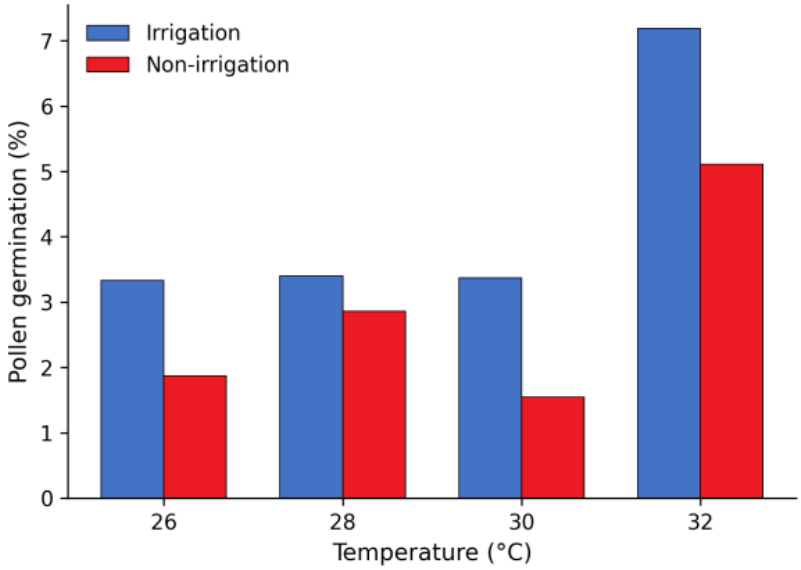
Note. (a) Rainfall; (b) ambient temperature; (c) floral temperature; (d) relative humidity.

Pollen germination increased with increasing temperature in both treatments, reaching the highest values at 32 °C (Figure 2). Across all temperatures, pollen germination was consistently numerically higher in the irrigated treatment than in the non-irrigated treatment, although this difference was not statistically significant ($p > .05$) at any

incubation temperature. The greatest numerical differences were observed at 30 and 32 °C, indicating a possible, though statistically unconfirmed, trend of irrigation improving pollen germination under warmer conditions. Kumarathunge et al. (2024) reported the role of irrigation in mitigating heat stress on pollen quality. Pollen viability did not differ significantly between irrigated (84.28%) and non-irrigated (88.01%) palms, suggesting that the effects of irrigation on viability may become evident only under prolonged drought (Nainanayake et al., 2008) and that rainfall during the study period moderated environmental stress.

Figure 2

Pollen Germination (%) of Coconut Under Irrigated and Non-Irrigated Conditions at Different Incubation Temperatures



Note. Differences between irrigated and non-irrigated treatments were not statistically significant at any incubation temperature ($p > .05$).

Nut yield attributes showed marginally higher nut retention and fewer fallen button nuts under irrigation (average number of bunches per tree, 10 and 10; nuts per bunch, 8 and 7; fallen button nuts per tree, 5 and 6, under irrigated and non-irrigated conditions, respectively), consistent with reduced fruit abortion under adequate water availability, as maintaining optimal temperature and adequate water availability is known to reduce fruit abortion in coconut (Ranasinghe et al., 2015). However, the differences were not statistically significant for any of these parameters ($p > .05$). Soil moisture was markedly higher under irrigated (6.62%) than under non-irrigated (3.36%) conditions. Irrigated soils showed a slightly higher EC (142 µS/cm) than non-irrigated soils (128 µS/cm), consistent with greater ion mobility under higher moisture conditions (Hawkins et al., 2017). Soil pH did not differ significantly between the irrigated (8.1) and non-irrigated

(7.9) treatments, yet both remained slightly above the optimum range for coconut (5.5–7.5).

Conclusions and Implications

GMIS improved soil moisture and slightly reduced ambient temperature under dry zone conditions. Irrigated palms showed a numerically higher pollen germination trend and marginally improved nut yield attributes with fewer fallen button nuts, although these differences were not statistically significant. Overall, the findings indicate that GMIS improved soil moisture availability and showed a promising, though not yet statistically confirmed, trend towards supporting reproductive performance under water-limited conditions. The lack of statistical significance for several parameters is probably attributable to the rainfall received during the study period, which moderated drought stress and reduced the contrast between treatments; GMIS may therefore still contribute to climate-resilient coconut production in the Dry Zone of Sri Lanka. Further research under prolonged drought and elevated-temperature conditions is recommended to fully assess the long-term benefits of GMIS for resilient, sustainable coconut production in Sri Lanka.

***Keywords*:** Climate adaptation, *Cocos nucifera*, heat stress mitigation, micro-irrigation, reproductive performance

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Effect of Cooking Methods on the Quality of Purple-Fleshed Sweet Potato Flour (*Ipomoea batatas* L.)

Sudasinghe I.U.[1], Weerakoon W.M.S.U.[2], Wijesundara W.M.N.M.[2] and Arachchige M.P.M.[2,*]
[1]*Department of Export Agriculture, Uva Wellassa University, Passara Road, Badulla, Sri Lanka,* [2]*Department of Food Science and Technology, Uva Wellassa University, Passara Road, Badulla, Sri Lanka*
*Corresponding author (email: melani@uwu.ac.lk)

Introduction

Sweet potato (*Ipomoea batatas* L.) is the sixth most important food source globally (Carrera et al., 2021). Purple-fleshed varieties are rich in anthocyanins and phenolic compounds such as caffeoylquinic acids (Cheong et al., 2022). These phytochemicals provide antioxidant, anti-carcinogenic and anti-inflammatory benefits (Xu et al., 2015). Purple sweet potato flour is widely used as a functional ingredient in bread, noodles and snacks (Truong et al., 2010).

Cooking methods such as boiling, steaming, baking, deep frying, and steam-blanching with oven drying can significantly alter nutrients, phenolics and anthocyanins through leaching or thermal degradation (Nayak et al., 2015). However, a comprehensive comparison of all five methods on the quality of purple sweet potato flour, including instrumental texture measurement by texture profile analysis (TPA), is still lacking, especially for Sri Lankan cultivars.

Therefore, this study compared the effects of five cooking pre-treatments on the proximate composition, functional properties, antioxidant activity, total anthocyanin content and texture profile of purple-fleshed sweet potato flour.

Methodology

Purple-fleshed Sri Lankan sweet potato tubers were obtained from a local market in Sri Lanka. The raw material was washed, peeled and cut into uniform slices (0.5–1.0 cm thick) (Truong et al., 2010). Six treatments were applied: raw (freeze-dried control); boiling (100 °C, 15 min); steaming (96–100 °C, 15 min); baking (180 °C, 45–50 min, covered with aluminium foil); deep frying in coconut oil (180 °C, 3–5 min); and steam-blanching followed by oven drying (SB+OD) at 65 °C for 18 h (Cheong et al., 2022). After all cooking treatments, the samples were freeze-dried, ground using a laboratory mill and sieved through a 200-mesh sieve to obtain fine flour. All flour samples were then kept at room temperature in airtight containers until further analysis.

Proximate composition, including moisture (AOAC 925.10), ash (AOAC 940.26), crude fat (Soxhlet extraction method, modified from AOAC 920.39, 2003), protein (AOAC 978.04), fibre (AOAC 978.10) and carbohydrate (AOAC 920.87, by difference), was determined. Among the functional properties, total phenolic content (TPC) was determined using the Folin–Ciocalteu method as described by Truong et al. (2016); antioxidant activity, as 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity (DPPH RSA), was determined according to Zhang et al. (2022); and total anthocyanin content

(TAC) was determined using the pH differential method based on the AOAC 2005.02 official method with slight modifications (Cheong et al., 2022).

Physicochemical properties, including swelling power, water absorption capacity (WAC), oil absorption capacity (OAC), bulk density, swelling capacity, water activity and texture profile, were determined. WAC, OAC, swelling power and bulk density were measured according to Pereira et al. (2025). Water activity (a_w) was measured using a calibrated water activity meter at room temperature. TPA was performed using the method described by Peleg (2019), and the parameters recorded included hardness, fracturability, cohesiveness, springiness, adhesiveness, gumminess, chewiness and resilience. All analyses were conducted in triplicate (n = 3), and data were expressed as mean ± SD. Significant differences were determined by one-way analysis of variance (ANOVA) with Tukey's honestly significant difference (HSD) test at $p < .05$.

Results and Discussion

Tables 1 and 2 summarise how the cooking techniques affected the proximate composition and the physicochemical and antioxidant properties of purple sweet potato flour.

Table 1

Proximate Composition, Functional Properties and Water Activity of Purple Sweet Potato Flour Under Different Cooking Methods

Parameter	Raw	Boiled	Steamed	Baked	Deep-fried	SB+OD
Moisture (%)	4.05 ± 0.24	5.67 ± 0.19	3.59 ± 0.16	4.43 ± 0.09	2.87 ± 0.19	8.47 ± 0.21
Ash (%)	1.60 ± 0.01	1.26 ± 0.23	2.25 ± 0.11	1.79 ± 0.34	1.39 ± 0.002	1.00 ± 0.004
Fat (%)	0.66 ± 0.15	0.66 ± 0.14	0.66 ± 0.15	0.91 ± 0.14	21.81 ± 0.58	0.58 ± 0.15
Fibre (%)	4.00 ± 0.03	2.57 ± 0.06	2.64 ± 0.02	3.55 ± 0.04	2.10 ± 0.11	5.69 ± 0.02
Protein (%)	2.83 ± 0.04	2.94 ± 0.03	2.85 ± 0.05	2.60 ± 0.06	1.75 ± 0.04	2.54 ± 0.03
CHO (%)	86.99 ± 0.01	86.90 ± 0.24	88.00 ± 0.42	86.72 ± 0.50	81.61 ± 0.06	70.04 ± 0.06
WAC (g/g)	2.67 ± 0.02	6.83 ± 0.02	6.08 ± 0.02	4.51 ± 0.02	4.40 ± 0.04	5.55 ± 0.04
OAC (g/g)	2.24 ± 0.001	2.69 ± 0.01	2.27 ± 0.003	1.94 ± 0.002	1.49 ± 0.001	1.95 ± 0.002
Bulk density (g/mL)	0.52 ± 0.02	0.46 ± 0.05	0.65 ± 0.04	0.72 ± 0.01	0.82 ± 0.02	0.81 ± 0.03
Water activity (a_w)	0.434 ± 0.006	0.560 ± 0.005	0.516 ± 0.009	0.464 ± 0.006	0.297 ± 0.011	0.370 ± 0.006

Note. WAC = water absorption capacity; OAC = oil absorption capacity; CHO = carbohydrate; SB+OD = steam-blanching followed by oven drying. Results are presented as mean ± SD (n = 3).

Table 2

Antioxidant Properties and Texture Hardness of Purple Sweet Potato Flour Under Different Cooking Methods

Parameter	Raw	Boiled	Steamed	Baked	Deep-fried	SB+OD
TPC (mg GAE/g)	0.475 ± 0.008	0.237 ± 0.024	0.253 ± 0.008	0.470 ± 0.003	0.374 ± 0.021	0.361 ± 0.021
DPPH RSA (%)	72.17 ± 2.67	30.62 ± 4.26	54.65 ± 2.36	67.95 ± 3.06	43.11 ± 4.12	41.36 ± 7.39
TAC (mg C3G/100 g)	15.13 ± 1.32	2.05 ± 0.73	12.16 ± 2.17	15.13 ± 0.71	6.48 ± 0.09	10.80 ± 0.35
Hardness (g)	2010 ± 261	88.67 ± 23.01	113.33 ± 23.69	4256 ± 1523	154.00 ± 21.66	132.67 ± 47.27

Note. TPC = total phenolic content; GAE = gallic acid equivalents; DPPH RSA = 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity; TAC = total anthocyanin content; C3G = cyanidin-3-glucoside; SB+OD = steam-blanching followed by oven drying. Results are presented as mean ± SD (n = 3).

Compared with all other treatments, deep frying considerably increased the fat content (21.81 ± 0.58%) owing to oil absorption, while reducing the carbohydrate content (70.08%). SB+OD flour retained the highest fibre content (5.69 ± 0.02%) owing to the combination of slow drying and blanching, which better preserved cell wall integrity. Boiled flour had the highest WAC (6.83 g/g), which is attributed to starch gelatinisation during moist-heat cooking (Truong et al., 2010). The lowest water activity (0.297 ± 0.011) was found in deep-fried flour, indicating a longer shelf life and higher microbiological stability (Cheong et al., 2022).

Baking best preserved TPC (0.470 ± 0.003 mg GAE/g), DPPH RSA (67.95 ± 3.06%) and TAC (15.13 ± 0.71 mg C3G eq/100 g), with values comparable to those of the raw control. Boiling, on the other hand, resulted in the greatest loss in all antioxidant measures, which is consistent with anthocyanins and water-soluble phenolics leaching into the cooking water (Nayak et al., 2015; Palermo et al., 2014). Boiled flour was the softest (88.67 ± 23.01 g) owing to complete starch gelatinisation in water, while baked flour had the highest hardness (4256 ± 1523 g) owing to moisture removal and starch retrogradation at high temperature (Peleg, 2019).

Conclusions and Implications

Cooking methods considerably affected the proximate composition and the physicochemical and antioxidant properties of purple sweet potato flour. Baking retained TPC, DPPH RSA and TAC best, at levels nearly identical to those of the raw control, while boiling caused the greatest antioxidant losses through leaching. Deep frying significantly increased the fat content, and SB+OD produced the highest fibre retention with low water activity, indicating good shelf stability.

***Keywords*:** Anthocyanins, cooking methods, functional properties, purple sweet potato flour, texture profile analysis

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Stochastic Frontier Analysis of Dairy Farm Production Efficiency in the Baddegama and Balapitiya Veterinary Ranges, Galle District

Gajasinghe P.P.[1], Hitihamu H.M.S.J.M[2], and Magamage M.P.S[1]
[1]*Department of Livestock Production, Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka, P.O. Box 70140, Belihuloya, Sri Lanka,* [2]*Rural Development Division, Hector Kobbekaduwa Agrarian Research and Training Institute, Wijerama Mawatha, Colombo 07, Sri Lanka*
*Corresponding author (email: pasinduprasad6@gmail.com)

Introduction

Dairy farming is central to Sri Lanka's rural economy, supporting income generation, employment and nutritional security across the country. Despite this importance, domestic milk production of approximately 400 million litres satisfies less than 40% of national demand, necessitating annual imports exceeding Rs. 72 billion. Galle District, situated in the wet zone, contributes only 2.12% of national milk output, yet the technical efficiency of dairy production in this district has not been examined empirically. Existing Sri Lankan efficiency studies are concentrated almost exclusively in dry zone districts such as Kurunegala and Anuradhapura, leaving a significant knowledge gap regarding wet zone dairy production systems.

A critical policy question persists as to whether the district's comparatively low output stems from resource scarcity or from inefficient utilisation of existing resources. Within Galle District, the Baddegama veterinary area recorded the highest annual milk production (964,360 litres), while the Balapitiya veterinary area recorded the lowest (174,769 litres), a five-fold disparity that warrants systematic investigation. Without localised evidence, policymakers and veterinary officers lack a basis for determining whether interventions should focus on expanding resource provision or on improving farmers' utilisation of the resources they already possess.

This study therefore assessed the technical efficiency of dairy production and identified the factors influencing technical efficiency in the Baddegama and Balapitiya veterinary areas of Galle District. The specific objectives were to estimate technical efficiency levels, to compare efficiency between the two veterinary areas and to identify the farm- and farmer-specific factors that determine efficiency, thereby providing the first empirical evidence on dairy production efficiency in this wet zone district.

Methodology

The Baddegama and Balapitiya veterinary areas were purposively selected as the highest and lowest milk-producing veterinary areas in Galle District, respectively, to enable a contrasting comparison of technical efficiency. Primary data were collected from 215 registered dairy farmers (160 from Baddegama and 55 from Balapitiya) using structured questionnaires. Sample sizes were determined using Slovin's formula at a 95% confidence level and a 5% margin of error, from a total registered population of 330 farmers.

A single-stage stochastic frontier analysis (SFA) employing the Cobb–Douglas production function was applied, following Battese and Coelli (1995), to estimate the production frontier and the determinants of technical inefficiency simultaneously. Milk

production (litres per animal per day) was the dependent variable. Farm-specific inputs included the number of milking animals, concentrate feed, pasture feed, veterinary costs, labour hours and 24-hour water provision. Farmer-specific variables entered into the inefficiency model included age, gender, education, farming experience, family size, membership of a farmer organisation, milking method, breeding method, pasture land size, cattle shed availability and access to extension services. Data were analysed using STATA statistical software, with separate models estimated for the pooled sample and for each veterinary area.

Results and Discussion

The pooled model returned a gamma value of 0.78 and a lambda value of 1.8829, confirming that technical inefficiency, rather than random noise, accounted for the majority of output variation and validating the use of the stochastic frontier framework. The number of milking animals ($\beta = 0.1127$), total concentrate feed ($\beta = 0.2413$), total pasture ($\beta = 0.2173$) and 24-hour water provision ($\beta = 0.1378$) were all positive and significant determinants of production, while veterinary cost was negatively associated with output ($\beta = -0.1683$), reflecting reactive rather than preventive animal health spending. Labour hours were not significant, consistent with the predominance of relatively inelastic family labour among smallholders.

Educational level, farming experience and machine milking significantly reduced technical inefficiency, whereas older farmer age significantly increased it. In Balapitiya, male-headed farms demonstrated significantly higher efficiency than female-headed farms, an area-specific finding not observed in Baddegama, which points to unequal access to resources and management support for women farmers in that area.

The mean technical efficiency scores were 0.6256 for Baddegama, 0.4536 for Balapitiya and 0.5816 for the pooled sample, indicating that farmers operated at approximately 58% of their productive potential, leaving a recoverable efficiency gap of 42% without additional resource investment. More than half (53.03%) of the pooled sample, and 81.82% of Balapitiya farmers specifically, operated below a technical efficiency of 0.60. These findings are consistent with, and reinforce the severity of, prior Sri Lankan evidence: Sheromiha and Kularatne (2016) reported 45% average efficiency among smallholder dairy farmers, Bandara and Weligamage (2018) reported 49.6% in the Eastern Dry Zone, and Hitihamu et al. (2025) reported 60% across four dry zone districts. This indicates that systemic technical inefficiency, rather than isolated farm failure, characterises smallholder dairy production across Sri Lanka's climatic zones.

Conclusions and Implications

Dairy production in Galle District is constrained primarily by systemic technical inefficiency linked to farmer characteristics and management practices, rather than by scarcity of productive resources. The pronounced efficiency gap in Balapitiya, where more than 80% of farmers operate below 60% efficiency, identifies this area as a priority zone for intervention. Strengthening farmer education and extension delivery, promoting continuous water availability and improved access to concentrate feed, encouraging

machine milking and shifting veterinary care towards preventive management are recommended as cost-effective pathways to increase milk output without additional herd expansion. Given that domestic production meets only about one-third of national demand, efficiency-led gains among existing smallholders represent a sustainable route to reducing Sri Lanka's dependence on imported dairy products. Future research extending this analysis to other wet zone districts would help to establish the generalisability of these findings.

***Keywords*:** Dairy production, Galle District, stochastic frontier analysis, technical efficiency, wet zone dairy farming

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Assessing the Future of Paddy Cultivation in Gampaha District Through Production Trends and Farmers' Perceptions

Athukorala K.A.D.R.Y.*, Bandara A.L.J. and Herath H.M.L.K.
Department of Agribusiness Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila (NWP), 60170, Sri Lanka
*Corresponding author (email: ravinduathukorala324@gmail.com)

Introduction

Rice (*Oryza sativa* L.) cultivation underpins Sri Lanka's food security, supporting approximately 1.8 million farming families and covering nearly 34% of cultivated land (Diyawadana et al., 2016). The ancient village tank cascade system irrigates approximately 35% of rice lands (Jayasiri et al., 2023). However, climatic, economic and social pressures increasingly threaten the long-term sustainability of rice cultivation, with projected yield reductions of up to 40% (Cordell et al., 2021). Gampaha District faces growing land-use competition and deteriorating water infrastructure due to rapid urbanisation (Weerasinghe et al., 2025). Given the limited number of integrated assessments (Esham & Garforth, 2013), this study aimed to assess production trends and their determinants, examine farmers' perceptions, and identify adaptation strategies and future prospects.

Methodology

The study was conducted across 11 of the 13 Divisional Secretariat divisions in Gampaha District, Western Province, Sri Lanka, predominantly within the WL3 agro-ecological zone. Using stratified random sampling across urban, semi-urban and rural strata, 252 paddy farmers were surveyed via pre-tested semi-structured questionnaires administered in Sinhala. Secondary data on sown and harvested extent (ha) and yield (kg/ha) were obtained from the Department of Census and Statistics, while qualitative data were gathered through key informant interviews (KIIs), focus group discussions (FGDs) and open-ended survey responses.

Temporal trends in paddy sown extent, harvested extent and yield were analysed for 1979–2025 using the Mann–Kendall test and Sen's slope estimator. Multiple linear regression (MLR) was used to examine the factors influencing paddy harvest performance (Equation 1), and binary logistic regression (BLR) was employed to assess farmers' intentions to expand paddy cultivation (Equation 2). Perception-based indices were derived from Likert scale data using principal component analysis. All quantitative analyses were carried out using RStudio (version 4.6.0), and the qualitative thematic analysis was conducted using NVivo (version 1.7.2). The two models were specified as follows:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \varepsilon \qquad (1)$$

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_5 Z_5 + \cdots + \beta_{12} Z_{12} + \varepsilon \qquad (2)$$

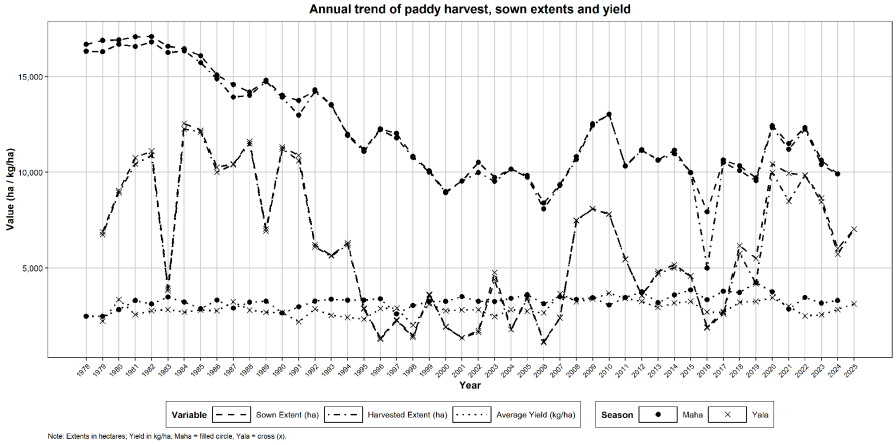
where *Y* is the general paddy harvest (kg/acre) and *p* is the probability of expansion; the predictors include age, farming experience, cultivated area, ownership, harvest, profit, urban development, reduced interest, government support, extension services, labour scarcity and government policy protection indices.

Results and Discussion

As illustrated in Figure 1, the trend analysis showed significant declines in *Maha* sown and harvested extent (−150 ha/year each) and in *Yala* harvested extent (−74 ha/year), while average yields improved in both *Maha* (+14.6 kg/ha/year) and *Yala* (+9.7 kg/ha/year), indicating stable productivity despite a contracting cultivated area. Disruptions from the 2016–2017 floods, the 2021 fertiliser ban and the 2022 economic crisis further accelerated the decline in cultivated extent, with the *Yala* season area remaining below historical levels in 2025.

Figure 1

Annual Trend of Paddy Harvest, Sown Extents and Yield in Gampaha District, 1978/79–2024/25



Note. SE = sown extent (ha); HE = harvested extent (ha); AY = average yield (kg/ha). *Maha* = ●; *Yala* = ×.

Table 1 presents the results for the determinants of paddy harvest. The model explained only 5.4% of the variation in harvest yield (adjusted R^2 = .054). Among all variables, cultivated area and water source were the only statistically significant predictors of harvest, indicating that larger cultivated extents and improved water access contribute positively to paddy production.

Table 1

Multiple Linear Regression Results for Paddy Harvest Determinants (n = 252)

Variable	Estimate	Std. error	*t*	*p*
(Intercept)	1322.81	186.75	7.083	< .001***
Area	15.548	6.445	2.412	.017*
Water source	153.10	54.551	2.807	.005**

Note. *p < .05. **p < .01. ***p < .001. F = 3.330, p = .004; adjusted R^2 = .054.

Table 2 shows the BLR results for cultivation expansion. The binary logistic regression model was statistically significant ($\chi^2 = 66.246$). Age had a significant negative effect, suggesting that older farmers were less likely to expand paddy cultivation. In contrast, farming experience, cultivated area and extension services positively influenced the likelihood of expansion. Government support programmes and policy protection measures showed significant negative effects.

Table 2

Binary Logistic Regression Parameter Estimates for Paddy Cultivation Expansion Propensity

Variable	Estimate	Odds ratio	SE	*Z*	*p*
(Intercept)	6.5452	695.87	1.939	3.376	< .001***
Age	−0.0919	0.9122	0.022	−4.124	< .001***
Experience	0.0547	1.0563	0.021	2.603	.009**
Area	0.2032	1.2253	0.102	1.989	.046*
GPC1	−0.6436	0.5254	0.211	−3.053	.002**
GPC2	0.6101	1.8407	0.220	2.774	.006**
GPC3	−0.5258	0.5911	0.196	−2.695	.007**

Note. *$p < .05$. **$p < .01$. ***$p < .001$. SE = standard error; GPC1 = government support programme index; GPC2 = extension services index; GPC3 = government policy protection index; AUC = area under the curve. Model: $\chi^2 = 66.246$, Nagelkerke $R^2 = .314$, classification accuracy = 71.8%, AUC = .791.

The thematic analysis of the FGDs and KIIs revealed multifaceted challenges encompassing labour scarcity, escalating production costs, climate variability, recurrent flooding, deteriorating water management and urbanisation-driven land attrition. Farmers reported employing adaptive strategies including mechanisation, the adoption of improved varieties and drainage enhancement, while both farmers and officials underscored the need for robust land protection policies, strengthened institutional frameworks and improved economic returns to sustain the long-term viability of cultivation.

Conclusions and Implications

The findings demonstrate a progressive contraction in cultivated extent across Gampaha District, notwithstanding sustained productivity levels. Sustainability is critically undermined by climate variability, water management deficiencies, labour scarcity, escalating production costs, accelerating urbanisation and dwindling youth engagement. Cultivated area and water accessibility emerged as the principal determinants of harvest performance, while expansion intentions were significantly influenced by farmer age, experience, landholding size and institutional support. Despite the widespread adoption of mechanisation and adaptive practices, profitability concerns persist. To safeguard the sector's long-term viability, policymakers must urgently prioritise cost reduction through targeted subsidies, infrastructure rehabilitation, expanded extension outreach, stringent agricultural land protection mechanisms and technology-driven interventions to attract youth and women into paddy cultivation.

Keywords**:** Farmer perceptions, future prospects, paddy cultivation, peri-urban agriculture, production trend analysis

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Native *Trichoderma asperellum* Against Rice Brown Leaf Spot Pathogen *Bipolaris oryzae*: A Dual Culture Study

Karunarathna U.G.D.S.[1,*], Mudugama M.V.S.S.[1], Bandara G.A.S.D.P.[2], Priyadarshani T.D.C.[1] and Egodawatta W.C.P.[1]

[1]*Department of Plant Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka, Anuradhapura 50000, Sri Lanka,* [2]*Department of Plant and Molecular Biology, Faculty of Science, University of Kelaniya, Sri Lanka*

*Corresponding author (email: karunarathnaduasha@gmail.com)

Introduction

Rice (*Oryza sativa* L.), a globally important staple feeding billions, has become increasingly susceptible to various biotic and abiotic stresses owing to the reduced genetic diversity resulting from yield-focused crop improvement efforts (Jephthah et al., 2025). Among these threats, brown leaf spot, caused by *Bipolaris oryzae* (teleomorph: *Cochliobolus miyabeanus*), is one of the five most destructive rice diseases, producing necrotic brown lesions that cause plant distortion and death, fewer grains per panicle and low kernel weight (Kaboré et al., 2025; Shabana et al., 2008).

Conventional management strategies for this disease include cultural practices, varietal resistance, biological control agents and synthetic fungicides, among which chemical fungicides remain the most widely used by farmers. However, their field application raises significant concerns, as these compounds pose a threat to humans, animals and the environment. Moreover, their high cost places them beyond the reach of resource-poor farmers (Kaboré et al., 2025). Biological control using fungal and bacterial biocontrol agents and botanical extracts therefore offers an innovative, cost-effective and eco-friendly alternative for managing this destructive pathogen (Kaboré et al., 2025). Among the available biocontrol agents, *Trichoderma* species such as *T. asperellum* have been well studied for their ability to inhibit fungal phytopathogens, either through direct suppression of their growth and development or by enhancing host plant immunity (Guzmán-Guzmán et al., 2023).

Despite this potential, the efficacy of locally isolated, native *T. asperellum* strains against *B. oryzae* remains underexplored. The present study therefore aimed to assess the antagonistic potential of a locally isolated, molecularly confirmed native strain of *T. asperellum* against *B. oryzae* under *in vitro* conditions using a dual culture assay.

Methodology

Molecularly characterised, long-term stored cultures of *T. asperellum* (GenBank accession number ON040617), previously isolated from the Dambulla region of Sri Lanka, and of *B. oryzae* (GenBank accession number MZ618926) were used to prepare stock cultures, which were incubated under controlled conditions (30 ± 1 °C and 70% relative humidity [RH]) for 7 days. Five-millimetre mycelial plugs of the pathogen and the biocontrol agent were then placed 8.5 cm apart on 9 cm potato dextrose agar (PDA) plates. Control plates containing the pathogen only were maintained alongside the treatment plates. All plates were incubated for 14 days under the same controlled

conditions (30 ± 1 °C, 70% RH) in a completely randomised design (CRD), with each treatment replicated four times. The radial growth of the pathogen was measured over the 14-day period, and the percentage inhibition of radial growth by the biocontrol agent was calculated using the following equation (Hashim et al., 2018):

$$\text{Percentage inhibition of radial growth} = \frac{C - T}{C} \times 100\%$$

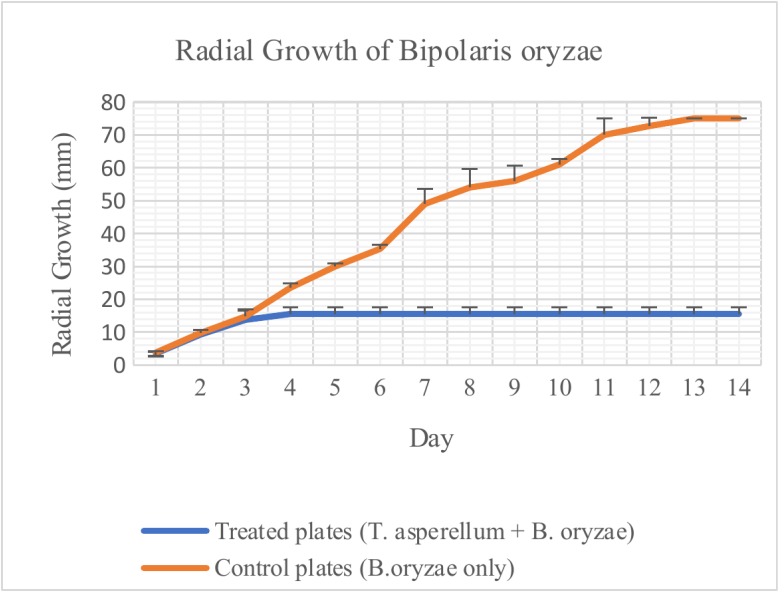
where C is the average colony radius of *B. oryzae* in the control plates and T is the average colony radius of *B. oryzae* in the dual culture plates. The data collected were analysed using the Wilcoxon rank-sum test in RStudio (version 4.5.1), with the significance level set at $p < .05$.

Results and Discussion

As illustrated in Figure 1, the native *T. asperellum* strain exerted a pronounced antagonistic effect against *B. oryzae*, substantially reducing its radial growth to 15.5 ± 2 mm, compared with a radius of 75 ± 2 mm in the untreated controls during the observation period.

Figure 1

Radial Growth of Bipolaris oryzae



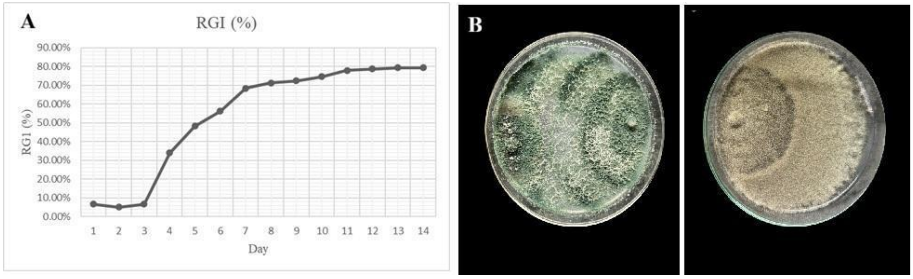
Note. Growth dynamics of *B. oryzae* in control plates (*B. oryzae* only) and dual culture plates (*T. asperellum* + *B. oryzae*) over 14 days.

The radial growth inhibition analysis, depicted in Figure 2, showed that *T. asperellum* inhibited pathogen growth up to a maximum of 79.33% over the 14-day study period, reflecting a progressive intensification of its inhibitory effect. Statistical analysis using the Wilcoxon rank-sum test confirmed that, by day 14, the radial growth of the pathogen

was significantly suppressed in the presence of *T. asperellum* relative to the untreated control ($p < .05$).

Figure 2

Radial Growth Inhibition of Bipolaris oryzae by Trichoderma asperellum



Note. (A) Percentage radial growth inhibition (RGI) of *B. oryzae* by *T. asperellum*. (B) Plan view of 14-day-old culture plates showing the dual culture of *B. oryzae* and *T. asperellum* (left) and the *B. oryzae* monoculture (right).

These findings align closely with those of Hashim et al. (2018), who similarly reported that *T. asperellum* suppressed the radial growth of the rice blast pathogen *Pyricularia oryzae* Cavara, achieving an inhibition of 86% when incubated at 25 °C.

Conclusions and Implications

This study demonstrated the strong biocontrol potential of a locally isolated native *T. asperellum* strain against *B. oryzae*, achieving a maximum growth inhibition of 79.33%. These results are consistent with the known modes of action of *Trichoderma* species, although the specific inhibitory mechanism was not determined here and warrants further investigation. Given the limitations and adverse impacts associated with chemical fungicides, these findings highlight the potential of this native strain to be used as a sustainable and eco-friendly biocontrol agent in managing rice brown leaf spot. Future field trials are, however, needed to validate the efficacy of this strain under real-world agronomic conditions.

***Keywords*:** Biological control, dual culture assay, radial growth inhibition

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Technical Efficiency of Tea Smallholders in Mid Country Wet Zone (MW2b), Sri Lanka

Rupasinghe E.K.W.G.P.L.*, Bandara A.L.J. and Herath H.M.L.K.
Department of Agribusiness Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila (60170), Sri Lanka
*Corresponding author (email: pasindurupasinghe716@gmail.com)

Introduction

Tea smallholders account for about 75% of Sri Lanka's total tea production, making them crucial to rural livelihoods and export earnings (Shyamalie et al., 2020). However, existing studies reveal significant gaps between actual and potential output, indicating that improving technical efficiency can increase green leaf production without expanding land use. This study focuses on the Mid Country Wet Zone (MW2b), specifically the Udunuwara Divisional Secretariat (DS) Division, to evaluate the technical efficiency of tea smallholders and identify the key determinants of inefficiency. Empirical model selection confirms that the Translog function provides a better fit than the Cobb–Douglas model, justifying its use. By comparing efficiency levels, input elasticities and inefficiency drivers with findings from similar agro-ecological zones, this study aims to generate policy-relevant insights to enhance productivity, improve farmer incomes and support the long-term sustainability of Sri Lanka's smallholder tea sector.

Methodology

The study was conducted in the Udunuwara DS Division, Kandy District, a mid-country wet zone with 1,500–2,000 mm of rainfall, temperatures of 18–24 °C, and Reddish Brown Latosolic, Immature Brown Loam, Low Humic Gley and Red Yellow Podzolic soils. The primary focus of this research is on tea smallholders, who are legally defined in Sri Lanka as operators cultivating tea lands of less than 10 acres (approximately 4.05 hectares). Smallholders here cultivate tea on holdings under 10 hectares. A total sample of 300 farmers was selected via stratified random sampling from 13 of the 124 Grama Niladhari divisions, grouped into high, medium and low cultivation intensity categories based on their tea yield. The sampling frame was obtained from the official registry at the Department of Agrarian Development, Udunuwara, and a pilot study with 20 farmers was used to refine the questionnaire. Data were collected through face-to-face interviews using a structured questionnaire with closed-ended input/efficiency questions and open-ended socio-economic questions.

For the empirical model specification, Cobb–Douglas and Translog models were estimated via maximum likelihood estimation and compared using the Akaike information criterion (AIC). The Translog model had a lower AIC (479.00) than the Cobb–Douglas model (507.68), indicating a better fit, and was therefore selected for the analysis of efficiency and inefficiency effects. The Translog production frontier was specified as follows:

$$\ln Y_i = \beta_0 + \beta_1 \ln L_i + \beta_2 (\ln L_i)^2 + \beta_3 (\ln F_i)^2 + \beta_4 (\ln L_i \times \ln N_i) + \beta_5 (\ln L_i \times \ln F_i) + V_i - u_i \qquad (1)$$

where ln Y_i is the natural logarithm of green leaf output for farmer i, β_0 is the intercept, and β_1 to β_5 are the coefficients of ln Land, ln Land², ln Fert², ln Land × ln Labour and ln Labour × ln Fert, respectively. The inefficiency model was specified as follows:

$$u_i = \delta_0 + \delta_1 \text{Z_Age3}_i + \delta_2 \text{Z_Age4}_i + \delta_3 \text{Z_Age5}_i + \delta_4 \text{CSR1}_i + \delta_5 \text{TPA}_i + W_i \qquad (2)$$

where u_i is the technical inefficiency term for farmer i, δ_0 is the intercept, δ_1 (Z_Age3) represents farmers aged 30–39 years, δ_2 (Z_Age4) those aged 40–49 years, δ_3 (Z_Age5) those aged 50 years and above, δ_4 (Z_CSR1) access to credit for farm activities and δ_5 (TPA) the number of tea plants per acre.

Results and Discussion

Regarding production output, Table 1 shows a wide variation in green leaf production despite an average of 4,618 kg, indicating significant productivity differences. The small average land size (1.39 acres) confirms smallholder dominance, while the variation in labour and fertiliser reflects differing management practices. Stable green leaf prices but large variation in profit point to unequal economic performance among farmers.

Table 1

Overview of Production Output

Variable	Mean	Std. dev.	Min	Max
Annual total green leaf production	4618.25	5534.87	236	47151
Total cultivation area	1.39	1.52	0.25	13
Labour	108.05	66.96	18	330
Total fertiliser	483.3	553.93	25	6000
Average age of tea bushes	18.68	6.93	2	40
Farming experience	24.74	11.17	4	56
Price/kg	150.04	3.37	140	160
Estimated total profit	450383	768101.74	148	10605321

In the estimation of the production frontier, Table 2 shows that the Translog model outperformed the Cobb–Douglas model on log-likelihood (−201.50 vs. −225.84) and AIC (479.00 vs. 507.68). Land area had the greatest effect on output ($\beta = 2.488$, $p < .01$), fertiliser showed diminishing returns ($\beta = -0.350$, $p < .001$), and the land–labour and labour–fertiliser interactions indicated substitutability and complementarity, respectively.

Table 2

Maximum Likelihood Estimation of the Production Frontier

Variable	Coefficient	Standard error	*z*	*p*
Intercept	5.395	3.312	1.6287	.1034
ln(Land)	2.488	0.793	3.1374	< .0017*
Land square	0.641	0.147	4.3539	< .001**
Fertiliser square	−0.35	0.104	−3.3591	< .001**
ln_land × ln_labor	−0.34	0.154	−2.2509	.0244*
ln_labor × ln_fert	0.3764	0.1348	2.7930	.0052**
σ (sigma)	0.278	0.045	6.1693	< .001**
γ (gamma)	0.403	0.136	2.9492	.003**

Gamma ($\gamma = 0.404$, $p < .01$) shows that approximately 40% of output variation stems from technical inefficiency, meaning that gains are possible through better management and extension support.

Turning to the inefficiency effects model, Table 3 shows a mean technical efficiency of 0.693, with 31% of output unrealised. Farmer age ($\beta = -0.751$ to -0.563), credit access ($\beta = -0.330$) and planting density ($\beta = -0.0001$) all significantly reduced inefficiency ($p < .05$), emerging as the principal targets for closing the gap.

Table 3

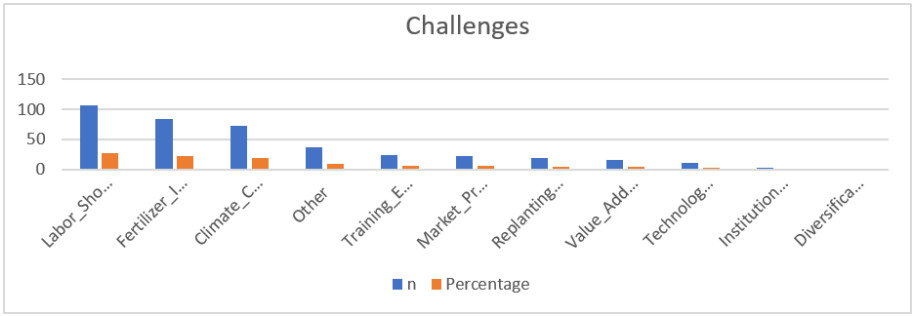
Determinants of Inefficiency Model

Variable	Coefficient	Standard error	*z*	*p*
Intercept	1.5727	0.474	3.3126	.0009***
Z_Age3 = 30–39 years	−0.7512	0.319	−2.3549	.0185*
Z_Age4 = 40–49 years	−0.5632	0.266	−2.1116	.0347*
Z_Age5 = 50 years and above	−0.7176	0.270	−2.6552	.007**
Z_CSR1 = Access to credit for farm activities	−0.3297	0.126	−2.6009	.009**
TPA = tea plants per acre	−0.0001	0.00007	−2.5571	.0106*

With regard to the challenges faced, Figure 1 shows labour shortage as the top challenge, followed by fertiliser issues and climate change, with market volatility, training, and replanting/technology access less common. This aligns with the quantitative results, confirming input constraints and environmental pressures as key barriers to productivity.

Figure 1

Key Challenges Identified by Tea Smallholders



Note. LS = labour shortage; FI = fertiliser issues; CC = climate change; O = other; TE = training and extension; MP = market price; RT = replanting technology; VA = value addition; TA = technology adoption.

Conclusions and Implications

Tea smallholders in Udunuwara achieve a mean technical efficiency of 0.69, leaving 31% of output unrealised. Land, labour and fertiliser drove output, while experience, credit and planting density reduced inefficiency. Labour, fertiliser, climate and price instability were

the key challenges. Better management, credit, training and improved clones can close the gap and sustain the sector.

***Keywords*:** Cobb–Douglas production function, stochastic frontier analysis, tea production, technical efficiency, Translog model

Funding/Acknowledgement: The author would like to express sincere gratitude to the Tea Small Holdings Development Authority (TSHDA), including tea officers, and to all individuals who assisted in data collection. The author is also grateful to the tea smallholders in the Udunuwara area for their valuable cooperation in providing the necessary data for this study.

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An Intelligent Multi-Agent Architecture for Climate Risk Assessment and Decision Support

Masood A.*
Department of Computer Science, Bahria University Lahore Campus
*Corresponding author (email: asifmasood.bulc@bahria.edu.pk)

Introduction

Climate change is increasing extreme weather, floods, droughts and heat events, creating risks to ecosystems and socio-economic systems (Intergovernmental Panel on Climate Change [IPCC], 2022; IPCC, 2023). Climate risks require integrated physical and contextual information (Lewis et al., 2020). Pakistan is particularly vulnerable owing to its geography and agricultural dependence, and the 2025 monsoon highlighted the need for timely, location-specific climate information (National Disaster Management Authority [NDMA], 2025a). The Pakistan Meteorological Department (PMD) and the NDMA provide monitoring, forecasts, warnings and disaster information, but these remain distributed across different information streams (NDMA, 2025b). Recent artificial intelligence (AI) research highlights retrieval-augmented generation (RAG) and multi-agent collaboration for knowledge-intensive reasoning (Wang et al., 2024; World Meteorological Organization [WMO], 2024; Xie et al., 2025). However, a gap remains between climate evidence and auditable decision support for disaster management.

The proposed tool addresses this gap through an integrated architecture comprising (i) a Retrieval-Augmented Climate Knowledge Base (RACKB) for shared semantic memory, (ii) an Orchestration Agent for coordinating specialised agents, (iii) a standardised Decision Support Package (DSP) integrating risk, impacts, evidence, confidence and actions, and (iv) human feedback for operational and knowledge updates. It connects climate information with coordinated, explainable decision support while complementing existing forecasting and warning systems (NDMA, 2025b).

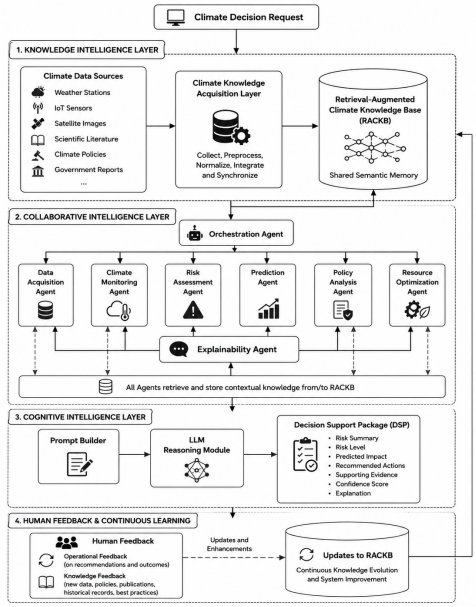
Methodology

The proposed framework integrates the established climate risk model of hazard, exposure and vulnerability (Lewis et al., 2020) with RAG-based external knowledge grounding (Wang et al., 2024). Its multi-agent workflow follows recent research on specialised agents, role-based actions, communication and feedback (WMO, 2024; Xie et al., 2025). The framework comprises three intelligence layers supported by human feedback.

Figure 1 shows the architecture. The Knowledge Intelligence layer collects heterogeneous climate data, which are cleaned, synchronised and stored in the RACKB using vector embeddings for semantic retrieval (Wang et al., 2024). In the Collaborative Intelligence layer, specialised agents coordinated by the Orchestration Agent retrieve evidence and generate a standardised DSP. This reflects recent large language model (LLM)-based multi-agent workflows and multi-agent RAG for hazard decision support (WMO, 2024; Xie et al., 2025).

Figure 1

Proposed Intelligent Multi-Agent Framework for Climate Risk Assessment and Decision Support



The human feedback mechanism uses expert evaluation and updated climate knowledge to refine the reasoning and the RACKB without retraining the LLM. The LLM supports reasoning and synthesis, while quantitative observations remain grounded in retrieved climate and disaster data.

Results and Discussion

An illustrative retrospective case study was conducted in the Lahore–Sheikhupura–Kasur region from 15 July to 15 August 2025. The framework integrated meteorological, satellite, disaster, scientific and policy information through the RACKB, with the Orchestration Agent generating the DSP shown in Table 1.

Table 1

Illustrative Decision Support Package Generated for the Central Punjab Monsoon Scenario

Parameter	Generated result	Decision implication
Study area	Lahore, Sheikhupura and Kasur Districts	Priority monitoring region
Assessment period	15 July – 15 August 2025	Peak monsoon assessment
Dominant climate hazard	Intense monsoon rainfall and urban flooding	Activate flood preparedness
Estimated rainfall	285 mm accumulated rainfall (≈ 25% above seasonal average)	Increased probability of urban flooding

Parameter	Generated result	Decision implication
High-risk locations	Laxmi Chowk, Gulberg, Johar Town (Lahore); Ferozewala (Sheikhupura); Chunian (Kasur)	Immediate surveillance and emergency preparedness
Population exposed	Approximately 1.8 million residents	Early warning dissemination
Agricultural area at risk	Approximately 14,500 hectares	Crop protection measures
Critical infrastructure at risk	42 km major road network, 3 hospitals, 12 schools, 2 power substations	Prioritise protection of essential services
Priority response actions	Flood alerts, drainage clearance, deployment of 18 emergency response teams, installation of temporary pumping stations	Reduced expected flood impacts
Decision confidence	92%	High confidence for operational planning

The generated assessment identified intense monsoon rainfall and urban flooding, consistent with the 2025 observations. The PMD recorded 472.3 mm of rainfall in Lahore City, 527.9 mm at Lahore Airport, 538.0 mm in Sheikhupura and 262.6 mm in Kasur. The Flood Forecasting Division (FFD) and the NDMA also reported heavy rainfall across Lahore, Sheikhupura, Kasur and Chunian (NDMA, 2025b). Flooding in Lakshmi Chowk, Gulberg and Johar Town further supports the identified high-risk locations.

These observations provide ground validation of the identified hazard and its broad spatial pattern. However, the values in Table 1 such as the exposed population, agricultural area, economic exposure, the 0.87 risk index and the 92% confidence remain tool-generated estimates that require validation against geographic information system (GIS) data, field and institutional records and a broader historical record. The case study therefore supports the operational usefulness of the framework while highlighting the need for formal quantitative benchmarking.

Conclusions and Implications

This paper presents an intelligent multi-agent architecture integrating climate information, retrieval-augmented knowledge and LLM reasoning into a standardised DSP. In the 2025 case study, the identified hazard and spatial risk pattern aligned with PMD, NDMA and FFD evidence, whereas the quantitative risk and exposure estimates require further field validation. The modular framework supports explainable, evidence-grounded decision support and knowledge updates without LLM retraining.

***Keywords*:** Agentic AI, climate risk assessment, decision support, large language models

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The Use of Triglycerides-Producing Marine Photosynthetic Microorganisms for Laboratory-Scale Biodiesel Production

Rathnayaka S., Muhandiram A., Ambepitiya H., Jayathilake C., Somasiri M., Basnayaka C., Ekanayake L., Edirisinghe R., Yapa N. and Fernando E.*
Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: eustace6192@as.rjt.ac.lk)

Introduction

Conventional petroleum fuels, including diesel, petrol (gasoline) and kerosene, are commonly used in transportation, agriculture and other industrial sectors because of their wide availability, higher energy density and efficiency. Hence, they have become economically and socially indispensable, despite their finite availability, and finding alternatives is therefore crucial. According to the American Society for Testing and Materials, biodiesel is a monoalkyl ester of fatty acids, or fatty acid (m)ethyl ester, derived from renewable feedstock such as vegetable oils (the biological source may vary). As a renewable and environmentally friendly fuel, biodiesel represents a promising alternative to conventional fossil fuels, contributing to global sustainability and reducing reliance on finite resources.

For the production of third-generation biodiesel, photosynthetic microorganisms such as microalgae and cyanobacteria are used (Alalwan et al., 2019) because of their ability to synthesise and accumulate a high lipid content, which can later be converted into biodiesel through transesterification. Marine photosynthetic microorganisms (microalgae) were selected for this research because of their high photosynthetic efficiency and high biomass production capacity, while conserving freshwater resources by using saline environments. Their ability to utilise the salts available in saline water as nutrients for growth reduces the need for additional nutrient inputs, making them an economically viable and sustainable option for biodiesel production (Amaro et al., 2011). The laboratory-scale experimentation conducted in this study is a fundamental step towards evaluating the feasibility of marine photosynthetic microalgae for large-scale biodiesel production in tropical coastal environments. To ensure accurate strain selection and identification, morphological and molecular characterisations were performed, and the fatty acid composition of the synthesised biodiesel was qualitatively analysed to lay the groundwork for future advances in biodiesel production using marine photosynthetic microorganisms.

Methodology

Marine photosynthetic microorganisms (microalgae) were collected from stagnant water bodies in coastal areas of Trincomalee, Sri Lanka, and isolated by the streak plate method on BG-11 medium (Basnayaka et al., 2024). The isolated microalgae were morphologically characterised using an Optika B-500 TPL microscope (400× magnification, high power, with a numerical aperture of 0.65). For molecular characterisation, DNA analysis was performed with the 16S rRNA gene marker. DNA was extracted using the Wizard™ genomic DNA extraction kit (Promega Corporation, USA) according to the manufacturer's protocol, and the 16S rRNA gene was amplified

by polymerase chain reaction following the protocol described by Basnayaka et al. (2024) and Somasiri et al. (2024). Finally, Sanger DNA sequencing was performed at Macrogen Sequencing Services, South Korea, and the evolutionary analyses (phylogenetic tree construction) were conducted in MEGA12.

Natural seawater culture media were used throughout the research. The conditions of the seawater, such as conductivity, pH and temperature, were maintained at those of the sites where the microalgae were collected. Culturing was performed in glass vessels (Figure 1) with an air supply (aeration at 3.5 L/min) under sunlight, and the natural day–night cycle was maintained throughout the culturing period.

Figure 1

Microalgae Culturing



The growth of the planktonic cyanobacteria was monitored using a haemocytometer, and the final growth curve was constructed using the average number of cells per 1 µL. Harvesting was carried out by centrifugation after the culture had reached the stationary phase (as determined from the growth curves) and showed a dark greenish appearance (Fuad Hossain et al., 2020).

Following harvesting, lipids were extracted using the Folch method (Folch et al., 1957). Fatty acid methyl esters (FAME) were prepared from the extracted lipids following AOAC method 969.33, and the FAME composition was determined by gas chromatography–mass spectrometry (GC-MS). Finally, the cetane number of the biodiesel was calculated from the FAME composition obtained by GC-MS, using the model of Lin and Wu (2022).

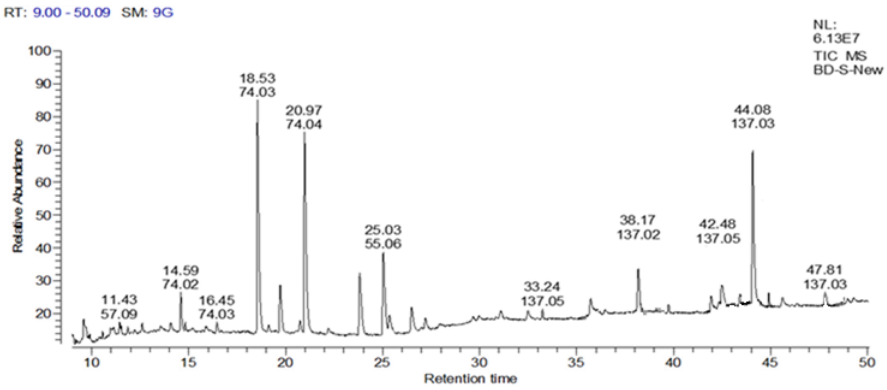
Results and Discussion

According to the growth curve of the isolated microalgae, the culture reached the stationary phase within an average of 8–10 days. Harvesting at the stationary phase offers several benefits for biodiesel production, such as pH-induced aggregation of the microalgae, which makes harvesting easier (Nawaz et al., 2024); higher biodiesel quality

through a higher cetane number; lower susceptibility to bacterial contamination due to depleted resources; and consistent biomass quality (Mathumathy et al., 2022). Even without any external nutrient supply, the average lipid yield of this marine planktonic cyanobacterium, 12.23% (±0.0983%) (w/w), is within the low to mid range of lipid contents reported for other cyanobacterial species (Cordeiro et al., 2017). According to the gas chromatography (GC) separation chromatogram of the extracted lipids of the planktonic cyanobacterium (Figure 2), the major components were hexadecanoic and heptadecanoic acids.

Figure 2

GC Separation Chromatogram of the FAME



The cetane number of the biodiesel calculated using the model of Lin and Wu (2022) was 52.01, which demonstrates superior performance with respect to conventional fuels and is also in line with biodiesel standards. The 16S rRNA-based molecular analysis (sequence length 1,348 bp) and the Basic Local Alignment Search Tool analysis (National Center for Biotechnology Information) showed that this planktonic cyanobacterium was closely related to *Cyanobacterium aponinum* (identity of 100%).

Conclusions and Implications

Based on the observations and results of this research, it can be concluded that *Cyanobacterium aponinum* (a marine photosynthetic cyanobacterium isolated from coastal areas of Sri Lanka) can be used in biodiesel production. It is able to grow to the stationary phase under completely natural conditions within 8–10 days, with an average lipid yield of 12.23% (±0.0983%) (w/w) from its dry biomass. The theoretical cetane number of the corresponding biodiesel was calculated as 52.01.

***Keywords*:** Biodiesel, marine microalgae, photosynthetic cyanobacteria

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On the Firefly Algorithm Modification to the Step-Fixed Charge and Facility Location Problem

Ekanayake E.M.D.B.[1,*] and Rodrigo W.N.P.[2]
[1]*Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka,* [2]*Department of Mathematics, University of Peradeniya, Peradeniya, Sri Lanka*
*Corresponding author (email: dananjayaekanayake96@gmail.com)

Introduction

The transportation problem is one of the central challenges in supply chain management. It involves the distribution of goods from multiple suppliers to multiple customers with the goal of minimising the total transportation cost. While the classical transportation model is formulated as a linear programming model (Lotfi & Tavakkoli-Moghaddam, 2013), many real-world distribution systems involve fixed route activation costs, facility opening costs and quantity-dependent transportation expenses. These considerations led to the formulation of the step fixed-charge transportation and location problem (SFCTLP) (Oyewole & Adetunji, 2018). Moreover, transportation problems such as the step fixed-charge transportation problem (SFCTP) exhibit a quantity-dependent fixed-cost structure, in which shipment quantities can fall below or exceed shipment values, resulting in different fixed-cost levels. As a result, optimal solutions may require more than the traditional ($m + n - 1$) allocations (Kowalski & Lev, 2008), which significantly increases the solution space and the computational complexity. Accordingly, methods to obtain approximate solutions to the SFCTP have been studied (Altassan et al., 2013). The SFCTLP can be regarded as an extension of the SFCTP (Oyewole & Adetunji, 2018). This study therefore proposes a modified firefly algorithm (MFA) incorporating a λ-based allocation mechanism and adaptive firefly movements to obtain high-quality feasible solutions for the SFCTLP efficiently.

Methodology

The objective of the SFCTLP is to minimise the total transportation cost, which includes the unit product transportation cost, the facility opening cost and the step fixed route costs. Consider a transportation network consisting of a set of m sources and n destinations. Let a_i represent the supply capacity at source i ($i = 1, 2, \ldots, m$), b_j the demand at destination j ($j = 1, 2, \ldots, n$), and x_{ij} the quantity transported from the ith source to the jth destination. The total transportation cost consists of the location (source) fixed cost (F_i), the variable unit transportation cost (c_{ij}), the fixed route cost (f_{ij}), which is the fixed cost of opening route (i, j), and the step fixed-charge cost (g_{ij}), which is the additional fixed cost incurred when the transported quantity exceeds the amount A_{ij} (Oyewole & Adetunji, 2018). The model is formulated as follows (Equation 1):

$$\text{Minimise } Z = \sum_{i=1}^{m}\sum_{j=1}^{n}\left(c_{ij}x_{ij} + F_i y_i + f_{ij}y_{ij} + g_{ij}z_{ij}\right) \qquad (1)$$

The objective function is subject to the following supply, demand, capacity, non-negativity and binary-variable constraints:

$$\sum_{j=1}^{n} x_{ij} \leq a_i y_i, \quad i = 1,2,\dots,m$$

$$\sum_{i=1}^{m} x_{ij} = b_j, \quad j = 1,2,\dots,n$$

$$\sum_{j=1}^{n} a_i\, y_i \geq \sum_{j=1}^{n} b_j$$

$$x_{ij} \geq 0 \quad \forall\, i = 1,2,\dots,m;\ j = 1,2,\dots,n$$

$$y_{ij} = \begin{cases} 1, & \text{if } x_{ij} > 0 \\ 0, & \text{if } x_{ij} = 0 \end{cases}$$

$$z_{ij} = \begin{cases} 1, & \text{if } x_{ij} > A_{ij} \\ 0, & \text{otherwise} \end{cases}$$

$$y_i = \begin{cases} 1, & \text{if } \sum_{j=1}^{n} x_{ij} > 0 \\ 0, & \text{if } \sum_{j=1}^{n} x_{ij} = 0 \end{cases}$$

The firefly algorithm (FA) (Yang, 2010) is a nature-inspired metaheuristic optimisation technique based on the flashing behaviour of fireflies. It is governed by three main assumptions: all fireflies are unisex and therefore mutually attracted; attractiveness is proportional to brightness and decreases with distance; and the brightness of a firefly is determined by the value of the objective function. The brightness of a firefly decreases with increasing distance, as expressed by the light intensity in Equation (2):

$$I = I_0 e^{-\gamma r_{ij}^2} \qquad (2)$$

where γ is the light absorption coefficient of the medium, which typically ranges from 0.1 to 10, and I_0 represents the light intensity at the source. This intensity is calculated from the Euclidean distance between fireflies and determines how attractive they are. The distance r_{ij} between two fireflies i and j is given by

$$r_{ij} = \|x_j - x_i\| = \sqrt{\sum_{k=1}^{d} \left(x_{j,k} - x_{i,k}\right)^2}$$

where $x_{i,k}$ is the kth component of the ith firefly. The attractiveness β between two fireflies is modelled as shown in Equation (3), where β_0 denotes the attractiveness at zero distance:

$$\beta = \beta_0 e^{-\gamma r_{ij}^2} \qquad (3)$$

The movement of the *i*th firefly towards a brighter *j*th firefly is governed by Equation (4), where a is the randomisation parameter within the interval [0, 1] and ε is a vector of random numbers generated from either a Gaussian or a uniform distribution:

$$x_{i+1} = x_i + \beta_0 e^{-\gamma r^2}\left(x_j - x_i\right) + a\varepsilon \qquad (4)$$

To improve the cost allocation matrix, a 2×2 swap heuristic introduced by Kartli et al. (2023) is applied. Two rows and two columns are randomly selected from the main allocation matrix to form a 2×2 submatrix M_1, and the total cost of this submatrix is denoted by Q_1:

$$M_1 = \begin{bmatrix} X_{11} & X_{12} \\ X_{21} & X_{22} \end{bmatrix}$$

Applying the pivot transformation yields the submatrix M_1' below. The swap is applied only if the secondary diagonal elements satisfy $x_{12} \geq A_{ij}$ and $x_{21} \geq A_{ij}$. Let the updated cost be Q_2; if $Q_1 - Q_2 \geq 0$, the swap is accepted.

$$M_1{}' = \begin{bmatrix} X_{11} + A_{ij} & X_{12} - A_{ij} \\ X_{21} - A_{ij} & X_{22} + A_{ij} \end{bmatrix}$$

The proposed MFA proceeds in eight steps. In Step 1, for each firefly $k = 1, 2, \ldots, N$, where N denotes the total number of fireflies, the random weight parameters λ_1^k, λ_2^k, $\lambda_3^k \in [0, 1]$ are generated subject to $\lambda_1^k + \lambda_2^k + \lambda_3^k = 1$. Using these parameters, the blended transportation matrix is constructed as

$$B_{ij}^k = \lambda_1^k c_{ij} + \lambda_2^k f_{ij,1} + \lambda_3^k f_{ij,2}$$

In Step 2, the greedy allocation rule below is used for the feasibility adjustment of the allocation matrices, and the transportation allocations are performed sequentially in ascending order of B_{ij}^k:

$$x_{ij} = \min\left(\text{remaining supply}_i,\ \text{remaining demand}_j\right)$$

In Step 3, the total transportation cost is calculated using Equation (1) for each firefly k, and the brightest firefly, corresponding to the minimum transportation cost, is determined:

$$X^{best} = \min(Z_k)$$

For each firefly k, the position vector λ_i^k is then updated towards the current best firefly λ_i^{best} through Steps 4 to 7. In Step 4, the Euclidean distance between the current firefly and the best firefly is computed as

$$r_{ij} = \sqrt{\sum_{i=1}^{3} (\lambda_i^k - \lambda_i^{best})^2}$$

and the attractiveness is then computed with $\beta_0 = 1$ and $\gamma = 0.5$ as

$$\beta = \beta_0 e^{-\gamma r_{ij}}$$

In Step 5, the movement towards the best firefly is determined and the position is updated:

$$\lambda_{new}^{k} = \lambda^{k} + \beta \cdot \left(\lambda_{i}^{best} - \lambda_{i}^{k}\right)$$

To keep the solution within the valid solution space, in which the components of $\lambda_{new}{}^{k}$ sum to 1, absolute values are taken and the vector is normalised:

$$\lambda_{new}^{k} = |\lambda_{new}^{k}|$$

$$\lambda_{new}^{k} = \frac{|\lambda_{new}^{k}|}{\sum_{i=1}^{3}|\lambda_{i}^{k}|}$$

In Step 6, the new parameter values $\lambda_{new}{}^{k}$ are used to construct the blended transportation matrix and the allocation matrix. In Step 7, a random movement of the firefly is applied using the 2×2 swap with the A_{ij} value, as described above. Finally, in Step 8, Steps 4 to 7 are repeated for the specified number of iterations to minimise the transportation cost and obtain the final improved solution.

Results and Discussion

The proposed MFA was applied to a benchmark example from Oyewole and Adetunji (2018), with A_{ij} = 5, using the data set presented in Tables 1 and 2.

Table 1

Data on Supply, Demand, Location Cost, and Unit Transportation Cost

Source *i*	F_i	c_{ij} (destination *j*)				a_i
		1	2	3	4	
1	100	1	3	1	3	25
2	200	2	2	3	2	25
3	250	2	1	2	1	25
4	150	1	3	1	3	25
b_j		10	30	20	15	

Table 2

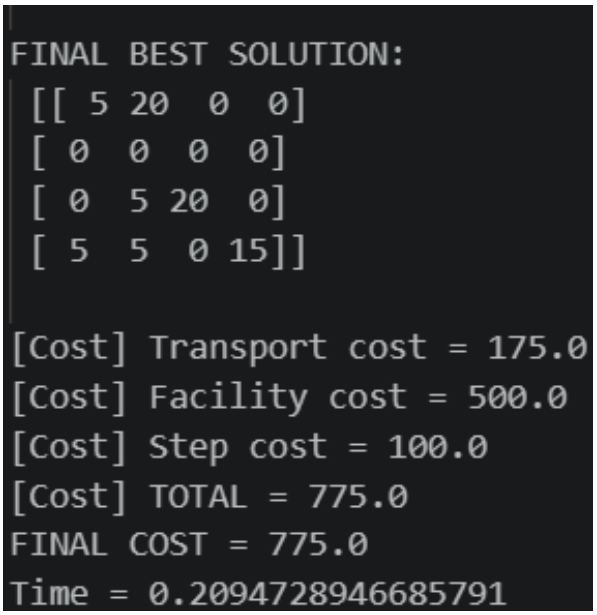
Data on Fixed and Step-Fixed Costs

Source *i*	f_{ij} : g_{ij} (destination *j*)			
	1	2	3	4
1	10:20	10:10	10:30	10:10
2	10:30	10:20	10:20	10:20
3	10:20	10:30	10:10	10:30
4	10:20	10:10	10:30	10:10

The problem was solved using Python, starting with three fireflies with random λ values. The best initial solution was generated with a cost of 780, which was further reduced to 775 in three iterations of the proposed algorithm. The corresponding allocation matrix, as output by the Python implementation, is shown in Figure 1.

Figure 1

Best Allocation Matrix



Compared with the cost of 790 obtained by existing heuristic methods for this problem (Oyewole & Adetunji, 2018), the proposed approach achieves a better result of 775. Overall, the numerical results confirm that the proposed method is capable of effectively producing high-quality solutions for the SFCTLP.

Conclusions and Implications

In this paper, an MFA based on the firefly algorithm and combined with the 2×2 swap method is proposed to solve the SFCTLP. When applied to a numerical benchmark example for evaluating the accuracy of the proposed algorithm, the proposed method gives a minimum total cost of 775, which is better than the best existing solution of 790. The results show a significant improvement in the quality and stability of the solution. Finally, the proposed approach is shown to be an efficient and reliable algorithm for obtaining solutions that minimise transportation costs.

***Keywords*:** Firefly algorithm, minimum cost, step-fixed charge and facility location problem

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Extraction, Metal Chelation and Characterisation of Soil-Derived Humic Acid

Senanayaka S.R.H.B. and Herath A.C.*
Department of Chemical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: ajithch037@gmail.com)

Introduction

Humic acid (HA), a major fraction of humic substances, is an important component of soil organic matter formed through the decomposition and humification of plant residues, animal remains and microbial biomass. It plays a crucial role in soil fertility, nutrient cycling and the regulation of chemical and biological processes. HA is insoluble under acidic conditions (pH < 2) but soluble in alkaline media and is characterised by a high molecular weight, aromaticity and structural complexity compared with other humic fractions (Dou et al., 2026). The heterogeneous structure of HA contains various functional groups, including carboxylic, phenolic hydroxyl, carbonyl, quinone, methoxyl and amino groups, which contribute to its acidity, ion-exchange capacity, redox activity and metal-binding ability. These functional groups enable HA to interact with nutrients and metal ions through complexation and chelation processes, influencing metal mobility, bioavailability and toxicity in soil and aquatic environments.

The structural and chemical properties of HA can be investigated using complementary analytical techniques. Ultraviolet–visible (UV–Vis) spectroscopy provides information on humification and aromaticity, Fourier transform infrared (FTIR) spectroscopy identifies the functional groups involved in metal interactions, fluorescence spectroscopy evaluates metal–humic binding behaviour, and cyclic voltammetry reveals redox properties associated with electroactive groups. Chemical oxygen demand (COD) measurement further indicates the oxidation characteristics of humic materials (Dedkov et al., 2000). In this study, soil-derived HA was extracted and characterised to evaluate its complexation behaviour with Ca^{2+}, Mg^{2+}, Al^{3+}, Pb^{2+}, Cr^{3+} and Cr^{6+} ions using COD analysis, surface acidity measurements, UV–Vis spectroscopy, FTIR spectroscopy, fluorescence spectroscopy and cyclic voltammetry. This investigation provides insights into the role of HA in nutrient interactions, metal transport, environmental remediation and the regulation of potentially toxic metals in natural ecosystems.

Methodology

HA was extracted from mound soil by alkaline extraction using 0.1 M NaOH followed by acid fractionation (pH 1–2). The precipitated HA was separated by centrifugation and purified using an Amberlite IR-120(H) cation-exchange resin column. The purified HA was chelated with the metal ions Ca^{2+}, Mg^{2+}, Al^{3+}, Pb^{2+}, Cr^{3+} and Cr^{6+} at pH 4. COD was evaluated using the standard potassium dichromate closed reflux method, and surface acidity functional groups were quantified through ion-exchange titrations. Stepwise potentiometric metal chelation profiling with the six metal ions was conducted at a baseline of pH 4.0 in a sodium nitrate background electrolyte, tracking proton-displacement pH shifts after each addition until saturation was reached. Structural

configuration variations and binding quenching dynamics were monitored using fluorescence spectroscopy to construct Stern–Volmer plots, while baseline functional group orientations and redox-active properties were characterised using FTIR spectroscopy and cyclic voltammetry.

Results and Discussion

HA exhibited a COD value of 106.4 mg L^{-1}. COD reflects the amount of oxygen required to chemically oxidise the organic matter present in a sample; therefore, higher concentrations of oxidisable compounds result in greater consumption of dichromate and consequently higher COD values. The elevated COD observed for HA can be attributed to its complex molecular structure, which is rich in phenolic groups, aromatic moieties and other redox-active functional groups. These constituents are readily oxidised during COD analysis, increasing the demand for the oxidising agent and leading to a higher measured COD. The result indicates the substantial organic content and oxidation potential of HA, highlighting its significant contribution to the overall organic load of the system (Dedkov et al., 2000).

Surface acidity characterisation revealed that HA possessed a total acidity of 2.0 meq g^{-1}, comprising 1.6 meq g^{-1} of phenolic acidity and 0.4 meq g^{-1} of carboxylic acidity. The predominance of phenolic functional groups indicates a highly aromatic and humified structure, consistent with the characteristics of mature humic substances. Phenolic hydroxyl groups contribute significantly to the chemical reactivity of HA by participating in proton dissociation, redox reactions and metal complexation processes. Although the carboxylic acidity was comparatively lower, the presence of both phenolic and carboxylic functional groups provides active binding sites for interactions with metal ions. These results suggest that the metal-binding behaviour of HA is largely governed by its phenolic-rich structure, which enhances its capacity for adsorption, ion exchange and metal chelation in environmental systems (Dou et al., 2026).

UV–Vis spectroscopic analysis of HA was conducted to evaluate its structural characteristics, aromaticity, molecular complexity and degree of humification. The HA spectrum exhibited the characteristic absorption behaviour of humic substances, with strong absorbance in the ultraviolet region followed by a gradual decrease towards the visible range, indicating the presence of heterogeneous organic compounds containing conjugated aromatic systems and oxygen-containing functional groups. The absence of distinct absorption peaks further confirms the complex and polydisperse nature of HA. The E_4/E_6 ratio of HA was determined to be 2.40; lower E_4/E_6 values are generally associated with a larger molecular weight, stronger aromatic condensation and a more advanced degree of humification. Similarly, the E_2/E_3 ratio of HA was 2.63, where lower E_2/E_3 values indicate the presence of larger molecular-size fractions and enhanced aromatic character. These spectroscopic indices demonstrate that the extracted HA possesses a highly humified structure with significant molecular complexity, high aromaticity and condensed aromatic components, reflecting its advanced stage of humification (Naidja et al., 2002).

FTIR spectroscopy confirmed the heterogeneous, polydisperse nature of the extracted HA. A broad band at 3200–3600 cm^{-1} (O–H stretching) indicated extensive hydrogen bonding across phenolic, alcoholic and carboxylic groups. Aliphatic C–H stretching appeared at 2920–2850 cm^{-1}, while the 1700–1550 cm^{-1} region indicated carbonyls (carboxylic acids, ketones and quinones). Aromatic C=C structures were marked near 1620 cm^{-1}, with C–O stretching and oxygen groups located at 1400–1200 cm^{-1} and 1100–1000 cm^{-1}. These features confirm a highly aromatic, well-humified matrix rich in reactive groups for ion exchange and chelation. Additionally, the 500–900 cm^{-1} region (M–O vibrations) suggests potential metal complexation, verifying the suitability of HA for environmental remediation (Naidja et al., 2002).

Complexation of HA with metal ions produced distinct FTIR spectral changes, indicating the involvement of oxygen-containing functional groups in metal binding. Ca^{2+} and Mg^{2+} caused only minor reductions in the O–H stretching region and slight shifts in the carboxylate bands, suggesting relatively weak coordination through deprotonated carboxyl and phenolic groups. These interactions primarily stabilised the HA structure without significantly altering its aromatic framework. Al^{3+} induced pronounced changes in the hydroxyl and carbonyl regions, reflecting strong interactions with carboxylate and phenolic functionalities and the formation of stable inner-sphere complexes. Pb^{2+} complexation resulted in notable alterations in the carboxylate and aromatic regions, indicating strong coordination with oxygen-containing functional groups and possible structural rearrangement within the HA matrix. Similarly, Cr^{3+} produced significant spectral shifts in the hydroxyl, carbonyl and fingerprint regions, consistent with stable chelation through phenolic hydroxyl and carboxylate groups. Among all the metals, Cr^{6+} caused the most substantial spectral perturbations, particularly in the O–H, C=O and low-wavenumber regions. Significant spectral shifts in the aromatic and quinone-associated FTIR regions strongly indicate that Cr^{6+} interactions may involve concurrent redox-active pathways, in which electron-donating phenolic and quinone moieties facilitate partial reduction of the metal centre. However, direct quantification of co-existing Cr^{3+} and Cr^{6+} species by X-ray photoelectron spectroscopy (XPS) or speciation modelling is required to confirm these reduction mechanisms decisively.

Fluorescence spectroscopy was employed to investigate the interactions between HA and the selected metal ions. The fluorescence response of HA varied significantly depending on the metal species, indicating differences in metal–humic complex formation and binding mechanisms. Cr^{6+} exhibited the strongest fluorescence quenching effect (Stern–Volmer constant K_{SV} = 32,541.07 $dm^3\ mol^{-1}$), suggesting strong interactions with HA fluorophores through electron-transfer processes and non-radiative energy dissipation pathways. Al^{3+} also induced significant fluorescence quenching (K_{SV} = 32,076.19 $dm^3\ mol^{-1}$), while Mg^{2+} showed comparatively weaker quenching behaviour (K_{SV} = 8,765.98 $dm^3\ mol^{-1}$). In contrast, Pb^{2+} caused a pronounced fluorescence enhancement, yielding negative Stern–Volmer responses (K_{SV} = −16,089.55 $dm^3\ mol^{-1}$). This behaviour is consistent with the structural encapsulation or enhanced rigidity of specific fluorophoric clusters within the HA macromolecular matrix upon complexation, which suppresses non-

radiative decay. Because humic matrices are highly heterogeneous, these enhancement trends should be interpreted as apparent structural responses that require further time-resolved fluorescence lifetime measurements to rule out scattering or inner-filter-effect artefacts. Similar fluorescence enhancement was observed for Ca^{2+} and Cr^{3+}, suggesting metal–humic complex formation that increases the rigidity and stability of fluorophoric structures. Overall, the fluorescence behaviour shows that HA contains diverse binding sites that can interact with metal ions through complexation and redox-active pathways. The contrasting quenching and enhancement effects reflect the influence of metal ion properties on the structural and electronic environment of HA, highlighting its potential role in metal retention and transport in environmental systems (Ghosh & Schnitzer, 1980; Ohno & Bro, 2006).

Cyclic voltammetry analysis was performed to evaluate the redox behaviour and electron-transfer characteristics of the extracted HA. The voltammogram exhibited a weak redox couple with cathodic and anodic peak potentials of approximately −0.19 V and +0.07 V, respectively. The presence of this redox pair indicates that HA contains electroactive functional groups capable of undergoing reversible redox reactions. These redox-active sites are primarily associated with quinone/hydroquinone, phenolic and other oxygen-containing aromatic moieties commonly present in humified organic matter. The relatively low peak intensity suggests a limited concentration of electrochemically active species or slow electron-transfer kinetics within the heterogeneous HA matrix. The observed redox behaviour confirms the ability of HA to participate in electron exchange processes, which are important for its environmental reactivity and interaction with metal ions. The electrochemical activity of HA is consistent with its high degree of aromaticity and humification, as indicated by the UV–Vis and FTIR analyses. These findings demonstrate that the extracted HA possesses redox-active functional groups that can contribute to electron transfer, metal complexation and contaminant transformation processes in environmental systems.

Conclusions and Implications

The extracted HA exhibited a highly humified, aromatic and redox-active structure rich in oxygen-containing functional groups that promote metal binding and electron-transfer processes. Stronger interactions were observed for Cr^{6+}, Pb^{2+}, Al^{3+} and Cr^{3+} than for Ca^{2+} and Mg^{2+}, highlighting the important role of soil-derived HA in controlling metal mobility and its potential for environmental remediation.

Keywords**:** Cyclic voltammetry, humic acid, metal chelation, spectroscopic characterisation, surface acidity

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Electrochemical Characterisation of Sulfur Dioxide–Benzoic Acid System in Acetonitrile

Nisfer I. and Herath A.C.*
Department of Chemical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: ajithch037@gmail.com)

Introduction

Electrochemical methods provide environmentally friendly and highly controllable approaches for studying oxidation–reduction reactions and generating reactive intermediates under mild conditions. Among these intermediates, sulfur dioxide radical anions ($SO_2^{\bullet-}$) have attracted considerable attention because of their involvement in sulfur-centred electrochemical transformations. In aqueous media, SO_2-derived radical intermediates are unstable because of rapid protonation and competing side reactions. Consequently, non-aqueous solvents such as acetonitrile offer a suitable environment for investigating their electrochemical behaviour because of their wide electrochemical potential window, low nucleophilicity and ability to stabilise radical intermediates.

Benzoic acid is an aromatic carboxylic acid capable of participating in hydrogen-bonding and proton-transfer processes in aprotic solvents, and these interactions may influence the stability and electrochemical behaviour of sulfur dioxide radicals. Although sulfur dioxide electrochemistry has been extensively investigated, studies addressing the electrochemical interaction between sulfur dioxide and benzoic acid in non-aqueous media remain limited. Furthermore, electrochemically generated products from this system have rarely been isolated and characterised. Therefore, the present study aimed to investigate the electrochemical behaviour of the sulfur dioxide–benzoic acid system in acetonitrile using cyclic voltammetry (CV) and bulk electrolysis and to characterise the resulting electrochemical product using electrochemical and physicochemical techniques.

Methodology

Acetonitrile and lithium perchlorate were purified prior to experimentation to minimise interference from moisture and dissolved impurities. A 0.1 mol dm^{-3} lithium perchlorate solution in acetonitrile was used as the supporting electrolyte. Electrochemical experiments were performed using a conventional three-electrode system consisting of a glassy carbon working electrode, a platinum counter electrode and a non-aqueous silver reference electrode.

Sulfur dioxide gas was generated in situ by reacting sodium sulfite with sulfuric acid and was purged into the electrolyte solution under controlled conditions. CV was conducted to determine the reduction behaviour of sulfur dioxide, benzoic acid and their combined system. Scan rate, concentration and repeated-segment studies were performed to evaluate the electron-transfer characteristics and reaction mechanisms. On the basis of the CV results, controlled-potential bulk electrolysis was carried out at selected reduction potentials with continuous stirring of the solution. The electrochemically generated product deposited on the working electrode was isolated, recrystallised, dried and

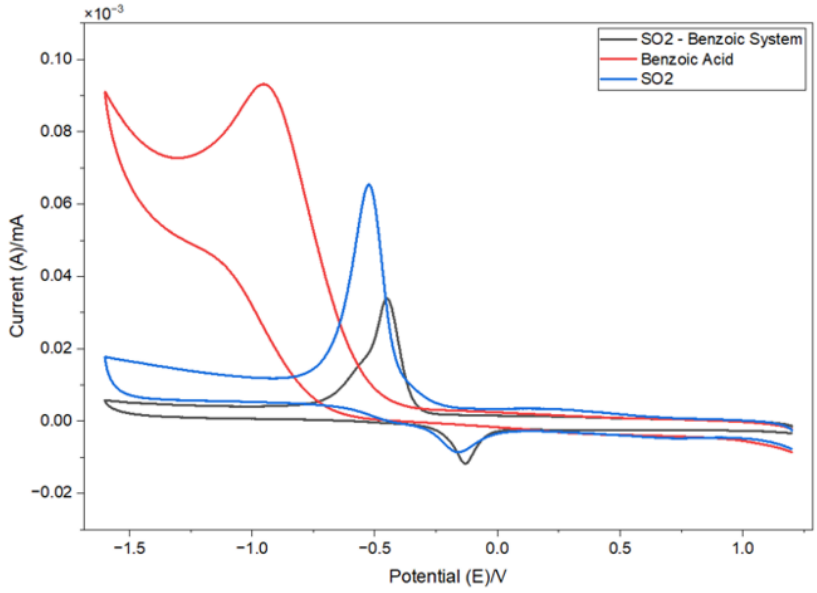
characterised by CV, melting point determination, solubility analysis, ultraviolet–visible (UV–Vis) spectroscopy and Fourier transform infrared (FTIR) spectroscopy.

Results and Discussion

CV revealed distinct electrochemical responses for sulfur dioxide (SO_2), benzoic acid (BA) and the combined SO_2–BA system in acetonitrile containing 0.1 mol dm^{-3} $LiClO_4$. Sulfur dioxide exhibited a cathodic reduction peak at approximately −0.60 V, corresponding to the one-electron reduction of SO_2 to the sulfur dioxide radical anion ($SO_2^{\bullet-}$), whereas benzoic acid showed reduction at approximately −0.95 V. The cyclic voltammogram of the combined system displayed an enhanced cathodic current and a modified voltammetric profile compared with those of the individual components (Figure 1), indicating electrochemical interaction between sulfur dioxide radicals and benzoic acid under non-aqueous conditions. The modified electrochemical response suggests that benzoic acid influences the behaviour of electrochemically generated sulfur dioxide radicals. The enhanced cathodic current further indicates that the mixed system undergoes electrochemical transformation rather than independent reduction of the individual species.

Figure 1

Comparison of Cyclic Voltammograms



Controlled-potential bulk electrolysis was performed to isolate the electrochemical product. The chronoamperometric curve showed a high initial current followed by a gradual decrease throughout electrolysis, reflecting the progressive consumption of electroactive species during product formation. A white film-like deposit was observed on the glassy carbon electrode at −0.60 V, whereas only a trace amount of product was

obtained at −0.95 V, confirming that product formation is favoured at the sulfur dioxide reduction potential.

Following recrystallisation, the isolated product appeared as light pink needle-like crystals (Figure 2), distinctly different from the white crystalline powder of benzoic acid. In addition, the melting point increased from 124–125 °C for benzoic acid to 172–173 °C for the isolated product, indicating the formation of a chemically distinct compound.

Figure 2

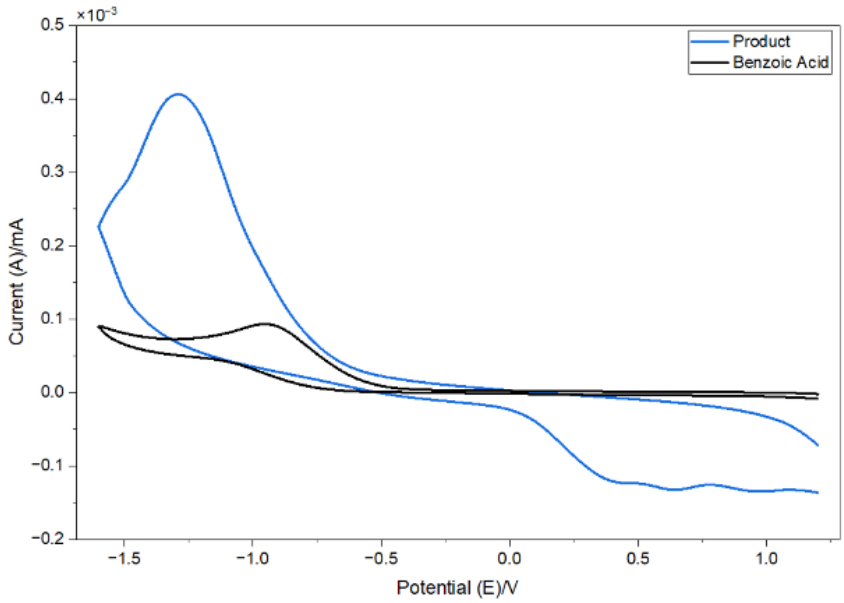
Colour and Shape Observed for the Product Formed



UV–Vis spectroscopy revealed increased absorption intensity together with a slight bathochromic shift in the absorption maxima of the isolated product compared with benzoic acid, suggesting modification of the electronic environment following electrochemical transformation. The FTIR spectra also exhibited noticeable changes in the O–H and C=O stretching regions, supporting structural modification after electrolysis. Collectively, the electrochemical (Figure 3), physical and spectroscopic analyses confirm that sulfur dioxide radicals generated in non-aqueous acetonitrile interact with benzoic acid to produce a new electrochemical product.

Figure 3

CV Obtained for Benzoic Acid and the Isolated Electrolysis Product



Conclusions and Implications

The sulfur dioxide–benzoic acid system was successfully investigated in non-aqueous acetonitrile using CV and controlled-potential bulk electrolysis. Sulfur dioxide underwent one-electron reduction at approximately −0.60 V to generate sulfur dioxide radical anions, while benzoic acid exhibited reduction at approximately −0.95 V. The combined system displayed modified voltammetric behaviour, demonstrating electrochemical interaction between sulfur dioxide radicals and benzoic acid.

Bulk electrolysis at −0.60 V produced the highest yield of electrochemical product. Electrochemical, physical and spectroscopic characterisation confirmed that the isolated product differed significantly from benzoic acid, indicating a successful electrochemically induced transformation. These findings contribute to the understanding of sulfur-centred radical electrochemistry in non-aqueous media and provide a basis for future investigations using advanced structural characterisation techniques such as gas chromatography–mass spectrometry (GC–MS), nuclear magnetic resonance (NMR) spectroscopy and X-ray crystallography.

***Keywords*:** Bulk electrolysis, cyclic voltammetry, electrochemical characterisation, non-aqueous electrochemistry, sulfur dioxide radical intermediates

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Laboratory-Scale Establishment of an Enhanced Biological Phosphorus Removal Bioreactor System for Enrichment of Polyphosphate-Accumulating Organisms

Herath H.M.H.M., Arachchi V.D.J., Karunarathne W.A.D.C., Somasiri B.M.C., Jayathilake C.M., Muhandiram P.M.A.C., Rathnayaka R.M.S.L.B. and Fernando E.Y.*

Department of Biological Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka

*Corresponding author (email: eustace6192@as.rjt.ac.lk)

Introduction

Eutrophication is a global environmental problem in aquatic ecosystems. It is triggered by the enrichment of nutrients such as phosphorus (P) and nitrogen (N), which cause algal blooms and the deterioration of water quality (Ong et al., 2010). Municipal wastewater is a significant and concentrated source of P pollution (Zhang et al., 2021). While chemical precipitation can remove P, it incurs high operational expenses and produces chemical-laden sludge, undermining circular economy goals (Pelevina et al., 2023).

Enhanced biological phosphorus removal (EBPR) has emerged as an environmentally sustainable alternative that uses polyphosphate-accumulating organisms (PAOs), particularly *Candidatus* Accumulibacter phosphatis, to remove P biologically from wastewater (Camejo et al., 2016). PAOs can be enriched by feeding them with organic substrates in the anaerobic "feast" phase, during which they release phosphate while storing the substrates as polyhydroxyalkanoates (PHAs). In the aerobic "famine" phase, PAOs accumulate phosphate from the bulk liquid as polyphosphate by using the stored PHAs.

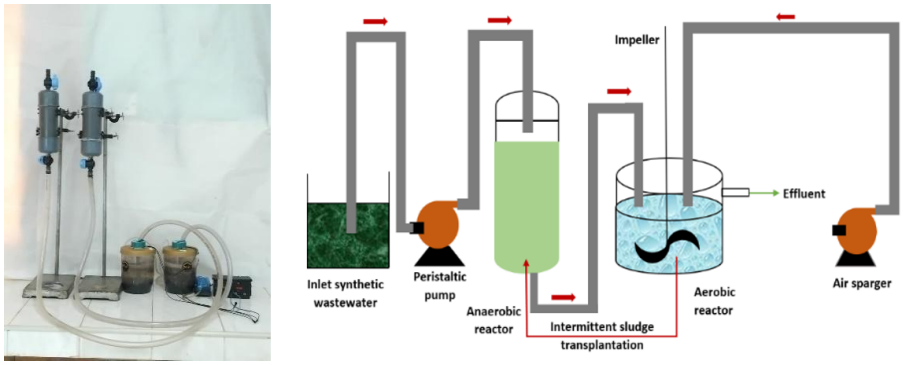
Most laboratory-scale EBPR research has been conducted using sophisticated, automated sequencing batch reactors (SBRs) in temperate climates (Flowers et al., 2009; Welles et al., 2016). However, in tropical, resource-limited settings such as Sri Lanka, ambient temperatures may alter the competitive balance between PAOs and glycogen-accumulating organisms (GAOs), potentially favouring GAO proliferation under certain operating conditions (Ong et al., 2010). Furthermore, effective, low-cost EBPR bioreactor designs that use readily available, inexpensive materials are needed, particularly for resource-limited settings. The present study addresses this gap by developing and evaluating a laboratory-scale EBPR system constructed from cost-effective, locally available materials, demonstrating its potential to support functional PAO enrichment without sophisticated infrastructure. The study aimed to establish a laboratory-scale EBPR bioreactor system operated under alternating anaerobic–aerobic conditions, to evaluate its phosphorus removal performance, to monitor chemical oxygen demand (COD), to enrich PAOs using glucose-based synthetic wastewater, and to characterise the microbial communities using fluorescence *in situ* hybridisation (FISH) and quantitative FISH (qFISH).

Methodology

Activated sludge obtained from the Negombo Municipal Wastewater Treatment Plant was used as the inoculum. A laboratory-scale EBPR system consisting of anaerobic and aerobic reactors connected in series was established and operated for 50 days (Figure 1).

Figure 1

Established Laboratory-Scale EBPR Bioreactor System



Note. (a) Photograph of the established bioreactor system; (b) schematic diagram of the system.

Synthetic wastewater containing glucose, NH_4Cl, KNO_3, KH_2PO_4, K_2HPO_4, $MgSO_4 \cdot 7H_2O$ and $CaCl_2 \cdot 2H_2O$ was supplied as the influent (Hu et al., 2002). The system was operated under alternating feast–famine conditions with a hydraulic retention interval of 48 hours. Two bioreactor systems were used as replicates, and four wastewater samples were collected from one bioreactor system within one cycle (48 hours) for analytical measurements. Phosphate concentrations were determined using the vanadomolybdophosphoric acid colorimetric method (American Public Health Association [APHA] et al., 2000), and COD was measured using the closed reflux titrimetric method according to APHA standard procedures (APHA et al., 2000). Microbial characterisation was conducted using FISH. The PAO651 probe was employed to detect *Candidatus* Accumulibacter phosphatis, while EUB mix probes were used to visualise the total bacterial population (Fernando et al., 2019). qFISH analysis was performed to estimate the relative abundance of PAOs within the microbial community using the image analysis software daime (Version 3.1, University of Vienna, Austria) and ImageJ (Version 1.54G) (Fernando et al., 2019).

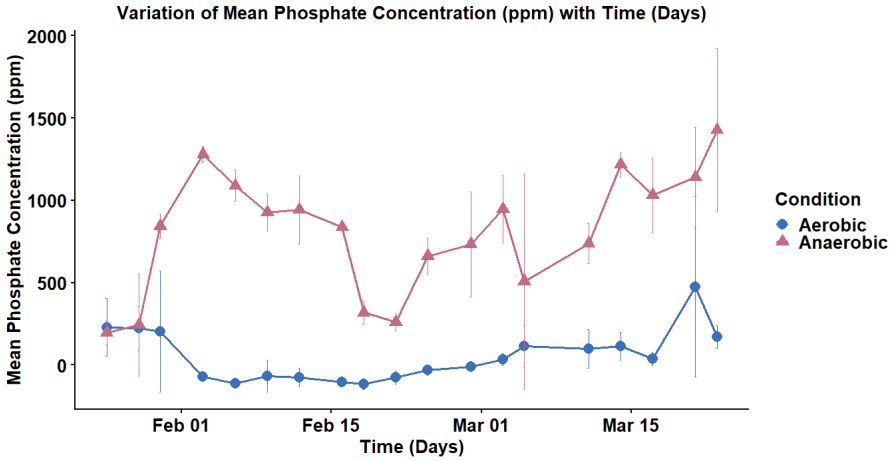
Results and Discussion

The EBPR system demonstrated characteristic phosphorus cycling over 50 days. Anaerobic phosphate concentrations increased from 250.38 ± 44.06 ppm to a maximum of 1,008.08 ± 306.23 ppm, confirming active PAO-mediated phosphate release under feast conditions. The aerobic reactors maintained consistently low phosphate concentrations (mostly below 150 ppm after acclimatisation), indicating efficient phosphate uptake (Figure 2). A transient spike observed in one reactor suggested

temporary PAO inhibition, but rapid recovery confirmed PAO resilience (Oehmen et al., 2007).

Figure 2

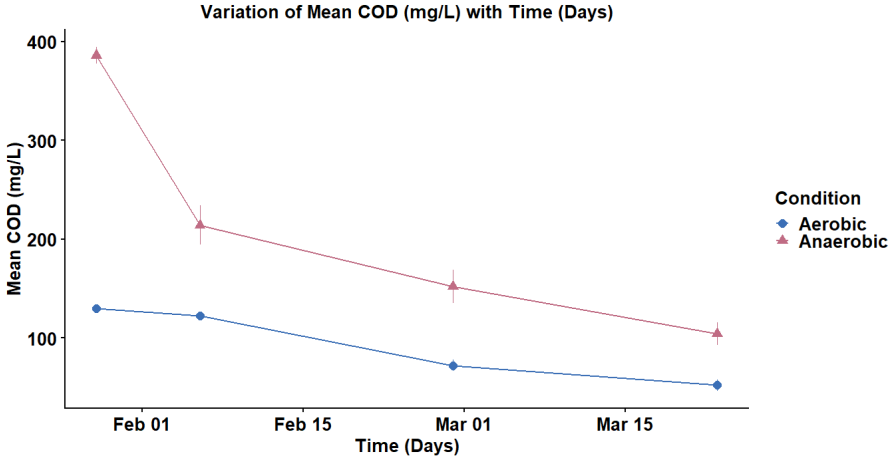
Variation of Mean Phosphate Concentration in Water Samples Between Anaerobic and Aerobic Phases of the EBPR System



COD decreased substantially in both phases, with anaerobic COD declining by 73% (from 386 to 104 mg/L) and aerobic COD declining from 130 to 52 mg/L during the operational period, confirming efficient substrate utilisation and microbial adaptation to feast–famine cycling (Figure 3).

Figure 3

Variation of Mean COD in Water Samples Between Anaerobic and Aerobic Phases of the EBPR System

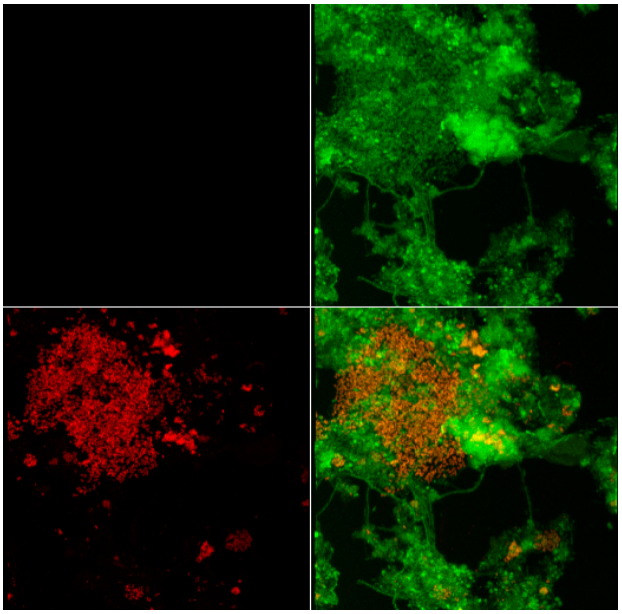


FISH analysis revealed a clear temporal shift from the dominance of filamentous bacteria in March 2026 to compact clusters of *Candidatus* Accumulibacter phosphatis by May

2026 (Figure 4). qFISH quantification confirmed progressive PAO enrichment, with biovolume fractions increasing from 2.89–4.42% in March 2026 to 22.48–28.92% by May 2026. These results demonstrate that a functional, low-cost EBPR system can successfully enrich PAOs under laboratory conditions in a tropical, resource-limited setting, providing a replicable design for developing countries.

Figure 4

Split-Channel Fluorescence Micrographs of Activated Sludge from the Aerobic Reactor Obtained on 4 May 2026



Note. The micrographs demonstrate microbial community composition through fluorescence *in situ* hybridisation. Red: *Candidatus* Accumulibacter phosphatis (Cy5-tagged PAO651 probe signal); green: all other bacteria (EUB-Mix probe set labelled with FLUOS).

Conclusions and Implications

The laboratory-scale EBPR reactor successfully established alternating anaerobic–aerobic phosphorus cycling and supported the enrichment of PAOs. Elevated phosphate release under anaerobic conditions, substantial phosphate uptake under aerobic conditions and significant COD reduction collectively demonstrated effective biological phosphorus removal. The successful detection of *Candidatus* Accumulibacter phosphatis by FISH analysis further confirmed the biological basis of phosphorus removal. The study demonstrates the potential of low-cost EBPR systems for sustainable wastewater treatment and nutrient management. These findings contribute to the development of environmentally friendly technologies for controlling P pollution and improving wastewater treatment performance in developing countries.

***Keywords*:** Activated sludge, enhanced biological phosphorus removal, eutrophication, polyphosphate-accumulating organisms

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Photodynamic Action of 5,10,15,20-Tetrakis(4-Carboxyphenyl) Porphyrin (H_2TcPP)–Au Nanocomposite Against Pathogenic *Aspergillus niger* and *Rhizopus* sp.

Wannige A.S. and Herath A.C.*

Department of Chemical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka

*Corresponding author (email: ajithch037@gmail.com)

Introduction

Fungal infections caused by opportunistic filamentous fungi have become an increasing global health concern, particularly among immunocompromised patients. Among these pathogens, *Aspergillus niger* and *Rhizopus* sp. are responsible for severe infections such as aspergillosis and mucormycosis, respectively, which are associated with high morbidity and mortality. The growing emergence of antifungal resistance and the limited efficacy of conventional antifungal drugs have created an urgent need for alternative therapeutic strategies capable of overcoming microbial resistance while minimising adverse effects. Antimicrobial photodynamic therapy (aPDT) has emerged as a promising non-invasive treatment approach that combines a photosensitiser, visible light and molecular oxygen to generate cytotoxic reactive oxygen species (ROS), including singlet oxygen, hydroxyl radicals and free radicals (Baltazar et al., 2015). These ROS induce irreversible oxidative damage to multiple cellular targets.

Among various photosensitisers, 5,10,15,20-tetrakis(4-carboxyphenyl) porphyrin (H_2TcPP) has attracted considerable attention owing to its strong visible-light absorption, high singlet oxygen quantum yield and excellent photochemical stability. The incorporation of noble metal nanoparticles, particularly gold nanoparticles (AuNPs), provides an effective strategy to enhance the photophysical performance of porphyrin photosensitisers (Shaikh et al., 2015). AuNPs exhibit excellent biocompatibility, high chemical stability and localised surface plasmon resonance (LSPR), which can improve light harvesting, facilitate charge transfer, suppress porphyrin aggregation and enhance ROS generation (Kurokawa et al., 2022). Consequently, Au–porphyrin nanocomposites have emerged as promising candidates for improved aPDT. The present study investigates the synthesis, characterisation and antifungal photodynamic activity of H_2TcPP-functionalised gold nanocomposites against the pathogenic fungi *Aspergillus niger* and *Rhizopus* sp. Spectroscopic techniques were employed to verify nanocomposite formation and to evaluate the electronic interactions between H_2TcPP and AuNPs. The photodynamic antifungal efficacy of the nanocomposite was subsequently assessed under visible-light irradiation to determine its potential as an effective light-activated antifungal platform.

Methodology

AuNPs were synthesised using the citrate reduction method and subsequently functionalised with H_2TcPP to prepare the H_2TcPP–Au nanocomposite. The formation of the nanocomposite was confirmed by ultraviolet–visible (UV–Vis) spectroscopy

(Spitaleri et al., 2020), while Fourier transform infrared (FTIR) spectroscopy and fluorescence spectroscopy were employed to investigate the structural interactions and photophysical properties of the synthesised material.

The antifungal photodynamic activity of the H_2TcPP–Au nanocomposite was evaluated against *Aspergillus niger* and *Rhizopus* sp. using the agar well diffusion method on Sabouraud dextrose agar (SDA). Fungal suspensions standardised to the 0.5 McFarland standard were treated with the H_2TcPP–Au nanocomposite, free H_2TcPP, AuNPs, ketoconazole and amphotericin B. Parallel experiments were conducted in the dark and under visible-light irradiation to evaluate light-dependent antifungal activity. All experiments were performed in duplicate, and the inhibition zones were measured after incubation.

Results and Discussion

The nanocomposite was first characterised spectroscopically. The ground-state electronic interactions and the successful formation of the H_2TcPP–Au hybrid platform were validated using comparative UV–Vis spectroscopy. Pristine H_2TcPP exhibits a highly intense Soret band at 420 nm alongside four well-resolved Q-bands at 514, 549, 590 and 646 nm, characteristic of a free-base porphyrin macrocycle under D_{2h} symmetry (*Application Notes & Protocols*, 2026; Phromsatit et al., 2021). Separately, unfunctionalised AuNPs feature a distinct, symmetrical LSPR band centred at 524 nm. The successful formation of the H_2TcPP complex is confirmed by the distinct broadening of the porphyrin Soret band and a significant broadening and red shift of the gold plasmon resonance band. Because the highly conjugated porphyrin ring is securely immobilised in immediate proximity to the metallic surface, it perturbs the local refractive index surrounding the gold core. This interfacial coupling alters the classic four-Q-band profile, resulting in the appearance of three shifted structural Q-band features superimposed on the broader plasmon resonance slope (Spitaleri et al., 2020). This collective appearance of shifted Soret profiles, altered Q-bands and a broadened gold plasmon band confirms stable ground-state complexation via peripheral carboxylate binding.

To determine the precise chemical linkage between the H_2TcPP photosensitiser and the AuNPs, the FTIR spectra were compared. Pristine, uncoordinated H_2TcPP exhibits a dominant, sharp carbonyl (C=O) stretching band near 1653 cm^{-1}, which represents the protonated carboxylic acid (–COOH) groups located at the four peripheral *meso*-phenyl positions of the macrocycle. In the spectrum of the H_2TcPP–Au nanocomposite, this characteristic uncoordinated C=O peak disappears completely. It is replaced by two new, strong vibrational features: an asymmetric carboxylate (COO^-) stretching band at 1540–1560 cm^{-1} and a corresponding symmetric carboxylate (COO^-) stretching band at 1380–1400 cm^{-1} (Şen et al., 2010). The complete attenuation of the free –COOH band, together with the systematic appearance of these distinct coordinated carboxylate modes, confirms that binding occurs through the deprotonated peripheral carboxylate ends via bidentate coordination to the gold surface. This robust chemical immobilisation anchors the macrocycles securely to the nanoparticle periphery, preventing central metal insertion and

structurally stabilising the final hybrid network against leaching or dissociation during long-term storage and in biological testing matrices.

To evaluate the excited-state dynamics and electronic communication within the gold hybrid framework, fluorescence emission titrations were performed. Pristine H_2TcPP displays a distinct dual-peak red emission with maxima at 650 nm and 715 nm (excitation at 420 nm), corresponding to radiative relaxation from the excited singlet state (S_1) to the ground state (S_0). Upon sequential titration of AuNPs into the porphyrin solution, a systematic, continuous decrease in fluorescence intensity was observed at both emission maxima. This progressive attenuation demonstrates efficient non-radiative interfacial energy or electron transfer from the excited porphyrin macrocycle to the metallic gold core (Spitaleri et al., 2020). To characterise the quenching kinetics, the titration data were modelled using the linear Stern–Volmer equation. The Stern–Volmer plot yielded a strictly linear relationship ($R^2 > .99$). This linearity rules out a collisional dynamic process, confirming a purely static quenching mechanism driven by the formation of a stable, non-fluorescent ground-state complex. From the slope of the regression line, the Stern–Volmer quenching constant (K_{SV}) for the gold platform was determined as 0.006 $dm^3\ mol^{-1}$. The successful formation of the hybrid nanomaterial is highlighted by the behaviour of the AuNPs as highly efficient fluorescence quenchers. Because the macrocycles are chemically anchored via their peripheral carboxylate groups, leaving the core free-base ring structurally intact, this efficient fluorescence quenching confirms that the photosensitiser is held in close interfacial proximity to the gold surface. This behaviour demonstrates a strong binding interaction and high electronic communication between the components, validating the photophysical integrity of the synthesised H_2TcPP–Au hybrid network.

The *in vitro* antimicrobial performance of the synthesised platforms was then evaluated under both dark and visible-light irradiation regimes to distinguish true photodynamic action from standalone systemic toxicity. The assays were conducted using a uniform treatment concentration of 500 ppm at pH 4.5. In the dark control assessments, unfunctionalised AuNPs exhibited no antifungal activity under either light or dark conditions, confirming that the metallic core is completely inert on its own. Similarly, the H_2TcPP–Au nanocomposite demonstrated zero toxicity under dark conditions, yielding a radial inhibition zone percentage of 0.0% against both *Aspergillus niger* and *Rhizopus* sp. The complete lack of inhibition in the dark establishes the excellent biocompatibility and non-toxic nature of the hybrid framework prior to light activation.

Upon visible-light irradiation, a distinct and species-specific photodynamic effect was observed. For *Aspergillus niger*, light activation of the H_2TcPP–Au nanocomposite triggered a significant increase in antifungal performance, achieving a substantial 74.9% radial inhibition. This marks a notable enhancement over the 61.2% inhibition displayed by the free, uncomplexed H_2TcPP ligand under the same light regime (free H_2TcPP in the dark remained at 0.00% inhibition). This significant improvement is directly attributed to the AuNPs acting as an effective anti-aggregating structural support, which preserves a

high capacity for continuous ROS generation upon light exposure, leading to enhanced oxidative stress and cell wall disruption in *A. niger*. Conversely, susceptibility testing against *Rhizopus* sp. revealed complete resistance across all operational parameters. Neither the free H_2TcPP ligand nor the integrated H_2TcPP–Au nanocomposite produced a measurable clear zone under any condition, yielding 0.0% radial inhibition under both light and dark conditions. This high resistance towards all treatments under all conditions matches the performance of the conventional antifungal controls.

Conclusions and Implications

This study successfully demonstrates the design and development of a stable H_2TcPP–Au hybrid nanocomposite through the self-assembly of H_2TcPP on the surface of AuNPs. The resulting light-activated nanocomposite exhibited efficient photodynamic antifungal activity at an operational concentration of 500 ppm and pH 4.5. No antifungal activity was observed under dark conditions, whereas visible-light irradiation induced significant inhibition of *Aspergillus niger*, achieving a radial inhibition of 74.9%. In contrast, *Rhizopus* sp. remained resistant under both dark and light conditions. These findings indicate that the surface functionalisation of AuNPs with H_2TcPP effectively minimises porphyrin self-aggregation while enhancing its photodynamic performance. Therefore, the H_2TcPP–Au nanocomposite represents a promising non-antibiotic, light-activated platform for the targeted treatment of localised fungal infections.

***Keywords*:** Antimicrobial photodynamic therapy, fluorescence spectroscopy, photosensitiser, porphyrin, reactive oxygen species

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VLF Investigation of Shallow Conductive Structures Associated with the Wahawa Geothermal Field, Sri Lanka

Chathurya K.A.D.D.[1,*], Harankahawa S.B.[2], Weligepola W.K.G.V.[2], Navodya T.M.D.[1], Wijewardane H.O.[1], Dahanayake U.[1] and Samaranayake S.A.[1]

[1]*Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Geological Survey and Mines Bureau, Colombo, Sri Lanka*

*Corresponding author (email: chathuryadinithi@gmail.com)

Introduction

In Precambrian crystalline terrains, non-volcanic geothermal systems are typically controlled by fractures, shear zones and lithological contacts that act as pathways for the circulation of geothermal fluids. However, these buried structures are often difficult to identify from surface observations alone, and geophysical investigations are required to characterise them (Samaranayake et al., 2022). In Sri Lanka, geothermal manifestations are mainly associated with the Precambrian basement complexes, although their distribution cannot be explained by the Highland–Vijayan Complex boundary alone, which suggests the influence of localised structural features (Chandrajith et al., 2013; Nimalsiri et al., 2015). The Wahawa geothermal field is situated in the Vijayan Complex and has hot springs associated with fractured crystalline rocks, NE–SW trending fractures, a NW–SE trending dolerite dyke and a shear zone (Samaranayake et al., 2022). In this study, the very low frequency (VLF) electromagnetic method was used to investigate the shallow conductive anomalies related to potential geothermal fluid pathways in the Wahawa geothermal field.

Methodology

The VLF electromagnetic method was used for the first time to survey a 1,400 m long east–west profile across the Wahawa geothermal field. Measurements were carried out at 5 m intervals using an IRIS VLF instrument (Model: VLF, Serial No. 151). Two VLF transmitters, with frequencies of 18.3 kHz and 19.2 kHz, were used for data acquisition.

The VLF survey profile extended from the hot spring area in the east to the dolerite dyke in the west. Tilt angle, in-phase magnetic component and ellipticity measurements were obtained along the profile. As the recorded data contained a large amount of noise, Fraser filtering and the Karous–Hjelt transformation were not applied. The interpretation was based on the observed changes in the VLF parameters and their relationship with the geological and other geophysical results.

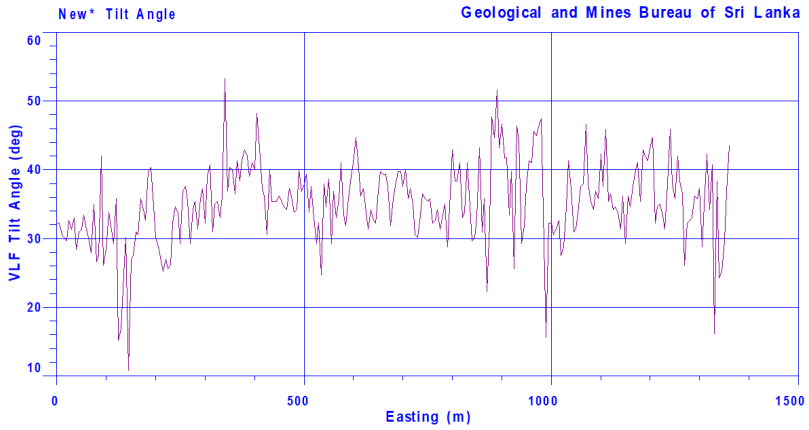
Results and Discussion

The VLF electromagnetic responses along the 1,400 m east–west profile were evaluated using the variations in tilt angle, ellipticity and in-phase magnetic component to identify possible shallow conductive structures associated with the Wahawa geothermal system. All three parameters vary along the survey line, indicating lateral variation in the electrical properties of the subsurface.

The tilt angle profile (Figure 1) displays highly fluctuating responses along the survey line, suggesting considerable heterogeneity in the shallow subsurface. There are several prominent positive peaks and sharp troughs at about 100–200 m, 850–1,050 m and 1,300–1,400 m. Such variations suggest potential electromagnetic responses associated with subsurface conductivity contrasts and structural discontinuities. However, the rapid oscillations along the whole profile are evidence of strong noise effects, and individual conductive bodies are not easy to isolate from the tilt angle response alone.

Figure 1

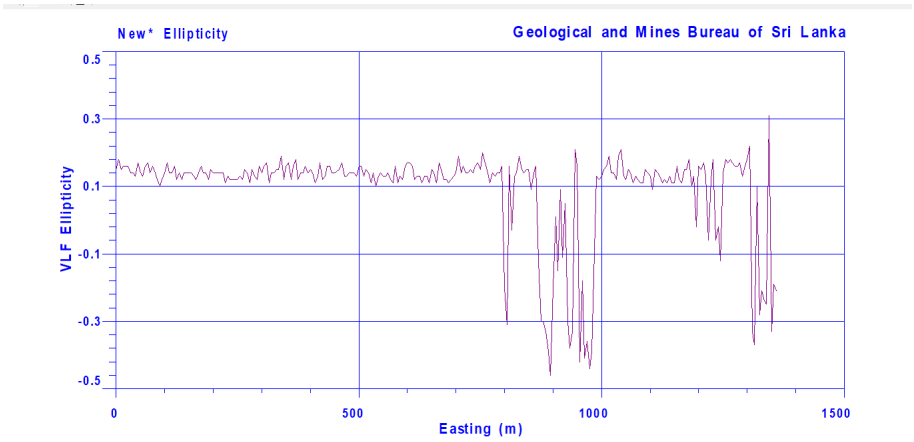
Tilt Angle Variation Along the VLF Profile



The ellipticity response (Figure 2) is relatively stable along most of the profile but shows clear negative excursions at about 800–1,050 m and 1,300–1,400 m. These anomalies indicate possible zones of enhanced conductivity, which may be associated with fractured regions or structural boundaries. The spatial correlation of the ellipticity anomalies with the variations in the tilt angle profile suggests that these zones may represent real subsurface features rather than random fluctuations.

Figure 2

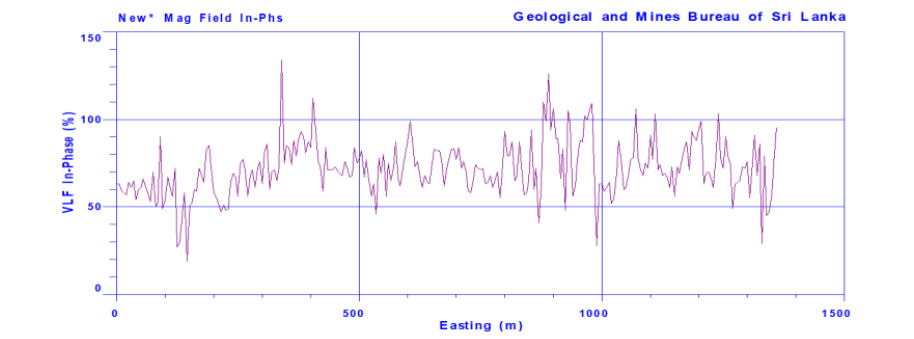
Ellipticity Variation Along the VLF Profile



Similarly, the in-phase magnetic component (Figure 3) shows large variability along the profile, with prominent anomalies at around 100–200 m, 300–450 m, 850–1,050 m and 1,300–1,400 m. The coincidence of these anomalies with the tilt angle and ellipticity responses provides additional evidence for possible conductive structures in the subsurface.

Figure 3

VLF In-Phase Profile



The western part of the profile (0–200 m), corresponding to the hot spring area, presents positive VLF responses, indicating increased conductivity associated with the circulation of geothermal fluids. These responses may indicate shallow fractured or weathered zones carrying geothermal fluids. In contrast, no significant VLF anomaly was observed over the highly resistive dolerite dyke between approximately 1,200 and 1,300 m, showing that the intact dyke body is not a conductive feature. Thus, the anomalies observed around the dyke region could be caused by the surrounding fractures or contact zones rather than by the massive intrusive body itself.

VLF data provide information on shallow electrical changes, but the high level of noise and the low signal strength limit the reliability of a structural interpretation based solely on this method. Resistivity investigations were therefore also used to constrain the identification of near-surface structural features. The combined interpretation suggests that the VLF observations support the presence of structurally controlled conductive zones associated with geothermal fluid pathways within the Wahawa geothermal field.

Conclusions and Implications

The VLF electromagnetic investigation provided useful information on the shallow electrical characteristics of the Wahawa geothermal field. The variations in the tilt angle, ellipticity and in-phase component responses point to the presence of subsurface conductivity contrasts along the survey profile. The similarity of the anomalies in the different VLF parameters may suggest the presence of structural discontinuities and fractured zones associated with the circulation of geothermal fluids.

The VLF responses observed near the hot spring area suggest the presence of shallow conductive features, which could be fluid-filled fractures or weathered zones that increase the permeability of the crystalline basement. In contrast, no significant VLF response was observed over the resistive dolerite dyke, which means that the intact intrusive body does not constitute a major conductive pathway, although the associated fractures and contact zones may influence fluid flow.

Owing to the high noise level and weak signal strength of the acquired VLF data, the method alone was not sufficient to develop a detailed structural model of the geothermal system. Nevertheless, when combined with resistivity and other geophysical investigations, the VLF data provide supporting evidence for the identification of shallow structural variations related to geothermal fluid pathways. The results highlight the importance of combining different geophysical methods to understand the structural controls of non-volcanic geothermal systems in crystalline basement terrains and to minimise the associated uncertainties.

***Keywords*:** Ellipticity, geothermal exploration, structural control, tilt angle, very low frequency

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Development of Omega-3-Enriched Mayonnaise Using Coconut, Rice and Flaxseed Oil

Dissanayake H.M.N.S.[1], Edirisinghe E.M.R.K.B.[1,*] and Senarath H.P.S.[2]
[1]*Department of Chemical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Department of Food Science and Technology, Faculty of Livestock, Fisheries & Nutrition, Wayamba University of Sri Lanka, Makandura, Gonawila, Sri Lanka*
*Corresponding author (email: ranjith_e@rjt.ac.lk)

Introduction

Mayonnaise is a widely consumed oil-in-water emulsion that contains a high proportion of edible oil and is valued for its desirable texture, flavour and consumer acceptability. However, conventional mayonnaise products are often associated with a high fat content and may lack beneficial fatty acids. Consequently, increasing attention has been directed towards the development of nutritionally improved mayonnaise formulations using functional edible oils (El-Waseif et al., 2022).

Gas chromatography–mass spectrometry (GC–MS) is a powerful analytical technique for determining the fatty acid composition of edible oils and supporting the selection of suitable ingredients for food product development. Commercial rice oil is recognised for its balanced fatty acid composition, containing appreciable levels of monounsaturated and polyunsaturated fatty acids, which contribute to both nutritional quality and oxidative stability (Wathsala et al., 2025). Coconut oil provides excellent oxidative stability owing to its high saturated fatty acid content, whereas flaxseed oil is an abundant source of α-linolenic acid (an omega-3 fatty acid), offering significant nutritional benefits. Therefore, this study used GC–MS fatty acid profiling to evaluate commercial rice oil, coconut oil and flaxseed oil and to identify suitable oil blend ratios for mayonnaise formulation. The prepared formulations were subjected to sensory evaluation to determine consumer acceptability, and the selected formulation was further assessed for storage stability through peroxide value, free fatty acid content, phase separation and fatty acid profile analysis over a 16-day storage period.

Methodology

Coconut oil, commercial rice oil and flaxseed oil were analysed for their fatty acid composition using GC–MS following fatty acid methyl ester (FAME) preparation. Based on the fatty acid profiles, six oil blend formulations containing different proportions of coconut oil, rice oil and flaxseed oil were prepared for mayonnaise production (Kajla et al., 2014).

Mayonnaise samples were formulated using the oil blends and standard ingredients, including egg yolk, vinegar, salt, sugar and mustard. The formulations were subjected to sensory evaluation by 10 semi-trained panellists using a five-point hedonic scale. Physicochemical analyses were performed in duplicate (n = 2), and the results were analysed using one-way analysis of variance (ANOVA) followed by Tukey's honestly significant difference (HSD) test (p < .05). Based on the sensory evaluation, the formulation containing 56% coconut oil, 39% commercial rice oil and 5% flaxseed oil

was selected for shelf-life evaluation (Tavakoli et al., 2021). The selected mayonnaise formulation and a commercially available mayonnaise product, used as the control, were stored at room temperature for 16 days. Samples were analysed on Days 0, 1, 4, 8, 12 and 16 for peroxide value (PV), free fatty acid (%FFA) content, phase separation and changes in the fatty acid profile using GC–MS (Chukwu & Sadiq, 2008).

Results and Discussion

GC–MS analysis revealed distinct fatty acid compositions among the selected oils (Table 1). Coconut oil exhibited the highest saturated fatty acid (SFA) content (86.89%), which contributes to oxidative stability. In contrast, commercial rice oil contained higher levels of monounsaturated fatty acids (MUFA, 40.76%) and polyunsaturated fatty acids (PUFA, 23.83%), providing a balanced fatty acid profile. Flaxseed oil showed the highest PUFA content (66.57%) and was particularly rich in α-linolenic acid, confirming its suitability as a source of omega-3 fatty acids. Similar observations were reported by El-Waseif et al. (2022), who demonstrated that flaxseed oil improves the omega-3 content and nutritional quality of mayonnaise formulations. These complementary fatty acid profiles supported the use of the selected oils for mayonnaise formulation (Ponkiyawati et al., 2025).

Table 1

Fatty Acid Composition of Coconut Oil, Commercial Rice Oil and Flaxseed Oil

Fatty acid type	Coconut oil (%)	Commercial rice oil (%)	Flaxseed oil (%)
SFA	86.89	28.94	11.57
MUFA	9.32	40.76	20.72
PUFA	2.47	23.83	66.57

Note. SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

Sensory evaluation of the six mayonnaise formulations revealed significant differences ($p < .05$) in appearance, colour, texture, taste and overall acceptability. Among the formulations, Sample B, containing 56% coconut oil, 39% commercial rice oil and 5% flaxseed oil, achieved the highest overall acceptability score (5.00 ± 0.00) and was selected for further storage studies. This finding agrees with Tavakoli et al. (2021), who reported that optimised oil formulations can maintain desirable sensory characteristics while improving nutritional quality. The balanced oil blend contributed to improved sensory quality and nutritional value.

The formulation remained stable, with no visible phase separation until Day 12 and only slight separation on Day 16. The FFA content increased gradually from 0.177% on Day 0 to 0.333% on Day 16, indicating progressive lipid hydrolysis during storage. Similarly, the PV increased from 1.03 to 6.44 meq O_2/kg over the storage period, reflecting the gradual formation of primary lipid oxidation products (Table 2). Comparable increasing trends were observed in the commercial mayonnaise sample. However, the formulated mayonnaise maintained acceptable physicochemical stability throughout the storage period. The fatty acid profiles changed only slightly during storage, indicating good retention of nutritional quality. The developed mayonnaise shows potential as a

nutritionally improved product formulated with an omega-3-rich oil blend, although direct quantification of omega-3 fatty acids is recommended.

Table 2

Changes in Free Fatty Acid Content and Peroxide Value During Storage

Storage day	FFA (%)		PV (meq O_2/kg)	
	Sample	Commercial	Sample	Commercial
0	0.1770	0.0715	1.0305	0.6500
1	0.2158	0.1110	1.4400	1.1500
4	0.2430	0.1445	2.2700	2.2000
8	0.2830	0.1810	3.8400	3.6000
12	0.3173	0.2123	5.1000	4.5500
16	0.3329	0.2820	6.4400	5.7500

Note. Values represent the mean of duplicate determinations (n = 2). FFA = free fatty acids; PV = peroxide value.

Conclusions and Implications

GC–MS fatty acid profiling demonstrated that coconut oil, commercial rice oil and flaxseed oil possess complementary fatty acid compositions suitable for mayonnaise formulation. The formulation containing 56% coconut oil, 39% commercial rice oil and 5% flaxseed oil achieved the highest sensory acceptability and exhibited satisfactory stability during 16 days of storage. Despite gradual increases in PV and FFA, the product maintained acceptable physicochemical stability. Therefore, the developed mayonnaise shows potential as a nutritionally improved functional mayonnaise formulated with an omega-3-rich oil blend. However, direct quantification of omega-3 fatty acids and longer storage studies are recommended to further validate its functional potential.

***Keywords*:** Fatty acid profiling, gas chromatography–mass spectrometry, omega-3 fatty acids, sensory evaluation, storage stability

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Digital Minimalism and Employee Job Performance: Evidence From IT Professionals in Sri Lanka

Weerasinghe T.D.*
Department of Human Resource Management, Faculty of Commerce and Management Studies, University of Kelaniya, Sri Lanka
*Corresponding author (email: dananjaya@kln.ac.lk)

Introduction

The rapid digitalisation of workplaces has significantly enhanced organisational efficiency, particularly within the information technology (IT) sector. However, it has also intensified issues related to digital overload, distraction and reduced employee focus (Mark et al., 2008; Tarafdar et al., 2019). Employees are increasingly exposed to constant notifications, multitasking demands and prolonged screen engagement, which negatively affect cognitive capacity and job performance (Rosen et al., 2011). While prior research has predominantly focused on technostress and excessive technology use, limited attention has been given to strategies that promote intentional and controlled technology use, such as digital minimalism.

Digital minimalism refers to the "conscious and purposeful use of digital technologies to minimise distractions and enhance meaningful engagement" (Newport, 2019). Emerging evidence suggests that practices such as reducing unnecessary digital interactions, managing notifications and establishing usage boundaries can improve attention control and job performance (Chen, 2019; Duke & Montag, 2017). Despite its growing relevance, empirical research examining digital minimalism within organisational settings, particularly in developing economies such as Sri Lanka, remains limited.

This study addresses this gap by quantitatively examining the impact of digital minimalism practices on the job performance of IT professionals. Specifically, the study aims to assess the direct effect of digital minimalism on employee focus, to assess the direct effect of digital minimalism on employee job performance, to examine the mediating effect of employee focus and to contribute to the emerging discourse on digital well-being and sustainable work practices. By providing empirical evidence, this study offers important theoretical, policy and practical implications for organisations seeking to enhance employee performance while promoting healthier digital work environments.

Digital environments often fragment attention and reduce productivity; however, intentional regulation of technology use can enhance cognitive functioning and work outcomes (Mark et al., 2008; Rosen et al., 2011). Digital minimalism emphasises the purposeful and controlled use of digital technologies, reducing unnecessary interruptions and cognitive overload (Newport, 2019). Prior research suggests that excessive digital interruptions impair attentional capacity and task engagement (Mark et al., 2008). Conversely, practices such as limiting notifications and minimising multitasking improve sustained attention and cognitive control (Chen, 2019; Duke & Montag, 2017). Attentional control theory further posits that individuals who regulate distractions demonstrate better focus and task efficiency (Derryberry & Reed, 2002). Accordingly, the

first hypothesis is advanced: digital minimalism has a significant positive effect on employee focus (H1).

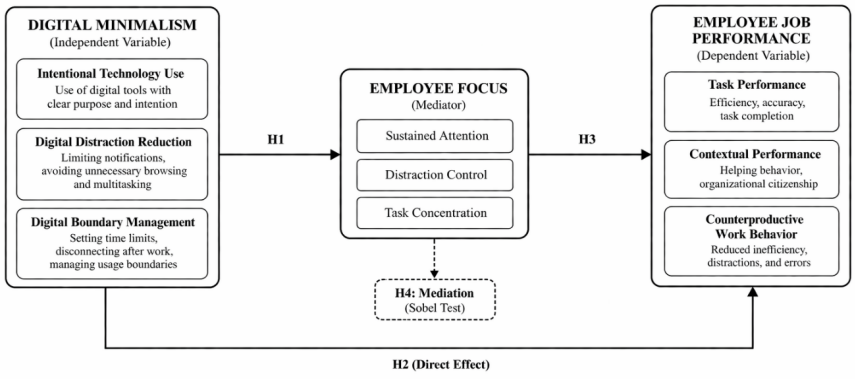
Unregulated technology use has been linked to decreased performance, errors and counterproductive work behaviours (Tarafdar et al., 2019). In contrast, mindful and minimal use of digital tools enhances efficiency, reduces cognitive strain and improves task completion (Chen, 2019). Studies on workplace interruptions also show that minimising digital distractions leads to better performance outcomes (Mark et al., 2008). Therefore, digital minimalism is expected to influence employee job performance positively, and the second hypothesis is advanced: digital minimalism has a significant positive effect on employee job performance (H2).

Employee focus, defined as the ability to maintain attention and resist distractions, is a critical determinant of job performance. Research indicates that higher levels of attentional control lead to improved task accuracy, efficiency and overall performance (Derryberry & Reed, 2002). Frequent task switching and attentional lapses, often caused by digital distractions, negatively affect productivity (Rosen et al., 2011). Thus, employees who maintain stronger focus are more likely to perform effectively in their roles, and the third hypothesis is advanced: employee focus has a significant positive effect on employee job performance (H3).

Digital minimalism is likely to enhance job performance indirectly by improving employee focus. According to cognitive load theory, reducing unnecessary stimuli allows individuals to allocate more cognitive resources to task-relevant activities, thereby improving performance (Sweller, 2011). Empirical studies also suggest that the negative effects of digital distractions on performance operate through reduced attention and concentration (Mark et al., 2008; Rosen et al., 2011). Hence, employee focus is expected to act as a key explanatory mechanism linking digital minimalism to job performance, and the fourth hypothesis is advanced for the mediating effect: employee focus mediates the relationship between digital minimalism and employee job performance (H4). The hypothesised relationships are depicted in the conceptual framework of the study (Figure 1).

Figure 1

Conceptual Framework of the Study



Methodology

This study adopted a quantitative, cross-sectional research design to examine the impact of digital minimalism on employee job performance, with employee focus as a mediating variable. The study population comprised IT professionals employed in Sri Lanka. A total of 420 respondents were selected using simple random sampling from five IT companies, which were purposively chosen on the basis of the size of their permanent employee cadre to ensure adequate representation. Primary data were collected through a structured online questionnaire administered via Google Forms.

All constructs were assessed using validated standard measurement scales adapted from prior studies, with responses anchored on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Digital minimalism (independent variable) was assessed using an adapted multidimensional scale derived from the information and communication technology (ICT) mindfulness and digital detox literature, capturing intentional technology use, distraction reduction and boundary management (Chen, 2019; Duke & Montag, 2017; Van Deursen et al., 2015). Employee focus (mediator) was assessed using the Attentional Control Scale (ACS) developed by Derryberry and Reed (2002). The dependent variable, employee job performance, was assessed using the Individual Work Performance Questionnaire (IWPQ) of Koopmans et al. (2014), encompassing task performance, contextual performance and counterproductive work behaviour.

Data were analysed using IBM SPSS Statistics version 26. The data set was first screened for missing values and outliers. Descriptive statistics and reliability and validity statistics were then generated. Next, the data set was tested for the multivariate assumptions of normality, linearity, homoscedasticity and multicollinearity prior to hypothesis testing. Pearson correlation analysis was used to examine the relationships among the variables, while simple regression analysis was employed to test the direct effects of digital minimalism on employee focus and job performance (Field, 2013). To assess the

mediating effect of employee focus, the Sobel test was applied to determine the significance of the indirect effect, following established mediation analysis procedures (Sobel, 1982). Residual analysis was also performed to test model fit.

Ethical standards were strictly maintained throughout the study. Participants were informed about the purpose of the research, and informed consent was obtained prior to participation. The study ensured the anonymity and confidentiality of responses, and the data were securely stored and used solely for research purposes.

Results and Discussion

A total of 420 valid responses were analysed. All constructs demonstrated satisfactory internal consistency, with Cronbach's alpha values exceeding the recommended threshold of 0.70 (Hair et al., 2019): digital minimalism ($\alpha = 0.88$), employee focus ($\alpha = 0.86$) and employee job performance ($\alpha = 0.90$) indicated strong reliability. These results confirm the suitability of the measurement scales for further statistical analysis.

Pearson correlation analysis revealed significant positive relationships among the study variables. Digital minimalism was positively correlated with employee focus ($r = 0.52$, $p < .01$) and employee job performance ($r = 0.47$, $p < .01$). Employee focus also showed a strong positive correlation with job performance ($r = 0.58$, $p < .01$). These findings are consistent with prior research suggesting that reducing digital distractions enhances attention and improves workplace outcomes (Mark et al., 2008; Rosen et al., 2011). The moderate-to-strong correlations indicate meaningful associations without multicollinearity issues (Field, 2013).

Multiple regression analysis was conducted to test the hypothesised relationships. Digital minimalism had a significant positive effect on employee focus ($\beta = 0.52$, $p < .001$, $R^2 = 0.27$), supporting H1. This suggests that employees who engage in intentional and controlled technology use demonstrate higher levels of attention and concentration. Moreover, digital minimalism significantly predicted employee job performance ($\beta = 0.34$, $p < .001$, $R^2 = 0.22$), supporting H2. This finding aligns with studies indicating that minimising digital interruptions enhances productivity and efficiency (Tarafdar et al., 2019). Similarly, employee focus had a strong positive effect on job performance ($\beta = 0.46$, $p < .001$, $R^2 = 0.33$), supporting H3. This confirms that the ability to maintain attention is a critical determinant of effective job performance (Derryberry & Reed, 2002).

The mediating role of employee focus was tested using the Sobel test. The results indicated that the indirect effect of digital minimalism on job performance via employee focus was significant ($z = 4.87$, $p < .001$), supporting H4. Furthermore, when employee focus was included in the regression model, the direct effect of digital minimalism on job performance decreased (β reduced from 0.34 to 0.18, $p < .05$), indicating partial mediation. This suggests that digital minimalism enhances job performance both directly and indirectly through improved focus. The results of the correlation, regression and mediation analyses are summarised in Table 1.

Table 1

Summary of Correlation, Regression and Mediation Analysis Results

Relationship	Correlation (*r*)	Regression (β)	*t*	*p*	R^2	Result
Digital minimalism → employee focus	0.52**	0.52	13.84	< .001	0.27	Supported (H1)
Digital minimalism → job performance	0.47**	0.34	8.86	< .001	0.22	Supported (H2)
Employee focus → job performance	0.58**	0.46	12.32	.001	0.33	Supported (H3)
Digital minimalism → job performance (with mediator)	—	0.18	3.88	.05	—	Partial mediation
Mediation analysis (Sobel test)						
Path	Indirect effect		Sobel *z*	*p*	Mediation type	
Digital minimalism → employee focus → job performance	0.24		4.87	.001	Partial mediation (H4 supported)	

Note. ** $p < .01$; $N = 420$.

The findings of this study provide strong empirical support for the role of digital minimalism as a critical driver of employee performance in digital work environments. The positive effect of digital minimalism on employee focus highlights the importance of intentional technology use in mitigating cognitive overload and enhancing attentional control. This is consistent with the principles of attentional control theory, which emphasise the role of distraction regulation in improving cognitive performance (Derryberry & Reed, 2002).

The significant relationship between digital minimalism and job performance further reinforces the argument that reducing unnecessary digital engagement can improve efficiency and task outcomes. This finding extends prior research on technostress by shifting the focus from the negative consequences of technology use to proactive behavioural strategies that enhance digital well-being (Tarafdar et al., 2019). Moreover, the mediation results demonstrate that employee focus serves as a key psychological mechanism through which digital minimalism influences performance. This supports cognitive load theory, which posits that minimising extraneous stimuli allows individuals to allocate cognitive resources more effectively to task-relevant activities (Sweller, 2011). Taken together, the study contributes to the emerging literature on digital well-being by providing quantitative evidence that "less is more" in digital work contexts, particularly in knowledge-intensive sectors.

Conclusions and Implications

This study provides empirical evidence that digital minimalism significantly enhances employee job performance, both directly and indirectly through employee focus. The findings demonstrate that IT professionals who engage in intentional and controlled use of digital technologies are better able to maintain attention, reduce distractions and perform their tasks effectively. The significant mediating role of employee focus further

confirms that attention regulation is a key psychological mechanism linking digital behaviour to performance outcomes. These results align with attentional control theory, which emphasises the importance of managing distractions to optimise cognitive functioning, and with cognitive load theory, which suggests that minimising unnecessary stimuli improves task efficiency. Taken together, the study reinforces the notion that in highly digitalised work environments, reduced and purposeful technology use leads to improved job performance.

This study contributes to the emerging literature on digital well-being and organisational behaviour by introducing digital minimalism as a proactive behavioural construct, extending beyond the dominant focus on technostress and technology overload (Tarafdar et al., 2019). It also enriches existing theories by empirically validating employee focus as a mediating mechanism, thereby integrating attention-based perspectives into digital workplace research.

The findings offer several important managerial implications for organisations, particularly in the IT sector. Organisations should promote digital minimalism practices, such as managing notifications, reducing unnecessary digital interactions and encouraging focused work periods. Human resource management (HRM) policies can also incorporate digital well-being initiatives, including training programmes on mindful technology use and attention management. Similarly, managers should design work environments that minimise digital interruptions, thereby enhancing employee concentration and productivity. Implementing structured practices such as digital detox intervals can also help employees sustain attention and improve performance outcomes. At a broader level, organisations and policymakers should recognise digital well-being as a component of sustainable work practices. Encouraging balanced and responsible technology use can contribute to long-term employee productivity, mental well-being and organisational sustainability.

***Keywords*:** Digital minimalism, digital well-being, employee focus, IT professionals, job performance

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Attitudinal Responses to Artificial Intelligence in Sustainable Purchasing Context: A Generation Z Perspective

Jayasinghe U.H.[1,*] and Maphosa V.[2]
[1]*Department of Marketing Management, KIU University, Battaramulla 10120, Sri Lanka,* [2]*Information Communication and Technology Services, National University of Science and Technology, Bulawayo, Zimbabwe*
*Corresponding author (email: umenhewajayasinghe@gmail.com)

Introduction

Current consumer purchasing behaviour has been influenced by the rapid integration of artificial intelligence (AI) into digitalised marketing settings (Davenport et al., 2020; Ho & Chow, 2024). Business organisations have adopted e-commerce platforms with AI-powered marketing applications such as recommendation systems, chatbots, predictive analytics and smart filtering, which influence information searching, the evaluation of alternatives and the finalisation of purchasing decisions (Huang & Rust, 2021). Meanwhile, business organisations focus strongly on sustainability owing to heavy environmental pollution, rapidly increasing public awareness of sustainability issues and the 17 Sustainable Development Goals of the United Nations (United Nations, 2015; Vinuesa et al., 2020). Generation Z has been identified as a sustainability-conscious generation that interacts with sustainability-oriented digital promotions. Although its members show positive sustainable attitudes, their actual purchasing behaviour does not align with those attitudes (Djafarova & Foots, 2022). The sustainable consumption literature has discussed this as an "attitude–behaviour gap" or "value–action gap" (Carrington et al., 2010; Yadav & Pathak, 2017). This gap was further supported by a preliminary study conducted in 2026 among fifty Generation Z consumers in Colombo: although 98% of the respondents showed favourable attitudes towards AI-powered sustainable purchasing, only 12% were inspired to make actual purchases based on those applications. This further confirmed that favourable sustainable attitudes do not always translate into actual sustainable purchasing behaviour.

Depending on how Generation Z consumers view AI involvement in their purchasing, this gap may either narrow or widen in AI-mediated settings. Ethical, trustworthy, user-centric and responsible AI involvement can develop positive attitudes towards AI applications; conversely, scepticism and less trusted, irresponsible AI involvement may develop negative attitudes (Cao & Liu, 2023; Nogueira et al., 2025). While the existing literature has explored AI technology across different marketing phenomena and consumer behaviours, limited attention has been given to how attitudes towards AI are associated with sustainable purchasing behaviour, especially in developing markets such as Sri Lanka. Given the persistent attitude–behaviour gap reported in the sustainable consumption literature, identifying factors associated with actual sustainable purchasing behaviour has become highly critical. This is also consistent with the theory of planned behaviour, which recognises attitudes as an important predictor of behavioural outcomes (Ajzen, 1991).

Against this broader context, the present study specifically examines the relationship between attitudes towards AI and sustainable purchasing behaviour among Generation Z consumers in Colombo. Rather than examining the attitude–behaviour gap directly, this study focuses on attitudes as one factor associated with sustainable purchasing. This is based on evidence from the developing-country context, where studies on AI-enabled sustainable consumption remain limited.

Methodology

A quantitative research approach was adopted to address the key objective, and a structured online questionnaire was used to collect primary data from 384 Generation Z consumers in Colombo District. To establish validity, the questionnaire measured attitudes towards AI and sustainable purchasing behaviour using multi-item Likert scales adapted from the established literature (Guerra-Tamez et al., 2024; Yadav & Pathak, 2017), which were reviewed by experts to ensure the clarity and comprehensibility of the items. Composite variables were built by computing mean scores for each construct. SPSS version 26 was employed for the data analysis, and simple linear regression analysis was applied to test the direct relationship between the variables (Figure 1), consistent with the study objectives.

Figure 1

Conceptual Framework



Source: Adapted from Guerra-Tamez et al. (2024) and informed by Ajzen (1991).

Results and Discussion

Of the 384 responses, 331 qualified for the final analysis on the basis of the screening criteria. Most respondents belonged to the 20–27 age category, and the final sample showed balanced gender participation and frequent engagement in online purchasing. Both variables showed standard Cronbach's alpha values: attitudes towards AI ($\alpha = 0.752$) and sustainable purchasing behaviour ($\alpha = 0.825$). The model explained 49% of the variance in sustainable purchasing behaviour, revealing considerably strong explanatory power. The analysis of variance (ANOVA) results demonstrated that the overall model was significant ($F = 318.358$, $p < .001$). Moreover, the regression results indicate a strong and statistically significant positive effect of attitudes towards AI on sustainable purchasing behaviour ($\beta = 0.959$, $p < .001$). This suggests that positive attitudes towards AI may encourage Generation Z consumers to engage more actively in sustainable purchasing by increasing confidence in AI-enabled market settings, consistent with previous studies highlighting AI as a decision-support mechanism in consumer purchasing (Guerra-Tamez et al., 2024; Huang & Rust, 2021).

Conclusions and Implications

The findings of this study emphasise that attitudes towards AI have a strongly positive effect on sustainable purchasing behaviour among Generation Z consumers in Colombo District. Generation Z consumers with more favourable attitudes towards AI also report higher levels of sustainable purchasing behaviour within an AI-enabled market setting, which indicates that consumer attitudes towards AI are one of the factors associated with sustainable purchasing in such settings. Moreover, technology-encouraged sustainable purchasing behaviour is shaped by a combination of interacting factors, including trust, transparency, technological literacy and consumers' overall view of technological involvement in purchasing decision-making (Djafarova & Foots, 2022). When these factors support purchasing, attitudes towards AI act as a facilitator of sustainable purchasing behaviour.

From a theoretical perspective, this study extends knowledge of the importance of consumer attitudes and judgements in AI-powered contexts, specifically regarding the Generation Z segment and developing economy settings. It further contributes to the growing body of literature linking AI-related psychological factors with sustainability-oriented purchasing patterns. From a practical perspective, the findings encourage marketers to cultivate positive consumer attitudes towards AI by emphasising transparency, reliability and user-friendliness in AI-driven shopping interfaces. Marketers should also understand the importance of consumer attitudes, opinions and judgements when applying modern technological applications at consumer "touch points", and how different segments interact with their marketing applications.

As the findings are based on cross-sectional, self-reported data, they should be interpreted with caution. Future research is encouraged to adopt the model in a longitudinal study design and to use more comprehensive analytical approaches, such as structural equation modelling, to examine additional factors influencing sustainable purchasing behaviour. Future studies could also focus on specific AI applications to assess the effectiveness of each, which would be highly beneficial for marketers planning to invest in AI applications.

Keywords**:** AI-powered marketing, artificial intelligence, attitudes towards AI, sustainable consumption, sustainable purchasing behaviour

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Impact of Online E-Commerce on Online Purchase Intention: The Mediation Role of Brand Trust; Electrical Building Material Sector, Sri Lanka

Ranjith H.K.M.P.*, Hendeniya H.M.U.S. and Ranjith H.K.D.S.
Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: maduwanthapasidu03@gmail.com)

Introduction

In the 21st century, individuals and companies are increasingly using modern digital technologies such as the Internet of Things, blockchain, cloud computing, machine learning, artificial intelligence and many internet-based resources in their business and day-to-day lives (Li et al., 2024). The emergence of internet technologies has had a great impact on consumers' daily activities, and many offline activities have now migrated to the online environment. In the past 10 years, research on social commerce has grown exponentially, reflecting the widespread adoption of social commerce tactics and methods (Wang et al., 2022). E-commerce, the modern art of buying and selling goods or services using the internet, enables companies to expand their market beyond their geographical boundaries (Fonseka et al., 2021). The main objective of this study is to investigate how the adaptation of e-commerce platforms influences online purchase intention, with brand trust as a mediating factor, specifically in the electrical building material industry in the Western Province of Sri Lanka.

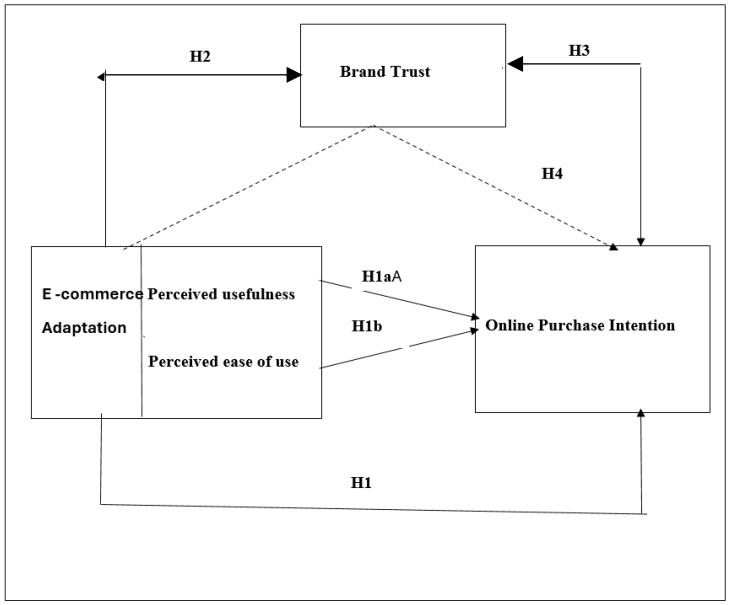
The electronic and electrical sector in Sri Lanka has emerged as a significant contributor to the country's economic growth, evolving over the past four decades into a key industrial manufacturing sector (Pathirana & Abeysekera, 2021). The main product categories in the electrical building materials sector include cable manufacture, switchgear manufacture, allied accessories, electrical appliances, panel boards, lighting and semiconductors (*Sector Overview—Electrical and Electronic Sector*, 2025). Sri Lanka's electrical and electronic materials industry is thought to be quite competitive, particularly in areas such as wire cables and electrical and electronic fittings (Munasinghe & Dissanayake, 2018). The main problem identified in this study, on the basis of past studies, is that the purchasing behaviour for cables and related accessories in Sri Lanka appears complex owing to the nature of the product and consumer behaviour, and most electrical building material items are purchased only once in a lifetime by a customer. Another serious issue is that the product falls under a complex buying situation owing to its risk factor (Munasinghe & Dissanayake, 2018). Many industries in Sri Lanka's building materials market, which are already at the end of their life cycles, do not expect to increase profits by attracting new customers (Pathirana & Abeysekera, 2021). Companies therefore need to seek new approaches to attract and retain their customer base, and one powerful method is to enhance their digital presence by implementing e-commerce platforms to reach their customers.

While there is research on industrial products in Sri Lanka, comparatively few studies have examined how e-commerce adoption is related to electrical building material products. Brand trust plays a significant role in establishing strong brand relationships

with consumers, especially in the electrical cable manufacturing business, where it results in purchase intention and positive referrals for cable brands (Munasinghe & Dissanayake, 2018). Accordingly, this research adopted the technology acceptance model (TAM) and the theory of reasoned action to understand the behaviour of online consumers. Under the TAM, two main dimensions are identified for measuring e-commerce adoption, namely perceived usefulness and perceived ease of use (Harsanto et al., 2015); the resulting conceptual framework is shown in Figure 1. Previous studies have investigated the effects of e-commerce platform adaptation on online purchase intention and brand trust in different industries and product categories, such as the automobile industry, fast-moving consumer goods (FMCG), the skin care industry and the health care sector (Tuan et al., 2022). However, there is a lack of empirical research examining the impact of e-commerce on online purchase intention, with the mediating effect of brand trust, among users of e-commerce platforms in the electrical building material industry in the Western Province of Sri Lanka, which constitutes the research gap addressed in this study.

Figure 1

Conceptual Framework



Methodology

This study adopted a positivist philosophy, which focuses on empirical evidence, scientific methods and the objective observation of phenomena in understanding the social world. The study primarily adopted a deductive approach, as a straightforward research question was derived from existing theories. The study used an explanatory, quantitative research design with a survey strategy and a cross-sectional time horizon, which allowed information to be captured from a comprehensive set of respondents at a specific point in time. The population of the study comprised consumers using e-

commerce platforms to purchase electrical building materials in the Western Province of Sri Lanka. The sample was selected using non-probability convenience sampling, which helped to save both time and cost, an important consideration given the limited resources. The sample size was determined to be 383 participants. Primary data were gathered directly from individuals through an online closed-ended questionnaire, and secondary data were drawn from sources such as journal articles, reports and books. Both descriptive and inferential statistics were used to report and interpret the findings, and the data were analysed using the Statistical Package for the Social Sciences (SPSS).

Results and Discussion

The demographic details show that the majority of respondents were male (82.8%), with females comprising 17.2% of the sample. Most respondents belonged to the 18–25 age category (45.6%) and the 26–35 category (44.8%), whereas only 9.6% were between 36 and 55 years of age. With regard to the employment sector, respondents were mainly employed in the public sector (47.9%) and the private sector (38.39%). Most respondents had a monthly income of Rs. 50,001–100,000 (72.1%), followed by Rs. 100,001–150,000 (8.3%).

Cronbach's alpha was employed to measure the internal consistency of the constructs, and all variables exceeded the accepted threshold value of 0.70, confirming reliability; for instance, perceived ease of use recorded an alpha value of 0.800, purchase intention 0.865 and brand trust 0.843. The regression model summary indicated a satisfactory model fit, with an R^2 value of 0.676, explaining 67.6% of the variance in purchase intention. The coefficient analysis identified perceived ease of use (B = 0.603) as the most influential factor affecting purchase intention. Moreover, both perceived usefulness (p = .014) and perceived ease of use (p < .001) significantly influenced purchase intention. Correlation analysis further revealed positive and significant relationships between each pair of variables at the 0.01 significance level.

The mediating variable, brand trust, showed a partial mediation effect, with a direct effect of 0.225 (22%), an indirect effect of 0.379 (37%) and a total effect of 0.603 (60%). As perceived ease of use is the most influential dimension of purchase intention, e-commerce platforms need to focus more on platform design, user-friendliness, platform layout and overall user convenience. These strategies will support the conversion of users into actual purchasers.

Conclusions and Implications

This study examined the impact of e-commerce platform adoption on online purchase intention, with the mediating role of brand trust, in the electrical building material sector in the Western Province of Sri Lanka. The findings indicate that e-commerce adoption positively shapes online purchase intention for electrical building materials, with perceived ease of use and perceived usefulness as key drivers and brand trust functioning as a critical mediator that amplifies purchase intention towards electrical building materials. Among these dimensions, perceived ease of use emerged as the most influential factor affecting purchase intention, indicating that consumers are more likely to engage

in online purchasing when e-commerce platforms are simple, convenient and user-friendly. These findings are strongly supported by the TAM, according to which users are more willing to adopt online technologies when they perceive them as useful and easy to use (German Ruiz-Herrera et al., 2023).

In practical terms, companies operating in the electrical building material sector and platform designers who wish to adopt e-commerce platforms should prioritise user-friendly interfaces and layouts, fast loading speeds, simple navigation systems, clear product categorisation and transparent product information to enhance customer trust and provide a personalised user experience. These strategies will help businesses to improve customer purchase intention and brand visibility, increase competitiveness and achieve sustainable growth in the Sri Lankan electrical building material industry.

***Keywords*:** Brand trust, e-commerce adoption, electrical building material sector, online purchase intention, technology acceptance model

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Digital Communities in Shaping Female Beauty Standards: A Netnography Study

Hendeniya H.M.U.S.* and Ranjith H.K.M.P.
Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: maduwanthapasidu03@gmail.com)

Introduction

The negotiation of beauty standards in Sri Lanka's digital environment reveals an intricate interplay of colonial legacies, current socio-economic disparities, and the structural dynamics of social media algorithms. Facebook, which accounts for more than 61% of the country's social media engagement and was the leading platform with over 8 million users in early 2025, has emerged as the key space in which women encounter diverse beauty ideals, ranging from those promoted by multinational corporations to local rituals grounded in indigenous Ayurvedic traditions (Kumara & Jayawardhana, 2018). Although platforms such as TikTok and Instagram also shape beauty trends, especially among younger users influenced by influencer marketing campaigns, Facebook dominates as a crucial platform for reaching these target audiences (Singh et al., 2024). Facebook remains the dominant social media platform in Sri Lanka, with 83% of internet users actively engaging on the platform (Digital Outlook Sri Lanka, 2025). Historically, Sri Lanka's colonial experience under Portuguese, Dutch, and British rule entrenched a strict colour hierarchy that favoured light skin and Western attributes as symbols of modernity and social standing. The main objective of the study is to explore the influence of social media communities on the achievement of idealised beauty standards among women.

This study addresses three key gaps in the existing literature: the limited incorporation of postcolonial South Asian viewpoints in research on digital beauty, the algorithmic silencing of voices in the social media environment, and the scarcity of empirical investigation into how Sri Lankan women engage with beauty standards. Prevailing studies on digital beauty discourse have predominantly focused on Western or East Asian regions (Fardouly & Vartanian, 2016). Given the rapid expansion of Sri Lanka's beauty industry and the growing integration of digital technologies into everyday life, a significant empirical gap therefore remains regarding how Sri Lankan women reinterpret beauty standards within online spaces. Prior studies have focused more on cosmetic consumption patterns, awareness of product safety, and the socio-economic determinants of cosmetic use, particularly among specific populations such as university students (Udayanga et al., 2023). The central research problem is that, despite the rapid expansion of digital beauty communities in Sri Lanka, there remains limited understanding of how women negotiate, reproduce, and challenge beauty standards within these online spaces. Existing studies have primarily emphasised cosmetic consumption, product safety concerns, consumer demographics, and consumer behaviour, while paying insufficient attention to the sociocultural processes through which beauty ideals are constructed and contested in digital environments. Consequently, the influence of postcolonial identities, algorithmic platform dynamics, and peer interactions in shaping contemporary beauty discourse remains inadequately investigated in Asian contexts. Prior studies conducted in

other postcolonial contexts, such as Nigeria, have explored how Eurocentric beauty ideals are internalised and perpetuated in digital spaces (Yens et al., 2025). However, such analyses have not been adequately undertaken in the Sri Lankan context, where colonial legacies intersect with contemporary processes of digital modernisation. This study contributes theoretically by extending digital beauty discourse beyond Western and European settings through a postcolonial South Asian lens. By examining how Sri Lankan women negotiate beauty ideals within Facebook communities, the study advances knowledge of the intersection of digital participation, algorithmic visibility, and identity construction, showing how colonial aesthetic legacies are reinterpreted through contemporary online practices.

Existing studies offer contrasting perspectives on the influence of digital communities in shaping beauty standards. Some scholars argue that digital platforms intensify unrealistic beauty expectations through visual comparison, influencer culture, and algorithmic amplification (Fardouly et al., 2015). In contrast, recent research suggests that online communities can facilitate resistance, body positivity, and alternative forms of identity construction. This inconsistency highlights an unresolved scholarly debate concerning whether digital communities primarily reinforce dominant beauty ideologies or create spaces for empowerment and counter-discourse. Such contradictions are particularly significant in postcolonial societies, where globalised beauty narratives intersect with local cultural values. The present study therefore contributes to addressing this theoretical ambiguity within the Sri Lankan context. Past literature shows that communities of practice, black feminist thought, and postcolonial theories have been applied within Western or European contexts; applying them in a South Asian context therefore provides novelty to this study and conceptualises hybrid beauty practices as a form of cultural negotiation.

Methodology

This study is grounded in an interpretivist research paradigm, which is particularly appropriate for research that seeks to explore how people make sense of their experiences, interact with others, and negotiate identities in dynamic environments such as online communities. A qualitative approach is adopted to capture the depth and complexity of these social phenomena. This approach allows for the collection and interpretation of rich, detailed data, facilitating an in-depth understanding of the cultural negotiations and identity work that occur within Facebook beauty groups (Denzin & Lincoln, 2018). Netnography serves as the primary methodological approach for this research. The study adopts an exploratory qualitative research design, which is particularly appropriate for examining complex and under-researched social phenomena such as the negotiation of beauty standards within Sri Lankan Facebook beauty groups. The target population comprises Sri Lankan women who participate in online beauty-related discussions within Facebook communities.

Approximately 50 to 100 posts were analysed in each of the four groups: රෑ රහස් ලස්සනට ඉමු (Glass Skin & Beauty Tips); රූපලාවන්‍ය ගැටලු, නිශ්පාදන සහ උපදෙස්; ලස්සන රහස්

With Tashani; and ලස්සනට ඉඹු With Hashee (රූ රහස් Beauty tips). These groups were deliberately chosen because of their large active membership, strong user engagement, relevant content, and open access for ethical observation. Data were extracted using APIFY, a web-scraping tool for gathering social media data. The study adopted a manual approach to qualitative data analysis, using Microsoft Excel as the primary tool for organising, coding, and thematically analysing the data. A purposive sampling strategy was employed to select four highly active Facebook beauty groups based on their relevance, membership size, and engagement levels. Purposive sampling was used because these four digital beauty spaces have the characteristics that the researcher needed to investigate. The collected data were manually coded, and six main themes were generated, namely Product Validation and Peer Trust, Hybrid Beauty Practices, Fairness and Glow Ideals, Resistance and Caution, Community Care and Emotional Support, and Platform Engagement.

Results and Discussion

The discussion synthesises six refined themes: Product Validation and Peer Trust, Hybrid Beauty Practices, Fairness and Glow Ideals, Resistance and Caution, Community Care and Emotional Support, and Platform Engagement Tactics. Product Validation and Peer Trust dominates, with members privileging user testimonials over commercial advice; for example, one member wrote, “Those, who use this, tell me the results; does it glow?” The Hybrid Beauty Practices theme captures the dynamic blending of globalised examples, such as K-beauty and branded serums, with local traditional examples, such as Ayurvedic and indigenous herbal remedies and beauty routines. Fairness and glow ideals persist, driven by colonial legacies and algorithmic reinforcement, with frequent requests for “colour up”, “pahapat wenna”, and “glow wenna” products. Sri Lankan studies confirm that 78% of women face societal pressure towards skin lightening (Jayasinghe & Manike, 2024; Perera et al., 2021). Resistance and caution also emerge: despite the dominance of Eurocentric standards, the analysis highlights important instances of resistance and reflexivity among group members, including warnings against bleaching (“Bleaching gaanna epa”) and endorsements of natural tones and safe remedies. Community care and emotional support create affective spaces within the groups, filled with empathy-laden threads such as “Help please, thank you so much.” Finally, the empirical evidence on Platform Engagement and Algorithmic Participation suggests conscious engagement with platform mechanics: members use strategies such as “Up” and “hearts” to maximise visibility, encourage participation, and navigate algorithmic curation. Overall, these themes highlight collective epistemologies reshaping beauty discourses in digital Sri Lanka.

Collectively, these findings demonstrate how digital beauty communities function as spaces in which beauty ideals are simultaneously constructed, reinforced, and negotiated. Interpreted through postcolonial theory, the persistence of fairness and glow ideals reflects the continuing influence of colonial beauty hierarchies, while black feminist thought highlights women’s agency in resisting dominant beauty norms through

alternative narratives and community support. Furthermore, communities of practice theory explains how peer interactions facilitate the co-creation and exchange of experiential knowledge within Facebook groups. These findings further demonstrate that, within the Sri Lankan postcolonial context, digital communities serve not only as platforms for beauty consumption but also as spaces for identity negotiation and collective knowledge construction.

Conclusions and Implications

The study primarily aimed to investigate how Sri Lankan women negotiate, construct, and challenge female beauty ideals within the dynamic and interactive context of Facebook beauty groups. Whereas previous studies of digital beauty cultures have predominantly centred on Western or East Asian contexts, this work addresses a critical empirical and theoretical gap concerning the lived digital experiences of women in a postcolonial South Asian context. The study was grounded in a qualitative, interpretivist paradigm, using netnography as its core methodology. The thematic analysis yielded six interconnected themes that collectively encapsulate the central dynamics of these online communities: Product Validation and Peer Trust, Hybrid Beauty Practices, Fairness and Glow Ideals, Resistance and Caution, Community Care and Emotional Support, and Platform Engagement Tactics. For example, the Product Validation and Peer Trust theme revealed that the communities function as powerful ecosystems of informal peer review, in which members systematically privilege experiential knowledge over formal commercial claims. Furthermore, the findings demonstrate that, while colonial legacies and global media trends continue to reinforce beauty standards and trends, participants actively adapt and hybridise local and international practices, rely heavily on peer-generated knowledge, and strategically engage with Facebook's algorithmic systems to amplify their voices.

Based on these empirical findings, which illuminate the complex dynamics of Sri Lanka's digital beauty communities, recommendations are proposed for managers, marketers, and brand strategists in the beauty, personal care, and digital marketing sectors. These recommendations are designed to be actionable, ethical, and strategically aligned with the observed behaviours and values of contemporary Sri Lankan consumers. For example, the study demonstrates that, within these digital communities of practice, peer validation is a more powerful and trusted form of knowledge than traditional brand advertising. To leverage this dynamic ethically, companies must fundamentally shift their approach from direct promotional messaging to fostering authentic community dialogue.

Keywords**:** Beauty standards, digital beauty communities, netnography, social media, Sri Lankan women

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Work-Life Balance and Employee Performance in Trincomalee Budget Hotels

Namasivayam V.* and Dassanayake D.M.C.
Department of Tourism and Hospitality Management, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: vithushan153@yahoo.com)

Introduction

Hospitality is labour-intensive, and its lower-level employees work extended shifts with heavy workloads and little scheduling discretion, conditions that compromise work-life balance (WLB) and are linked to reduced well-being, burnout, and withdrawal (Deery & Jago, 2015; Prentice et al., 2025; Saito et al., 2025).

Sri Lankan hotel evidence is confined to one segment: De Seram and Gnanapala (2016) surveyed 187 executive-grade employees across the John Keells (Cinnamon) chain and reported all three dimensions used here (job content, personal factors, and family factors) as positively related to performance, but without reporting coefficients or diagnostics. The opposite end of the market remains unexamined: small, independently owned budget properties staffed by lower-level employees on short tenure and low pay, where WLB pressure is most acute and formal human resource practice is thinnest. Trincomalee, in the post-conflict Eastern Province, is served predominantly by such properties. Outside hotels, Mendis and Weerakkody (2014) found a moderate WLB–performance correlation in telecommunications ($r = .543$, $n = 100$).

A second gap is methodological: the triad has been carried forward without psychometric validation, so its discriminant validity relative to self-rated performance is untested. This study tests it against the reported reliabilities.

Objective (i) is descriptive: to assess the level of WLB and employee performance in this population. The explanatory objectives are to examine the relationship with employee performance of (ii) job content, (iii) personal factors, and (iv) family factors, and (v) to determine their relative contribution. Hypotheses attach to objectives (ii) to (iv): H1 to H3 state that each dimension has a significant positive relationship with employee performance.

Methodology

The design was a quantitative cross-sectional survey, with job content (JC), personal factors (PF), and family factors (FF) as independent variables and employee performance (EP) as the dependent variable. Work-family border theory (Clark, 2000) treats work and family as domains separated by borders that vary in permeability and flexibility, with balance arising when individuals regulate the crossing of these borders. Job content maps onto the flexibility of the work-side border through scheduling, targets, and organisational support; family factors map onto its permeability; and personal factors map onto the orientation of the border-crosser. The three-dimensional structure is the one used in the Sri Lankan literature (De Seram & Gnanapala, 2016; Mendis & Weerakkody, 2014); items

were adapted from Guest (2002), White et al. (2003), Deery and Jago (2015), and MacInnes (2006). No validated WLB scale was adopted, a limitation addressed below.

A listings search on 1 August 2024 identified more than 50 budget properties in Trincomalee, of which the 20 highest-ranked on Holidify were selected purposively. Their 442 lower-level employees formed the study population. Slovin's formula at $e = .05$ gave a sample of 210, allocated proportionately across properties and drawn at random within each. Five-point Likert scales comprised six JC, eight PF, six FF, and nine EP items. Content validity rests on the adapted items; no pilot study or expert panel review was conducted, and construct validity was not established at the design stage. Questionnaires were researcher-administered on hotel premises during shifts, with management permission and immediate collection, which accounts for the high return: 207 of the 210 questionnaires were complete (98.57%) and formed the basis for all analysis. The analysis, conducted in SPSS (Version 21), used reliability estimation, descriptive statistics, Pearson correlation, and multiple regression.

Results and Discussion

All four constructs showed high means with narrow dispersion: JC ($M = 4.44$, $SD = 0.35$), PF ($M = 4.42$, $SD = 0.36$), FF ($M = 4.38$, $SD = 0.33$), and EP ($M = 4.43$, $SD = 0.31$). Skewness was modest (0.208 to 0.443), kurtosis was negative throughout (−1.002 to −1.310), and no respondent scored below 3.75 on any construct, so univariate normality is acceptable, although the distributions are flat and bounded above. Reliabilities were adequate: α = .791 (JC), .868 (PF), .766 (FF), and .786 (EP). Table 1 reports the intercorrelations and Table 2 the regression results.

Table 1

Intercorrelations Among Study Variables

Variable	1	2	3	4
1. Job content	—			
2. Personal factors	.843***	—		
3. Family factors	.166*	.211**	—	
4. Employee performance	.920***	.912***	.233***	—

Note. $N = 207$. Significance was reported one-tailed in the original analysis; asterisks here reflect two-tailed p-values. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 2

Multiple Regression of Employee Performance on Work-Life Balance Dimensions

Predictor	*B*	*SE*	β	*t*	*p*	95% CI [*LL*, *UL*]	VIF
(Constant)	0.483	0.109	—	4.443	< .001	[0.268, 0.698]	—
Job content	0.458	0.034	.524	13.535	< .001	[0.391, 0.525]	3.46
Personal factors	0.387	0.033	.459	11.757	< .001	[0.322, 0.452]	3.52
Family factors	0.045	0.020	.048	2.273	.024	[0.006, 0.084]	1.05

Note. $N = 207$. $R^2 = .912$, adjusted $R^2 = .911$; $F(3, 203) = 702.378$, $p < .001$. CI = confidence interval; *LL* = lower limit; *UL* = upper limit; VIF = variance inflation factor. The 95% confidence intervals were reconstructed from the reported regression coefficients and standard errors; VIF values were reconstructed from the reported predictor intercorrelations. These statistics were not available in the original SPSS output.

The model explained 91.2% of the variance. Job content was the strongest predictor (β = .524), followed by personal factors (β = .459), with family factors small although significant (β = .048, p = .024). All three hypotheses were supported in the hypothesised direction, consistent with De Seram and Gnanapala (2016) in the star-class segment; for reasons set out below, the coefficients should be read as an ordering, not as magnitudes. In border-theory terms, the work-side border appears more consequential for perceived performance than the family-side border.

An R^2 of this size requires explanation rather than endorsement. Multicollinearity is not the cause: the variance inflation factors (VIFs) in Table 2 are within accepted limits. Three other explanations apply. The first is construct overlap: the JC and PF scales contain items on pay adequacy, career fit, perceived respect, and task self-efficacy that share content with self-rated performance, whereas the FF scale, whose coefficient is the small one, measures only the work-family interface. The second is response compression: Mendis and Weerakkody (2014) reported standard deviations of 0.603 and 0.598 on comparable constructs, against 0.31 to 0.36 here. The third is common method variance: all constructs were self-reported by one source on one occasion in a single format, conditions under which bias is likely and hard to correct (Podsakoff et al., 2024). Disattenuating the JC–EP and PF–EP correlations by the reported reliabilities returns values above unity (1.17 and 1.10). Because Cronbach's α is a lower-bound estimate of reliability, this overcorrects; it does not establish that the composites are in error, but it does indicate inflation beyond what the measurement supports. Without the original data, neither common method variance nor construct overlap could be tested directly. The R^2 of .912 is therefore an upper bound.

Conclusions and Implications

Work-life balance is positively associated with employee performance in Trincomalee's budget hotels, and job content is the dominant dimension. The substantive contribution is this ordering in a segment and employment grade that Sri Lankan hotel research has not covered; the methodological contribution is the finding that two of the three dimensions do not separate empirically from self-rated performance.

Practical implications rest on the ordering, not on the coefficient sizes, which the measurement does not support. Job content ranks first; its items concern scheduling flexibility, achievable targets, and organisational support, so shift design, roster predictability, and target setting should take precedence. Personal factors rank second, pointing to person–job fit and career development. Pay adequacy sits within these scales, so remuneration is not outside the evidence, although the measurement problem prevents it from being ranked. Family factors rank a distant third, giving little basis for prioritising family support ahead of scheduling and job-content measures.

Five limitations apply. First, the cross-sectional design cannot establish causal direction. Second, the 20 properties were selected purposively, so the sample is random only within a non-probability set of hotels, limiting generalisation beyond comparable Trincomalee

properties. Third, performance was self-rated; supervisor ratings would provide an independent criterion. Fourth, linearity, homoscedasticity, and independence of residuals were not tested in the original analysis. Fifth, and most consequentially, construct validity remains a limitation rather than a resolved question: because the original dataset is no longer accessible, confirmatory factor analysis and item-level discriminant validity testing could not be conducted retrospectively, and the one check available from the reported summary statistics, reliability disattenuation, failed. The JC and PF scales therefore require reconstruction and validation before the magnitudes reported here can be relied upon; replication with separated sources and a validated instrument is the next step.

***Keywords*:** Budget hotels, employee performance, Sri Lanka, Trincomalee, work-life balance

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Impact of User-Generated Content on Brand Evangelism: The Mediating Role of User Emotion

Deshika K.L.I.* and Adhikari A.M.S.I.
Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: deshikaindu@gmail.com)

Introduction

The fitness industry has undergone a significant transformation with the rapid growth of social media, which provides consumers with new opportunities to interact with brands beyond traditional marketing. TikTok has become an influential platform for creating, sharing and consuming fitness-related content, including workout routines, transformation stories, product recommendations and health tips (Coherent Market Insights, n.d.; Grand View Research, n.d.). User-generated content (UGC) provides experience-based information that can influence consumer perceptions and brand-related behaviours (Ho et al., 2026). Sri Lankan TikTok users are increasingly exposed to content that influences their preferences, emotions and behavioural patterns (DataReportal, n.d.). The Western Province was selected because Colombo, Gampaha and Kalutara contain a substantial concentration of fitness establishments, providing a relevant setting for examining digital fitness consumer behaviour (Xmap AI, n.d.). However, limited research has examined the relationship between fitness-related UGC and brand evangelism among Sri Lankan TikTok users. Further, although previous studies suggest that user emotion may connect UGC with behavioural outcomes, its mediating role remains insufficiently established. Therefore, this study examines the impact of UGC on brand evangelism and the mediating role of user emotion among TikTok users engaging with fitness-related content in the Western Province of Sri Lanka.

Methodology

The study adopted a positivist philosophy and a deductive approach, using a quantitative, cross-sectional survey design. Emotional contagion theory (ECT) served as the main theoretical foundation, explaining how individuals may experience and share emotions by observing others' facial expressions, tone and behaviour (Herrando & Constantinides, 2021). Parasocial interaction theory (PSI) supported ECT by explaining users' perceived connections with content creators (Hedrick Mckenzie & Kresovich, 2022). At the same time, the stimulus–organism–response (S-O-R) model provided a broader framework linking UGC as a stimulus to users' emotional responses and subsequent brand-related behaviours (Ibrahim et al., 2025). The target population comprised individuals who engage with fitness-related content on TikTok within the Western Province of Sri Lanka. A structured questionnaire was distributed through social media platforms and fitness-related online communities. A total of 427 questionnaires were distributed, of which 384 were valid and used for analysis. Non-probability snowball sampling was employed because there was no clearly defined sampling frame for TikTok users engaging with fitness-related content in the selected geographical context. The initially identified

eligible participants were asked to refer other suitable respondents within their networks, thereby enabling access to a dispersed and difficult-to-identify digital population.

UGC was measured using three dimensions: credibility, risk reduction and usefulness (Sang et al., 2024). Brand evangelism was assessed using brand purchase intentions and positive and oppositional brand referrals (Becerra & Badrinarayanan, 2013), while user emotion was measured by positive emotional responses to fitness-related content. All constructs were measured on a five-point Likert scale using validated items adapted from the established literature.

Results and Discussion

The findings demonstrated a strong positive relationship between UGC and brand evangelism ($r = .819$, $p < .01$), and regression analysis confirmed that UGC significantly predicted brand evangelism ($\beta = .819$, $p < .001$). The dimensions of UGC, namely credibility, risk reduction and usefulness, were also significantly associated with brand evangelism. Multiple regression analysis showed that these dimensions collectively explained 68.1% of the variance in brand evangelism. Among them, credibility emerged as the strongest predictor ($\beta = .407$, $p < .001$), followed by usefulness ($\beta = .281$, $p < .001$) and risk reduction ($\beta = .204$, $p < .001$), demonstrating the importance of trustworthy, informative and risk-reducing content in encouraging brand-related behaviours.

UGC also significantly influenced user emotion ($\beta = .729$, $p < .001$), and user emotion significantly influenced brand evangelism ($\beta = .633$, $p < .001$). These findings support the proposed direct relationships and indicate that fitness-related UGC can generate positive emotional responses and strengthen brand-supportive behaviours.

However, the mediation analysis produced an important theoretical finding. Although UGC significantly influenced user emotion and user emotion significantly influenced brand evangelism, the indirect effect was not statistically significant. Therefore, the proposed mediating role of user emotion was not supported. This finding challenges the expected emotional pathway suggested by the S-O-R framework and indicates that UGC may influence brand evangelism primarily through direct mechanisms rather than through user emotion. The study thus suggests that alternative psychological or behavioural mechanisms may better explain the relationship between UGC and brand evangelism within the Sri Lankan TikTok fitness context.

Conclusions and Implications

The study concludes that UGC plays a significant role in shaping brand evangelism among TikTok users in the Sri Lankan fitness industry. Credibility emerged as the strongest predictor, followed by usefulness and risk reduction, highlighting the importance of authentic, trustworthy and informative user-generated experiences in encouraging consumers to purchase, recommend and support fitness brands. Therefore, fitness brands and gym operators should actively encourage customers to create and share authentic workout experiences, transformation stories, product reviews and testimonials.

They should also provide useful and accurate information that reduces consumer uncertainty and strengthens confidence in fitness-related products and services.

Theoretically, the study extends ECT, PSI and the S-O-R model to TikTok-based fitness marketing. Although UGC influenced user emotion and brand evangelism, user emotion did not significantly mediate this relationship. This challenges the expected emotional pathway and suggests that the role of emotion may vary across contexts. Future research should examine alternative mechanisms such as trust, brand attachment, engagement and brand identification.

From a sustainability perspective, the findings also provide an opportunity to consider digitally supported fitness services. Since respondents demonstrated engagement with home-based fitness activities, fitness providers may consider hybrid models combining online and offline services. Such models could improve access to fitness participation and potentially support resource-efficient engagement by reducing unnecessary travel while maintaining social interaction and community participation.

***Keywords*:** Brand evangelism, fitness industry, TikTok, user emotion, user-generated content

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French Tourists' Pre-Visit and Post-Visit Perceptions of Sri Lanka as a Tourist Destination

Premarathna P.G.C.R.* and Adhikari A.M.S.I.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: chamodpremarathna1101@gmail.com)

Introduction

Sri Lanka offers cultural heritage sites, wildlife, scenic landscapes, and beaches, and it has attracted growing international interest since the end of its civil conflict in 2009, with arrivals rising to 2.3 million by 2018. The Easter Sunday attacks in 2019 and the COVID-19 pandemic disrupted this growth, making targeted market strategies more important than ever. France is a major outbound tourism market, and French tourists are known for their interest in culture, authenticity, and meaningful travel experiences, preferences that match well with what Sri Lanka offers. Yet France remains an underserved source market. Despite this potential, little research has examined how French tourists specifically perceive Sri Lanka. Most studies treat international tourists as one broad group, ignoring how cultural background shapes destination evaluation. Without nationality-specific evidence, tourism authorities rely on assumptions rather than on actual visitor perceptions. This study explores French tourists' pre-visit perceptions, cultural meanings, travel experiences, and recommendations regarding Sri Lanka, applying Consumer Culture Theory (Arnould & Thompson, 2005) and Hofstede's Onion Model of Culture (Hofstede, 2001) as theoretical frameworks.

Methodology

This study used a qualitative, interpretivist approach with inductive reasoning, as tourist perceptions are subjective and culturally shaped, making numerical measurement insufficient (Saunders et al., 2019). Sri Lanka was treated as a bounded case within an exploratory, cross-sectional design (Yin, 2018). Twelve semi-structured interviews were conducted in French, preserving emotional nuance and accuracy that translation would distort (Leclerc & Martin, 2004). Participants were selected through purposive sampling at Sigiriya, Kandy, Galle Fort, and Ella; the inclusion criteria were French citizenship and a minimum stay of five days. Theoretical saturation was reached at twelve interviews (Strauss & Corbin, 1998). Each interview lasted 30 to 45 minutes and was audio-recorded, transcribed verbatim in French, and translated into English. Data were analysed using Braun and Clarke's (2019) reflexive thematic analysis, supported by NVivo.

Results and Discussion

Three main themes were identified from the data: pre-visit perceptions of Sri Lanka; cultural meanings and travel experiences; and recommendations for tourism marketing and service improvements. French tourists arrived with strong pre-visit images built around spirituality, peace, nature, and authenticity. Many described Sri Lanka first through its Buddhist identity, associating it with a spiritual depth absent from everyday life in France. One participant stated that what drew her was "the spirituality, not beaches or hotels." Safety perceptions were positive and shaped largely by personal conversations

with friends and family. These organic information channels (Gunn, 1972) created confident pre-departure attitudes. Nature consistently exceeded expectations, with participants describing the vegetation and wildlife as far more striking than any image they had seen before arriving. Authenticity was a deliberate choice: most participants selected Sri Lanka because they perceived it as less commercialised than Bali or Thailand, and this expectation was confirmed during the trip. These findings align with the CCT concept of consumer identity projects (Arnould & Thompson, 2005), whereby choosing a culturally rich destination expresses the traveller's self-image as curious and independent-minded.

The second theme shows that word of mouth was the most powerful information channel. Personal recommendations from family and friends carried more weight than social media or advertising, and several participants described how a single trusted conversation had redirected their travel plans entirely. This reflects the CCT concept of marketplace cultures (Arnould & Thompson, 2005), whereby shared stories within social networks create collective destination images without commercial mediation. During travel, participants sought genuine cultural connection. Shared meals, visits to local markets, and informal encounters with Sri Lankan families were consistently described as the highlights of their trips. Some felt that rigidly organised tour structures had limited the depth of local contact they had hoped for. Relaxation and personal renewal were also valued outcomes, with participants noting that the pace of life and the warmth of Sri Lankan people produced a calm that contrasted with everyday life in France. Most travelled in small organised groups of 8 to 12 people, which provided language support and comfort while still allowing cultural engagement. This preference reflects Hofstede's (2001) uncertainty avoidance dimension, whereby structured travel reduces the emotional cost of navigating an unfamiliar environment.

The third theme presents participants' recommendations for improving Sri Lanka's tourism offer. They favoured natural and authentic marketing images over polished campaigns, arguing that showing real people, local markets, and everyday life would attract French visitors more effectively than luxury resort imagery. French-language accessibility at heritage sites was a recurring concern, and participants suggested low-cost QR codes linking to French-language explanations. Small group formats of no more than 12 to 15 people were described as essential for quality cultural engagement. Verified homestay networks and community cooking programmes were strongly recommended, as these had provided the most memorable experiences of their trips. These recommendations are consistent with the findings of Leclerc and Martin (2004), Endi and Prasetyo (2020), and Prabawa et al. (2023).

Conclusions and Implications

French tourists arrive in Sri Lanka with a positive image built through personal conversations rather than advertising. Friends, family members, and past travellers are more influential than any campaign. Once they arrive, they look for genuine human contact, shared meals, and unmediated encounters with local life. Wang's (1999) concept

of existential authenticity captures this well: what matters to them is the feeling of real connection, not the historical credentials of a site. Sri Lanka's natural environment and cultural depth align closely with these expectations, and most participants left more satisfied than they had been on arrival. The gap lies not in what the destination offers but in how inconsistently that offer reaches French travellers through French channels, in their language, and through formats they trust.

CCT (Arnould & Thompson, 2005) proved a productive frame for interpreting French tourist behaviour in Sri Lanka, while Hofstede's (2001) cultural dimensions, particularly high uncertainty avoidance and individualism, explained patterns that a satisfaction survey alone would have missed. Conducting the interviews in French was methodologically consequential: participants spoke with a precision and emotional honesty that a translated approach would have flattened. For tourism authorities, three implications follow from the findings. First, French-language materials at heritage sites, even low-cost QR codes, would reduce the information gap that repeatedly frustrated participants. Second, small group formats of no more than 12 to 15 people should be actively promoted as the default product for this market rather than treated as a niche option. Third, verified homestay networks and community cooking programmes should be developed and marketed directly to French travellers, since these were consistently described as the most memorable parts of the trip. The word-of-mouth network that currently drives French arrivals is built entirely on in-destination experience, so every service improvement feeds directly back into it. Future research could extend this work by comparing French tourists' perceptions across multiple South Asian destinations to test which findings are specific to Sri Lanka and which reflect broader patterns in how French travellers engage with the region.

Keywords**:** Authenticity, Consumer Culture Theory, destination image, French tourists, Sri Lanka

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Factors Affecting Taxpayers' Satisfaction in Sri Lanka

Prathiraja P.A.N.S.* and Sameera V.G.N.
Department of Accountancy and Finance, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: mnsandeepani@gmail.com)

Introduction

The taxation system is a fundamental mechanism for generating government revenue and supporting national development. In Sri Lanka, income tax has gained increasing importance following the implementation of the Inland Revenue (Amendment) Act No. 45 of 2022, which expanded the tax base and increased tax rates. Although these reforms were introduced to strengthen fiscal stability, they have raised public concerns regarding the fairness, transparency, complexity and effectiveness of the tax system. Such negative perceptions may reduce taxpayer satisfaction, weaken voluntary compliance and ultimately affect government revenue collection.

Taxpayer satisfaction is an important element of effective tax administration, as satisfied taxpayers are more likely to comply voluntarily with their tax obligations. However, previous studies have mainly focused on tax compliance behaviour, while limited attention has been given to the determinants of taxpayer satisfaction in Sri Lanka following the recent tax reforms. The existing literature identifies fairness and transparency, simplicity of the tax system, quality of e-tax services and income tax rates as important factors influencing taxpayer perceptions; however, the empirical findings remain inconsistent.

According to the Theory of Planned Behaviour and Tax Morale Theory, taxpayers' perceptions of tax administration influence their attitudes and behavioural intentions (Ajzen, 1991; Luttmer & Singhal, 2014). Fair and transparent tax systems enhance trust, while simple procedures and effective electronic services can reduce compliance difficulties. However, the effects of tax system simplicity, e-tax service quality and income tax rates on taxpayer satisfaction remain inconclusive. Tax awareness and knowledge may strengthen taxpayers' understanding and perceptions of taxation. These inconsistencies highlight an empirical research gap, particularly within the Sri Lankan context after the recent tax policy reforms (Bandara & Weerasooriya, 2019; Jayawardane & Low, 2017).

Therefore, this study examines the factors affecting taxpayer satisfaction in Sri Lanka, focusing on fairness and transparency, simplicity, e-tax system quality and income tax rates. The findings are expected to contribute to the literature and provide useful insights for improving tax administration.

Methodology

This study adopted a quantitative, deductive research approach and an explanatory research design to examine the factors influencing taxpayer satisfaction in Sri Lanka. Data were collected through a structured questionnaire developed from a validated measurement scale, with responses measured on a five-point Likert scale.

The target population consisted of individual income taxpayers registered with the Inland Revenue Department of Sri Lanka. According to the Inland Revenue Department (2022), the relevant taxpayer population was 204,467, which gave a required sample size of 384 respondents. Owing to practical limitations, however, 177 valid responses were obtained. A convenience sampling technique was employed to collect data from taxpayers with experience of the Sri Lankan tax system.

Taxpayer satisfaction (TPS) was the dependent variable, while fairness and transparency (FT), simplicity of the tax system (SIM), quality of the e-tax system (QES) and income tax rates (TR) were the independent variables. Data were analysed using the Statistical Package for the Social Sciences (SPSS) through reliability analysis (Cronbach's alpha), validity assessment (Kaiser–Meyer–Olkin [KMO] values), descriptive statistics, correlation analysis and multiple regression analysis. The reliability results confirmed that all constructs achieved acceptable reliability levels, supporting the suitability of the measurement instruments for further analysis.

Results and Discussion

The study analysed data collected from 177 individual income taxpayers in Sri Lanka. Reliability and validity tests confirmed that all measurement scales were statistically acceptable, with Cronbach's alpha values exceeding the recommended threshold of .70 and KMO values above .50, indicating strong reliability and validity of the research instrument.

Descriptive analysis revealed variations in taxpayers' perceptions of the tax system. Respondents showed favourable perceptions of the quality of the e-tax system ($M = 4.09$) and the simplicity of the tax system ($M = 3.80$). However, perceptions of fairness and transparency ($M = 2.07$), income tax rates ($M = 2.44$) and overall taxpayer satisfaction ($M = 2.09$) were comparatively low, indicating concerns about the current tax system.

The correlation analysis (Table 1) showed that fairness and transparency had a strong positive relationship with taxpayer satisfaction ($r = .845$, $p < .01$), and income tax rates also demonstrated a strong positive relationship ($r = .810$, $p < .01$). However, simplicity of the tax system and quality of the e-tax system did not show significant relationships with taxpayer satisfaction, suggesting that procedural improvements alone may not sufficiently enhance satisfaction.

Table 1

Summary of Correlation and Regression Results

Variable	Correlation with TPS (r)	Regression coefficient (β)	Sig. value
Fairness and transparency	.845**	.616	.001
Simplicity	.075	−.042	.615
Quality of e-tax system	.006	−.053	.576
Income tax rates	.810**	.383	.001

Note. TPS = taxpayer satisfaction. The regression model explained 76.6% of the variance in taxpayer satisfaction ($R^2 = .766$). ** $p < .01$ (two-tailed).

The regression analysis indicated that fairness and transparency and income tax rates were significant predictors of taxpayer satisfaction. The model explained 76.6% of the variation in taxpayer satisfaction (R^2 = .766). Fairness and transparency had a significant positive effect (β = .616, p < .001), and income tax rates also showed a significant positive effect (β = .383, p < .001). Conversely, simplicity and e-tax system quality were not significant predictors.

The results of hypothesis testing therefore confirmed that fairness and transparency and income tax rates significantly influence taxpayer satisfaction, supporting H1 and H4. Conversely, the relationships of simplicity of the tax system and quality of the e-tax system with taxpayer satisfaction were not significant; therefore, H2 and H3 were not supported.

Overall, the findings demonstrate that fairness and transparency and taxpayers' perceptions of income tax rates are the key determinants of taxpayer satisfaction in Sri Lanka. Policymakers and the Inland Revenue Department should therefore focus on enhancing transparency, ensuring fair tax practices and improving tax communication to promote satisfaction and voluntary compliance.

Conclusions and Implications

This study investigated the factors influencing taxpayer satisfaction in Sri Lanka by examining the effects of fairness and transparency, simplicity of the tax system, quality of the e-tax system and income tax rates. The findings revealed that fairness and transparency and income tax rates are significant determinants of taxpayer satisfaction, whereas simplicity of the tax system and quality of the e-tax system do not significantly influence satisfaction levels.

The study contributes to the taxation literature by providing empirical evidence on taxpayer satisfaction in Sri Lanka after the recent tax reforms, highlighting the importance of taxpayers' perceptions and experiences beyond traditional tax compliance research. From a practical perspective, policymakers and the Inland Revenue Department should enhance tax transparency, ensure fair treatment of taxpayers and improve communication on tax policies. Although digital tax services improve administrative efficiency, technological advancement alone is insufficient; a balanced approach integrating technology with fairness, transparency and effective communication is essential for improving taxpayer satisfaction in Sri Lanka.

***Keywords*:** Fairness and transparency, income tax rates, quality of e-tax system, tax system simplicity, taxpayer satisfaction

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Digital Governance and Financial Accountability: A Critical Analysis of Cyber Vulnerabilities in Sri Lanka's Public Finance System

Ganegama K.* and Fernando R.
Faculty of Law, General Sir John Kotelawala Defence University, Sri Lanka
*Corresponding author (email: kaushalyaganegama2@gmail.com)

Introduction

For a long time, public administration and financial management operated largely through manual systems with limited reliance on digital technologies. Only in recent years has the government increasingly shifted towards digital governance and electronic financial management systems to enhance transparency, efficiency and accountability in public administration. Today, governments rely heavily on digital financial systems to manage public finances, automate transactions and reduce opportunities for traditional forms of corruption such as bribery and embezzlement (United Nations Department of Economic and Social Affairs [UN DESA], 2024). These technologies are intended to improve financial accountability by ensuring traceability and limiting human discretion in decision-making processes. However, despite this transition towards digital governance, several administrative processes within the public sector continue to rely on manual procedures. This coexistence has led to inconsistencies in governance practices and exposed several gaps within the evolving digital financial framework.

At the same time, the rise of digital governance has introduced new risks. Cyber vulnerabilities, including phishing, unauthorised access and the manipulation of communication systems, have opened opportunities for cyber-enabled financial fraud. Recent developments in Sri Lanka have highlighted these concerns. A major incident in 2026, in which the government's Treasury reportedly lost approximately USD 2.5 million during a foreign loan payment, exposed grave weaknesses in digital financial control. Reports indicated that the money had been diverted through compromised communication systems and unauthorised access rather than through a direct breach of the Treasury's core financial system (Tamil Guardian, 2026).

Consequently, this study examines whether digital governance in Sri Lanka has strengthened financial accountability or whether it has facilitated more sophisticated forms of cyber-enabled financial misconduct. It also evaluates the effectiveness of digital governance in promoting transparency and accountability within public financial management. The study further examines the growing vulnerabilities in digital financial systems, including the risks associated with unauthorised access, phishing and system manipulation, to determine whether existing legal and institutional safeguards are sufficient to address emerging forms of cyber-enabled financial misconduct.

Methodology

The study adopts a qualitative research approach supported by a case study methodology and documentary analysis. It examines the legal, institutional and regulatory structures governing financial accountability and cybersecurity in Sri Lanka. Particular attention is

given to public financial management systems in order to identify the challenges arising from digitalisation.

The 2026 Treasury cyber-fraud incident is examined as the principal case study. The case study focuses on identifying vulnerabilities associated with digital governance, particularly access controls, authentication and verification procedures, communication systems and institutional oversight within public financial administration.

The study further relies on secondary documentary sources, including policy documents, statistical reports, institutional publications and cybersecurity reports, as well as recent media reports (Transparency International, 2024; UN DESA, 2024). These sources provide the documentary evidence required to examine the legal, institutional and technological dimensions of the research problem.

The collected material is analysed using thematic analysis. Relevant information is organised into recurring analytical themes, including digital financial accountability, access governance, authentication, institutional oversight, cybersecurity vulnerabilities, internal controls, and legal and regulatory adequacy. The findings from the Treasury case study are subsequently compared with relevant international cybersecurity governance standards, particularly the National Institute of Standards and Technology (NIST) Cybersecurity Framework 2.0, to identify institutional and regulatory gaps and assess potential areas for improvement (Pascoe et al., 2024).

Results and Discussion

The findings of this study indicate that, despite advances in efficiency, automation and record-keeping within the Sri Lankan financial management system, digital governance has not fully achieved its objective of financial accountability. While digital systems have reduced certain traditional forms of corruption, such as bribery and embezzlement, they may also create opportunities for new, sophisticated and less visible forms of cyber-enabled financial crime.

The 2026 Treasury cyber-fraud incident demonstrates the emerging threats within the digital financial governance framework in Sri Lanka. According to reports, cybercriminals were able to exploit weaknesses in communication and verification mechanisms by taking control of email accounts and manipulating repayment instructions relating to a foreign debt transaction. Instead of directly hacking the Treasury system itself, the attackers relied on methods such as business email compromise (BEC) techniques, identity manipulation and unauthorised access to communication channels. This shows that flaws in access governance, authentication procedures and internal verification mechanisms can be just as damaging as direct system breaches (Naleer, 2026; Tamil Guardian, 2026).

The incident also highlighted institutional shortcomings in public financial administration processes in Sri Lanka. Parliamentary discussions and professional reviews after the incident exposed uncertainty about approval processes, verification duties and accountability during debt transactions. These findings indicate that the challenges of

digital governance in Sri Lanka go beyond technology and reveal deeper institutional and administrative weaknesses.

The study also identifies significant technological and regulatory limitations. Although Sri Lanka has introduced legal measures such as the Personal Data Protection Act, No. 9 of 2022, the existing cybersecurity frameworks and enforcement mechanisms remain fragmented and insufficient (Parliament of Sri Lanka, 2022; Sri Lanka Computer Emergency Readiness Team [Sri Lanka CERT], 2024). Weak audit trails, poor authentication systems, a lack of coordination among institutions and limited real-time monitoring create opportunities for cyber-enabled financial fraud within public financial systems.

Furthermore, the findings reveal that cyber-related financial crimes in Sri Lanka are not limited to external threats. For instance, the fraud case involving the National Development Bank, which reportedly involved insider misconduct and substantial financial losses, demonstrates the risks arising from weak internal governance, poor oversight and ineffective whistleblowing mechanisms (Sri Lanka Brief, 2026). Similar issues identified in other state-related financial transactions suggest that institutional culture and internal accountability are significant concerns within Sri Lanka's governance framework.

Cyber incidents also pose serious risks to financial accountability and economic stability. Financial fraud involving public institutions undermines fiscal integrity, damages investor confidence and weakens the credibility of the public debt management process. Repeated cyber incidents may further affect foreign investment and Sri Lanka's ability to maintain international financial trust during a period of economic recovery and debt restructuring (World Bank, 2023).

Comparative analysis with countries such as India demonstrates that effective digital governance requires not only technological advancement but also strong institutional coordination and a cybersecurity governance structure. International best practices emphasise the importance of alignment with frameworks such as the NIST Cybersecurity Framework 2.0. In particular, its "Govern" function centres on executive accountability, strategic risk management, institutional responsibility and continuous oversight of cybersecurity efforts. Sri Lanka's current governance framework appears to lack this level of institutional maturity and strategic coordination (Pascoe et al., 2024).

Accordingly, the findings suggest that digital governance alone cannot guarantee financial accountability. Effective governance requires robust legal frameworks, institutional coordination, strong cybersecurity measures and clear accountability structures capable of responding to evolving cyber threats. Without these safeguards, digital systems might unintentionally facilitate new and more complex forms of corruption instead of eliminating them.

Conclusions and Implications

The study concludes that, even though digital governance has greatly improved efficiency, automation and transparency within Sri Lanka's public financial management system, it has not fully achieved financial accountability. Instead, the growing dependence on digital financial systems has shifted corruption from traditional forms into more complex cyber-enabled practices that are often difficult to detect and regulate.

The 2026 Treasury cyber-fraud incident demonstrated that flaws in access controls, authentication procedures, institutional oversight and communication systems can create serious vulnerabilities in digital governance structures. The findings further indicate that the current legal and institutional safeguards in Sri Lanka are fragmented and insufficient to address new cyber threats in the public finance sector effectively (Sri Lanka CERT, 2024).

The study also emphasises that cybersecurity should be seen not solely as a technical issue but as an essential aspect of governance and financial accountability. Effective digital governance structures require effective institutional coordination, appropriate accountability measures and proper cybersecurity mechanisms. Sri Lanka must therefore strengthen its legal, regulatory and institutional frameworks to ensure that digital governance promotes accountability instead of creating new opportunities for cyber-enabled financial misconduct. Greater emphasis should be placed on institutional responsibility, cybersecurity awareness, inter-agency cooperation and the adoption of internationally recognised governance standards to enhance resilience in the public finance system (Pascoe et al., 2024).

Keywords**:** Cyber-enabled corruption, cybersecurity, digital governance, financial accountability, public finance systems

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The Impact of Mindfulness on Anti-Consumption Behaviour: The Mediating Role of Authenticity

Rathnayaka V.A.S.* and Madhusanka J.D.T.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: vimarshaniapeksha13@gmail.com)

Introduction

Over the past few years, the fashion industry has become one of the most prominent industries in terms of environmental impact, contributing to greenhouse gas emissions, water use and textile waste (Horn et al., 2025). The emergence of fast fashion and the promotion of short product life cycles and short-lived clothing have worsened these problems. In this context, anti-consumption behaviour, that is, the intentional reduction or refusal of unnecessary consumption on the basis of environmental, ethical and personal values, has become an important subject of study. In addition to these values, mindfulness can help consumers make more conscious decisions, and authenticity can help them make decisions that are congruent with their ethical values (Lin & Park, 2023).

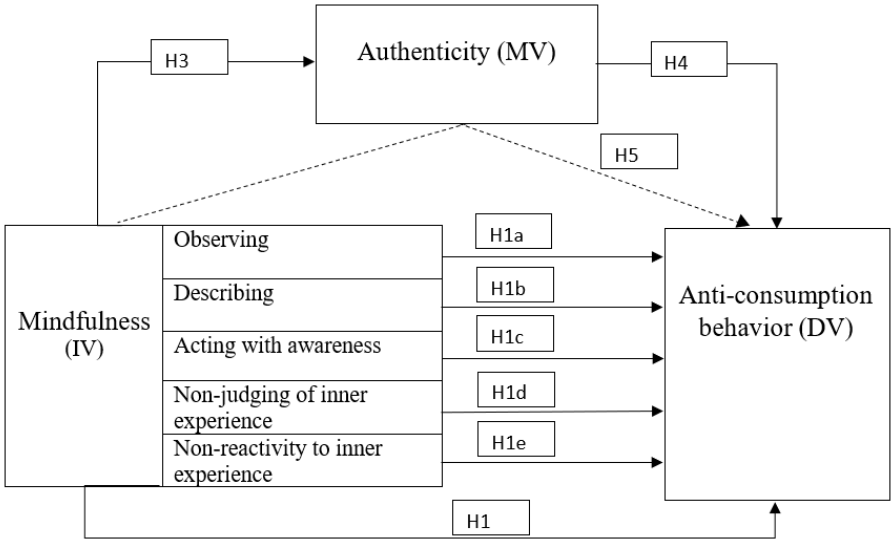
Although previous research has examined the relationships among mindfulness, authenticity and anti-consumption, empirical evidence remains limited in developing-country contexts, particularly within the fashion industry of Sri Lanka. Therefore, this study examines the relationships between mindfulness, authenticity and anti-consumption behaviour among fashion consumers in Sabaragamuwa Province, with particular attention to the mediating role of authenticity. Specifically, the study examines the relationship between mindfulness and anti-consumption behaviour, the relationship between mindfulness and authenticity, the relationship between authenticity and anti-consumption behaviour, and the indirect effect of mindfulness on anti-consumption behaviour through authenticity.

Methodology

This study adopted a quantitative research approach based on the positivist research philosophy and a deductive reasoning process. The conceptual framework (Figure 1) was informed by Self-Determination Theory, which provides a theoretical perspective for understanding how internal psychological processes may relate to consumer behaviour. In this framework, mindfulness, comprising the dimensions of observing, describing, acting with awareness, non-judging of inner experience and non-reactivity to inner experience, is the independent variable, authenticity the mediating variable and anti-consumption behaviour the dependent variable.

Figure 1

Conceptual Framework



The target population comprised fashion consumers aged 18 years and above residing in Sabaragamuwa Province. A sample of 384 respondents was determined based on the Krejcie and Morgan (1970) sample size table. Convenience sampling was employed for reasons of accessibility, and primary data were collected through a structured online questionnaire using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). Data were analysed using SPSS and the PROCESS macro. Descriptive statistics, reliability analysis, correlation analysis, multiple regression analysis and mediation analysis using 5,000 bootstrap samples were conducted.

Results and Discussion

A total of 384 valid responses were obtained, with Cronbach's alpha values ranging from .748 to .885. The Kaiser–Meyer–Olkin (KMO) value of .947 and Bartlett's test ($p < .001$) indicated that the data were suitable for factor analysis. Correlation analysis revealed significant positive relationships between mindfulness and anti-consumption behaviour ($r = .833$, $p < .001$), between mindfulness and authenticity ($r = .857$, $p < .001$), and between authenticity and anti-consumption behaviour ($r = .759$, $p < .001$). Among the mindfulness dimensions, non-reactivity showed the strongest correlation with anti-consumption behaviour ($r = .780$). All variance inflation factor (VIF) values were below 5 and all tolerance values were above 0.20, indicating no problematic multicollinearity (Hair et al., 2019).

Multiple regression analysis indicated that the five mindfulness dimensions jointly explained 71.6% of the variance in anti-consumption behaviour ($R^2 = .716$, $p < .001$). Non-reactivity was the strongest predictor ($\beta = .361$, $p < .001$), followed by observing ($\beta = .198$), describing ($\beta = .195$), acting with awareness ($\beta = .122$, $p < .001$) and non-judging

(β = .102). The mediation analysis also indicated a significant indirect effect of mindfulness on anti-consumption behaviour through authenticity (indirect effect = 0.141, BootCI [0.034, 0.269]), as the confidence interval did not include zero. The results of hypothesis testing are summarised in Table 1. These findings provide evidence of the relationships among mindfulness, authenticity and anti-consumption behaviour in the Sri Lankan fashion-consumption context.

Table 1

Hypothesis Testing Results

Hypothesis	Relationship	β	*p*	Decision
H1	MF → AC	0.811	< .001	Accepted
H1a	MFOB → AC	0.588	< .001	Accepted
H1b	MFNR → AC	0.709	< .001	Accepted
H1c	MFDE → AC	0.650	< .001	Accepted
H1d	MFAW → AC	0.502	< .001	Accepted
H1e	MFNJ → AC	0.497	< .001	Accepted
H2	MF → AT	0.890	< .001	Accepted
H3	AT → AC	0.712	< .001	Accepted
H4	MF → AT → AC	0.141	< .001	Accepted

Note. All hypotheses were statistically supported at the $p < .001$ significance level. MF = mindfulness; MFOB = observing; MFNR = non-reactivity; MFDE = describing; MFAW = acting with awareness; MFNJ = non-judging; AT = authenticity; AC = anti-consumption behaviour.

The findings indicate that overall mindfulness significantly predicted anti-consumption behaviour (β = .811, $p < .001$). Non-reactivity showed the strongest influence (β = .361), which is consistent with Lesmana et al. (2025), who found non-reactivity to be crucial in resisting impulsive purchases. Mindfulness also significantly influenced authenticity (β = .890, $p < .001$), supporting H2. Authenticity significantly influenced anti-consumption behaviour (β = .712, $p < .001$), supporting H3, which is consistent with Lin and Park (2023). Furthermore, the significant indirect effect suggests that authenticity mediates the relationship between mindfulness and anti-consumption behaviour.

Conclusions and Implications

The findings indicate significant positive relationships among mindfulness, authenticity and anti-consumption behaviour among fashion consumers in Sabaragamuwa Province. All five mindfulness dimensions were positively associated with anti-consumption behaviour, with non-reactivity emerging as the strongest predictor. The significant indirect effect further suggests that authenticity is an important mechanism through which mindfulness is associated with anti-consumption behaviour. The study extends existing research by examining these relationships within the Sri Lankan fashion-consumption context and by empirically examining the mediating role of authenticity. The findings suggest that fashion marketers and policymakers may encourage more conscious and sustainable consumption by promoting authenticity, mindful decision-making, product longevity and responsible consumption practices. However, the cross-sectional design prevents causal conclusions, while convenience sampling and the geographical focus on

Sabaragamuwa Province limit generalisability. Future studies could employ longitudinal or probability-based designs and examine additional psychological factors that may explain anti-consumption behaviour.

Keywords**:** Anti-consumption behaviour, authenticity, fashion industry, mindfulness

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Impact of Algorithmic Facebook Ad Personalisation on Unplanned Buying Behaviour: The Mediating Role of Customer Engagement

De Silva D.A.D.M.* and Madhusanka J.D.T.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: dinithimalshani315@gmail.com)

Introduction

The rapid development of artificial intelligence, data analytics and algorithmic technologies has transformed digital advertising by enabling businesses to deliver personalised advertisements based on consumers' interests, preferences and online behaviours. In social media environments, personalised advertising can enhance the relevance, usefulness and perceived trustworthiness of advertisements and influence consumer responses (Arora et al., 2022; Nguyen et al., 2024; Tran et al., 2023). Previous research has also demonstrated that customer engagement can influence consumer responses through cognitive, emotional and behavioural interactions with brands (Barhemmati & Ahmad, 2015; Lim & Rasul, 2022).

However, previous studies have predominantly examined personalised advertising and consumer purchasing outcomes as direct relationships, while comparatively little attention has been given to the psychological and behavioural mechanism through which perceived personalisation may be associated with unplanned buying. Existing research also provides limited evidence integrating perceived algorithmic Facebook ad personalisation, customer engagement and unplanned buying behaviour within the same framework, particularly in the Sri Lankan online fashion context. Furthermore, consumers cannot directly observe the technical algorithms underlying Facebook advertising; therefore, examining perceived algorithmic ad personalisation provides a more appropriate consumer-level perspective. This study addresses this conceptual and contextual gap by integrating personalisation, customer engagement and unplanned buying behaviour within the stimulus–organism–response (S-O-R) framework.

Methodology

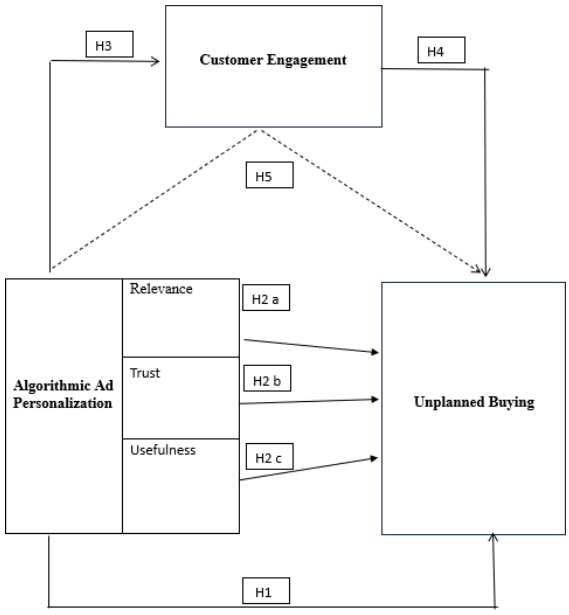
A quantitative research approach was adopted, using a structured questionnaire distributed through Google Forms among consumers engaged in online fashion shopping in the Western Province of Sri Lanka. A total of 384 valid responses were obtained using non-probability convenience sampling. The sample size of 384 was determined based on the sample size guideline of Krejcie and Morgan (1970). Measurement items for perceived algorithmic Facebook ad personalisation, customer engagement and unplanned buying behaviour were adapted from established literature and measured using a five-point Likert scale.

Reliability analysis demonstrated good to excellent internal consistency, with Cronbach's alpha values ranging from .858 to .913. The data were also suitable for factor analysis, as indicated by a Kaiser–Meyer–Olkin (KMO) value of .963 and a significant Bartlett's test of sphericity ($\chi^2(21) = 4{,}345.262$, $p < .001$). The high KMO value indicates that the sample and correlation structure were highly suitable for factor analysis. Data were analysed

using SPSS, including descriptive statistics, Pearson correlation and regression analysis. Hayes' PROCESS macro (Model 4) with 5,000 bootstrap samples was employed to examine the mediating role of customer engagement. The study was theoretically grounded in the S-O-R framework (Figure 1), in which perceived algorithmic Facebook ad personalisation, comprising relevance, trust and usefulness, represents the stimulus, customer engagement represents the organism and unplanned buying behaviour represents the response.

Figure 1

Conceptual Framework



Results and Discussion

The findings revealed strong and significant positive relationships among perceived algorithmic Facebook ad personalisation, customer engagement and unplanned buying behaviour. Personalisation significantly predicted unplanned buying behaviour (β = .925, $p < .001$; $R^2 = .855$) and customer engagement (β = .954, $p < .001$; $R^2 = .910$), while customer engagement significantly predicted unplanned buying behaviour (β = .930, $p < .001$; $R^2 = .864$). Among the personalisation dimensions, advertisement relevance showed the strongest influence (β = .347), followed by trust (β = .318) and usefulness (β = .293), all at $p < .001$. Mediation analysis confirmed that customer engagement partially mediated the relationship between personalisation and unplanned buying behaviour, with a significant direct effect ($B = 0.416$, $p < .001$) and a significant indirect effect ($B = 0.496$, 95% CI [0.387, 0.596]). These findings support the application of the S-O-R framework and indicate that personalised Facebook advertising is associated with unplanned buying both directly and through customer engagement.

Conclusions and Implications

This study concludes that algorithmic Facebook ad personalisation significantly influences consumers' unplanned buying behaviour both directly and indirectly through customer engagement. The findings demonstrate that personalised advertisements characterised by relevance, trust and usefulness contribute to stronger consumer engagement and encourage spontaneous purchasing decisions. Customer engagement emerged as an important mechanism linking personalised advertising and buying behaviour, confirming its partial mediating role. Theoretically, this study extends the application of the S-O-R framework to the context of digital marketing and contributes empirical evidence from a developing country. Methodologically, the study demonstrates the effectiveness of quantitative techniques and PROCESS macro mediation analysis in examining complex relationships among consumer behaviour variables. Practically, the findings suggest that online fashion retailers should focus on delivering relevant, trustworthy and useful personalised advertisements while fostering customer engagement to enhance marketing effectiveness and stimulate purchase behaviour. The study is limited by its cross-sectional design, convenience sampling method and focus on consumers in the Western Province of Sri Lanka. Future studies may employ probability sampling and longitudinal designs and investigate additional mediating or moderating variables to improve the generalisability of the findings.

Keywords**:** Algorithmic ad personalisation, customer engagement, Facebook advertising, online fashion industry, unplanned buying behaviour

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Impact of Self-Brand Congruence on Compulsive Buying Behaviour: The Mediating Role of Brand Attachment

Wijesuriya D.C.H.* and Iroshana M.W.U.K.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: hansiwije2002@gmail.com)

Introduction

Fashion consumption has long moved beyond practical need. Within this landscape, young consumers are increasingly selecting brands not only for what they offer but also for what they communicate about who they are (Gohar et al., 2023; Sirgy, 1982). Self-brand congruence, the match between a consumer's self-concept and a brand's image, lies at the centre of this dynamic. When the fit is strong, it tends to produce brand loyalty and favourable purchase intentions. What it may also produce, although this has been examined less, is compulsive buying behaviour (Japutra et al., 2017).

Compulsive buying is characterised by repetitive, uncontrolled purchasing driven by emotional rather than functional motives, and it carries considerable financial and psychological consequences (Faber & O'Guinn, 1992). Fashion products, with their visible identity-signalling function, are among the most commonly implicated categories (Gohar et al., 2023). Yet the pathway from identity–brand alignment to excessive purchasing, specifically through brand attachment, remains largely unexplored, particularly in emerging markets. Despite the growing relevance of fashion and online consumption among young consumers in Sri Lanka, little empirical work has examined how self-brand congruence and brand attachment jointly shape compulsive buying among young Sri Lankan fashion consumers.

This study addresses that gap. The main objective was to examine the impact of self-brand congruence on compulsive buying behaviour among young consumers aged 18 to 35 years in the Western Province of Sri Lanka, with brand attachment as the proposed mediator. The specific objectives were to investigate the individual effects of actual self-brand congruence and ideal self-brand congruence, the impact of self-brand congruence on brand attachment, and the mediating role of brand attachment in the full pathway.

Methodology

The study was grounded in Self-Congruity Theory (Sirgy, 1982) and Attachment Theory (Bowlby, 1977). Self-Congruity Theory holds that consumers gravitate towards brands that align with either their current self-image (actual self-brand congruence) or their aspirational self-image (ideal self-brand congruence). Attachment Theory explains how this alignment can evolve into a deeper emotional bond. Together, they form the basis for proposing that self-brand congruence is associated with compulsive buying both directly and through the emotional attachment that consumers develop. Six hypotheses were developed accordingly (H1–H5, including H2a and H2b for the two dimensions).

A quantitative, deductive research design was adopted. Data were collected using a structured, self-administered online questionnaire distributed through Google Forms to

young consumers residing in the Western Province. Convenience sampling was employed given the absence of a comprehensive sampling frame. A final sample of 400 respondents aged 18–35 years was analysed; 54.8% were female, and 54.8% were aged 18–24 years. Respondents were required to reside in the Western Province and to have experience of purchasing fashion-related products. All constructs were measured on a five-point Likert scale using established scales: self-brand congruence from Malär et al. (2011) as applied by Japutra et al. (2017), brand attachment from Thomson et al. (2005), and compulsive buying behaviour from Faber and O'Guinn (1992), supplemented by Maccarrone-Eaglen and Schofield (2017). Data were analysed using SPSS, with reliability tested using Cronbach's alpha, factorability assessed using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test, and mediation tested using Hayes' PROCESS macro (Model 4) with 5,000 bootstrap samples.

Results and Discussion

Measurement quality was satisfactory across all constructs. Cronbach's alpha ranged from .807 to .915 and KMO values ranged from .744 to .940, while Bartlett's tests of sphericity were significant, indicating that the data were suitable for factor analysis. All variables were approximately normally distributed, with skewness and kurtosis values within ±2. Descriptive analysis placed all variables at moderate levels, with brand attachment recording the highest mean ($M = 3.423$) and compulsive buying the lowest ($M = 2.720$).

Correlation analysis revealed a strong positive association between self-brand congruence and brand attachment ($r = .769$, $p < .01$) and moderate positive relationships between self-brand congruence and compulsive buying behaviour ($r = .470$, $p < .01$) and between brand attachment and compulsive buying behaviour ($r = .469$, $p < .01$), all significant at the .01 level.

Linear regression confirmed that self-brand congruence positively and significantly predicted compulsive buying behaviour ($\beta = .470$, $p < .001$, $R^2 = .221$), supporting H1. Self-brand congruence also strongly predicted brand attachment ($\beta = .769$, $p < .001$, $R^2 = .592$), the strongest relationship in the study, supporting H3. Brand attachment in turn significantly predicted compulsive buying behaviour ($\beta = .469$, $p < .001$, $R^2 = .220$), supporting H4. Multiple regression showed that both actual self-brand congruence ($\beta = .261$, $p < .001$) and ideal self-brand congruence ($\beta = .234$, $p = .002$) independently predicted compulsive buying behaviour, with actual self-brand congruence showing a marginally stronger effect, consistent with Malär et al. (2011). H2a and H2b were therefore both supported.

Mediation analysis revealed a significant total effect of self-brand congruence on compulsive buying behaviour (effect = 0.591, $p < .001$). After brand attachment was introduced, the direct effect remained significant but was reduced (effect = 0.336, $p < .001$), and the indirect effect through brand attachment was also significant (effect = 0.255, 95% CI [0.098, 0.403]). Since the confidence interval excluded zero, partial mediation was confirmed, supporting H5. The findings indicate that self-brand congruence is associated with compulsive buying both directly and indirectly through the

emotional attachment that consumers develop with brands reflecting who they are or aspire to be. The findings align with those of Japutra et al. (2017), Malär et al. (2011) and Japutra et al. (2019), who examined the relationships among self-congruence, brand attachment and compulsive buying. Gohar et al. (2023) also reported the mediating role of brand attachment in apparel-related compulsive buying.

Conclusions and Implications

All six hypotheses were supported. Self-brand congruence, in both its actual and ideal dimensions, significantly impacts compulsive buying behaviour among fashion consumers in the Western Province. Brand attachment partially mediated this relationship, confirming that, while identity alignment was positively associated with excessive purchasing, it also operated through the emotional bonds that consumers form with congruent brands. These findings shift attention towards the less-examined negative consequences of strong consumer–brand relationships, extending Self-Congruity Theory into a contemporary, digitally saturated fashion retail setting and contributing rare empirical evidence from an emerging market context. The theoretical contribution lies in showing that self-brand congruence can be linked to an undesirable consumer outcome and that brand attachment provides an emotional pathway through which this relationship operates.

For fashion retailers and marketers, the findings signal that identity-based branding strategies carry responsibility. While effective in deepening consumer engagement, such strategies can also feed compulsive purchasing patterns, particularly when combined with emotional urgency tactics such as scarcity messaging or trend pressure. Brands would therefore do well to build connections around authenticity rather than aspiration-driven pressure. For policymakers and consumer advocacy bodies, there is a case for financial literacy programmes targeting young adults that address the psychological drivers of identity-motivated spending. Limitations include the cross-sectional design, convenience sampling, the geographic and age-group restrictions, and reliance on self-reported data. Because the design was cross-sectional and the sampling was non-probability based, the findings should be interpreted as evidence of statistical relationships rather than causal effects. The relatively high correlation between self-brand congruence and brand attachment ($r = .769$) also warrants further consideration of discriminant validity in future research, as KMO and Bartlett's tests alone do not establish discriminant validity. Future research should consider longitudinal designs, additional mediators and moderators such as materialism and self-control, other product categories, and the specific dynamics of online retail environments.

Keywords**:** Brand attachment, compulsive buying behaviour, fashion retail, self-brand congruence, young consumers

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Impact of Excessive SNS Usage on Brand Avoidance: The Mediating Role of Social Media Fatigue

Aregoda T.M.K.N.* and Iroshana M.W.U.K.
Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: kaushanieregoda@email.com)

Introduction

In the modern world, social networking sites (SNS) have become an integral part of daily life, influencing communication, information seeking and brand interactions. Platforms such as Facebook, Instagram and TikTok have evolved beyond their original social purposes to become important marketing channels (Kaplan & Haenlein, 2010). This transformation is particularly evident in the online fashion industry, where SNS are widely used for promotions, customer engagement and sales. However, continuous exposure to large volumes of information, interactions and branded content may have negative psychological consequences. Social media fatigue refers to the psychological exhaustion and reduced motivation resulting from overwhelming SNS activities (Luqman et al., 2020), which may encourage consumers to disengage from brand-related communications and potentially lead to brand avoidance. Brand avoidance refers to consumers' deliberate efforts to distance themselves from a brand, such as ignoring brand content or reducing engagement. Accordingly, this study examines the impact of excessive SNS usage on brand avoidance and the mediating role of social media fatigue among consumers of online fashion brands in the Western Province of Sri Lanka. Specifically, it examines the effects of excessive social, hedonic and cognitive use on brand avoidance and the relationships among excessive SNS usage, social media fatigue and brand avoidance.

Excessive SNS usage can be understood through excessive social, hedonic and cognitive use, representing intensive engagement with SNS for social interaction, entertainment and information-related activities (Ma et al., 2025). Previous studies suggest that excessive SNS engagement can create overwhelming information and interaction demands, contributing to psychological exhaustion and social media fatigue (Luqman et al., 2017, 2020). Social media fatigue is a negative psychological state characterised by feelings of being drained, tired and exhausted from SNS activities (Fan et al., 2024). Continuous exposure to information, social interactions and communication demands may reduce users' willingness to engage with additional SNS content. Consequently, brand-related content may also be perceived as an additional demand, encouraging disengagement and brand avoidance.

The study is guided by the stimulus–organism–response (S-O-R) framework, which explains how external stimuli influence internal psychological states and subsequently generate behavioural responses (Luqman et al., 2017). In this study, excessive SNS usage represents the stimulus, social media fatigue the organismic state and brand avoidance the behavioural response. By integrating these variables within a single framework, the study examines both their direct relationships and the mediating role of social media fatigue,

providing evidence on the psychological pathway through which excessive SNS usage may contribute to brand avoidance.

Methodology

This study adopted a quantitative, deductive approach using a survey strategy. The target population consisted of active SNS users in the Western Province of Sri Lanka who followed, or were exposed to, online fashion brands through SNS platforms. The Western Province was selected because of its high level of urbanisation, digital connectivity and concentration of SNS users (Kemp, 2025; Lokupathirana & Weerakkody, 2025). A non-probability convenience sampling method was used to collect data from 384 respondents; the sample size was based on the Krejcie and Morgan (1970) sample size table at a 95% confidence level and a 5% margin of error and was supported by a study with a similar target population within the same geographical limits (Lokupathirana & Weerakkody, 2025). Convenience sampling enabled access to active SNS users within the available time and resource constraints; however, it limits the generalisability of the findings.

Data were collected through a structured, self-administered questionnaire using a five-point Likert scale to measure excessive SNS usage, social media fatigue and brand avoidance. Excessive SNS usage was operationalised through excessive social, hedonic and cognitive use. Seven hypotheses were tested accordingly. Data were analysed using SPSS through descriptive statistics, reliability and validity testing, correlation, regression and mediation analysis. The mediation analysis examined whether social media fatigue explained the indirect effect of excessive SNS usage on brand avoidance.

Results and Discussion

Reliability and validity analyses confirmed the adequacy of the measurement scales for further analysis. Correlation analysis revealed significant positive relationships among excessive SNS usage, social media fatigue and brand avoidance. Excessive SNS usage was positively associated with social media fatigue (r = .461, p < .001) and brand avoidance (r = .594, p < .001), while social media fatigue was positively associated with brand avoidance (r = .423, p < .001). These findings suggest that consumers who engage excessively with SNS are more likely to experience social media fatigue and to exhibit brand avoidance behaviours. Regression analysis further confirmed that excessive SNS usage significantly influenced both brand avoidance (β = .594, p < .001) and social media fatigue (β = .461, p < .001), while social media fatigue significantly influenced brand avoidance (β = .423, p < .001).

Among the dimensions of excessive SNS usage, excessive social use had the strongest effect on brand avoidance (β = .373, p < .001), followed by excessive hedonic use (β = .232, p < .001) and excessive cognitive use (β = .121, p = .016). These findings indicate that excessive SNS engagement may create an overwhelming digital environment through continuous social interaction, entertainment-oriented engagement and information-related demands, thereby encouraging consumers to disengage from brand-related content. Mediation analysis confirmed that social media fatigue partially mediated the relationship between excessive SNS usage and brand avoidance, with a significant

indirect effect (β = .114). This indicates that excessive SNS usage contributes to brand avoidance both directly and indirectly by increasing social media fatigue, which subsequently encourages avoidance behaviour. Accordingly, all seven hypotheses developed in the study were accepted. Overall, the findings support the S-O-R framework, whereby excessive SNS usage acts as the stimulus, social media fatigue represents the internal organismic response and brand avoidance emerges as the behavioural response.

Conclusions and Implications

The study concludes that excessive SNS usage significantly contributes to brand avoidance among the surveyed consumers of online fashion brands in the Western Province of Sri Lanka. Social media fatigue also plays an important mediating role by explaining part of the relationship between excessive SNS usage and brand avoidance. The study contributes to the digital consumer behaviour literature by integrating excessive SNS usage, social media fatigue and brand avoidance within the S-O-R framework. It provides empirical evidence that social media fatigue represents one psychological mechanism through which excessive SNS engagement may contribute to brand avoidance. From a practical perspective, online fashion brands should avoid assuming that greater communication frequency will automatically generate stronger engagement. Brands should balance the frequency, relevance and variety of SNS communications and reduce unnecessary repetition that may contribute to consumer fatigue and disengagement. The findings are limited to consumers of online fashion brands in the Western Province and are based on non-probability convenience sampling and self-reported data. Therefore, the results should not be generalised to all consumers or industries. Future research could examine these relationships across other industries and geographical contexts and investigate additional factors influencing brand avoidance.

Keywords**:** Brand avoidance, excessive social networking site usage, online fashion brands, social media fatigue, stimulus–organism–response framework

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Impact of Short Video Marketing on Purchase Intention: Mediating Role of Perceived Value in Sri Lankan Bakery Industry

Sewwandi P.G.N.* and Adhikari A.M.S.I.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: nimesikasewwandi2002@gmail.com)

Introduction

The rapid development of digital technology and social media platforms has transformed the way businesses communicate with consumers. Short video marketing has become an effective promotional strategy because it allows businesses to deliver engaging and informative content through platforms such as TikTok, Instagram Reels and YouTube Shorts. In the bakery industry, short video marketing is increasingly used to showcase products, communicate promotional offers, demonstrate product quality and improve customer engagement, and it has become an important digital marketing tool for bakery businesses seeking to influence consumer responses and purchasing decisions.

Previous studies have identified positive relationships between short video marketing and customer responses. Lin (2024) found that short video content can influence consumer attitudes and purchasing behaviour by improving product awareness and providing useful product information. He (2026) highlighted the importance of engaging and informative short video content in influencing consumers' responses to products. Further, Fan (2024) explained that purchase intention represents the consumer's willingness and likelihood to purchase a product after being exposed to relevant product information. These findings suggest that the characteristics of short video marketing can play an important role in shaping consumers' purchase intentions. Another important psychological factor that can explain how marketing stimuli affect consumer purchase intentions is perceived value (Shue Wu, 2025). Consumers who perceive more value in a product are more likely to develop favourable purchase intentions. From the perspective of short video marketing, informative, clear and engaging content can increase consumers' perceptions of the benefits and value offered by a product. Perceived value may therefore act as an important mechanism through which short video marketing influences purchase intention.

Previous studies have mainly examined short video marketing in industries such as fashion, cosmetics and e-commerce, with limited attention given to the bakery industry in Sri Lanka, and the mediating role of perceived value in the relationship between short video marketing and purchase intention has also received limited attention. The research problem addressed in this study is therefore the impact of short video marketing on consumer purchase intention and the mediating role of perceived value in the Sri Lankan bakery industry. Specifically, the study examines the effects of clarity, usefulness and promotional discounts on purchase intention, as well as the effect of short video marketing on perceived value and of perceived value on purchase intention. The study contributes to existing knowledge by addressing the contextual gap in the bakery industry in Sri Lanka and by examining perceived value as an intervening mechanism. The findings are

expected to provide useful insights for bakery businesses in developing effective short video marketing strategies.

Methodology

This study adopted a quantitative research approach with an explanatory research design to investigate the relationships between short video marketing, perceived value and purchase intention. The study was based on the stimulus–organism–response (S-O-R) theoretical framework, in which short video marketing represents the stimulus, perceived value the organism and purchase intention the response. A cross-sectional survey strategy was used to collect primary data from consumers purchasing bakery products in the Western Province of Sri Lanka. Bakery consumers residing in the Colombo, Gampaha and Kalutara districts formed the target population. Using the Krejcie and Morgan (1970) sample size determination approach, 384 respondents were selected through convenience sampling, targeting consumers who frequently purchase bakery products.

Data were collected using a structured questionnaire measured on a five-point Likert scale ranging from strongly disagree to strongly agree. The questionnaire included items related to the dimensions of short video marketing (clarity, usefulness and promotional discounts), perceived value and purchase intention. The reliability and validity of the measurement scales were assessed through Cronbach's alpha and Kaiser–Meyer–Olkin (KMO) tests. Hypotheses were developed to test the relationships between the variables. Data analysis was performed using descriptive statistics, correlation and multiple regression analysis in SPSS. The chosen methodology is appropriate because it allows for objective measurement of relationships and for statistical testing of the proposed framework in a real-world consumer context. It also supports the generalisation of findings to similar contexts in the Sri Lankan bakery industry.

Results and Discussion

A total of 384 valid responses collected from bakery customers in the Western Province of Sri Lanka were analysed using SPSS. Reliability and validity tests confirmed that the measurement scales were suitable for further analysis, with an overall Cronbach's alpha value of .932 and a KMO value of .956. Correlation and regression analyses were conducted to examine the relationships between short video marketing, perceived value and purchase intention. The findings revealed that short video marketing has a significant positive impact on consumer purchase intention, and its dimensions, namely clarity, usefulness and promotional discounts, were found to have a positive impact on purchase intention. Short video marketing had a significant positive effect on purchase intention ($\beta = .830$, $p < .001$), explaining 68.8% of its variance. Among its dimensions, usefulness had the strongest effect ($\beta = .350$), followed by promotional discounts ($\beta = .339$) and clarity ($\beta = .244$). Short video marketing also significantly affected perceived value ($\beta = .672$), and perceived value significantly affected purchase intention ($\beta = .656$). Mediation analysis confirmed that perceived value partially mediated the relationship between short video marketing and purchase intention (indirect effect = 0.123, BootCI [0.065, 0.185]). All hypotheses were accepted. These findings support previous research (Fan, 2024) and

the S-O-R theory, according to which short video marketing acts as the stimulus, perceived value as the organism and purchase intention as the response.

Conclusions and Implications

This study concludes that short video marketing has a significant positive impact on customer purchase intention in the bakery industry in the Western Province of Sri Lanka. Key factors such as clarity, usefulness and promotional discounts positively influence consumers' willingness to purchase bakery products. The findings also show that short video marketing enhances perceived value, which in turn positively affects purchase intention. Perceived value partially mediates the relationship between short video marketing and purchase intention, confirming its important role in the decision-making process. These results are supported by correlation, regression and mediation analyses.

From a theoretical perspective, this study contributes to the existing literature on digital marketing and consumer behaviour by integrating short video marketing, perceived value and purchase intention into a single conceptual framework. The findings support the relevance of S-O-R theory in explaining consumer responses to short video marketing in the Sri Lankan bakery industry. This study also provides empirical evidence from a developing country context in which limited research has been conducted on these relationships. From a practical perspective, the findings suggest that bakery business owners and marketing managers should focus on producing clear, useful and engaging short video content, incorporating attractive promotional offers, to increase consumers' perceived value and encourage purchase intentions. Effective use of short video platforms can help bakery businesses strengthen customer relationships and improve marketing performance.

This study has several limitations. The research was limited to consumers in the Western Province of Sri Lanka and adopted a cross-sectional design, which limits the generalisability of the findings and prevents the observation of changes over time. Future research could expand the geographical scope beyond the Western Province to include consumers in other provinces of Sri Lanka, thereby providing broader evidence on short video marketing and purchase intention. Similar studies could also be conducted in other industries, such as tourism, fashion, beauty and retail, to compare consumer responses across different contexts. Future researchers could examine additional mediating or moderating variables, such as brand trust, consumer satisfaction, consumer engagement and demographic factors. Longitudinal and mixed-methods approaches could also be used to provide a deeper understanding of changes in consumer behaviour and experiences with short video marketing.

Keywords**:** Bakery industry, perceived value, purchase intention, short video marketing, Sri Lanka

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Impact of Brand Experience on eWOM: Mediating Effect of Brand Love in Real Estate, Sri Lanka

Rohanadeera S.D.* and Adhikari A.M.S.I.
Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: rohanadeerasuleesha@gmail.com)

Introduction

The rapid advancement of digital technologies has fundamentally transformed the manner in which consumers interact with brands and share consumption-related experiences (Thoa & Cuong, 2024). Brand experience influences future decisions by shaping long-term memories, satisfaction and loyalty (Khan & Rahman, 2015). Electronic word-of-mouth (eWOM) has emerged as a powerful communication instrument influencing brand reputation, consumer trust and purchase decision-making (Dhun & Dangi, 2023). Brand experience, encompassing sensory, affective, intellectual and behavioural responses to brand-related stimuli, has been identified as a critical determinant of consumer behaviour (Brakus et al., 2009).

Based on the stimulus–organism–response (S-O-R) framework (Mehrabian & Russell, 1974), this study conceptualises brand experience as an external stimulus that influences consumers' internal emotional state, namely brand love, which in turn drives eWOM behaviour. The study is further supported by Consumer Brand Relationship Theory (Fournier, 1998), Social Influence Theory (Kelman, 1958) and the Triangular Theory of Love (Sternberg, 1986), which collectively explain the formation of emotional attachment and advocacy intentions.

In the real estate industry of Sri Lanka, customers' positive or negative brand experiences can influence their online reviews, recommendations and eWOM. Such experiences shape the online reputation and brand image of real estate firms, emphasising the importance of effective experience management. Although previous studies have examined the relationships between brand experience, brand love and eWOM in fast-moving consumer goods, retail and service contexts, empirical evidence within the real estate industry, particularly in developing economies, remains limited. The mediating effect of brand love in linking brand experience and eWOM has also received insufficient scholarly attention in high-involvement purchase settings. The primary objective of this study is therefore to examine the impact of brand experience on eWOM, with the mediating effect of brand love, among Generation Y consumers in the Western Province of Sri Lanka.

Methodology

This study adopted a positivist research philosophy and a deductive approach within the research onion framework (Saunders et al., 2007). The study employed a cross-sectional, explanatory research design, with data collected from respondents at a single point in time. The target population comprised Generation Y consumers aged 30–45 years residing in the Western Province of Sri Lanka who had experienced interactions with real estate brands. A snowball sampling technique was used to reach eligible respondents owing to

the absence of a comprehensive sampling frame. A total of 384 respondents were selected to ensure adequate statistical representation and analytical reliability.

The collected data were analysed using IBM SPSS Statistics. The reliability and validity of the measurement scales were evaluated through Cronbach's alpha, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. Pearson's correlation analysis was conducted to assess the strength and direction of the relationships among the constructs. Multiple regression analysis was used to examine the direct effects among variables, while Hayes' PROCESS macro was applied to test the mediating effect of brand love on the impact of brand experience on eWOM. The proposed hypotheses were then evaluated based on the statistical significance and explanatory power of the analytical results.

Results and Discussion

The findings provided strong empirical support for the proposed research framework. Reliability and validity assessments confirmed the robustness of the measurement model, with Cronbach's alpha values ranging from .812 to .979 and satisfactory construct validity (KMO = .735; Bartlett's test, $p < .001$). Descriptive statistics indicated favourable perceptions of brand experience, brand love and eWOM among Generation Y consumers. Correlation analysis revealed significant positive relationships among all constructs, with brand love demonstrating the strongest association with eWOM ($r = .924$, $p < .001$). Regression results showed that brand experience significantly influenced eWOM ($\beta = .809$, $p < .001$) and brand love ($\beta = .792$, $p < .001$), while brand love emerged as the strongest predictor of eWOM ($\beta = .924$, $p < .001$). Mediation analysis further confirmed that brand love partially mediates the impact of brand experience on eWOM (indirect effect = 0.724), highlighting the importance of emotional attachment in transforming positive brand experiences into online advocacy behaviour. The results of hypothesis testing are summarised in Table 1.

Table 1

Hypothesis Testing

	Correlation			Regression		
Hypothesis	*r*	*p*	Decision	β	*p*	Decision
H1	0.809	< .001	Accepted	0.809	< .001	Accepted
H1a	0.774	< .001	Accepted	0.352	< .001	Accepted
H1b	0.782	< .001	Accepted	0.328	< .001	Accepted
H1c	0.642	< .001	Accepted	0.185	< .001	Accepted
H1d	0.618	< .001	Accepted	0.056	< .001	Accepted
H2	0.792	< .001	Accepted	0.792	< .001	Accepted
H3	0.924	< .001	Accepted	0.924	< .001	Accepted
H4	Indirect effect = 0.724 (BootCI [0.641, 0.811])					Accepted

Conclusions and Implications

The findings of this study provide substantial empirical support for the proposition that brand experience serves as a critical antecedent of eWOM among Generation Y consumers in the Sri Lankan real estate industry. The results indicate that favourable sensory, affective, behavioural and intellectual brand experiences significantly enhance consumers' emotional attachment to real estate brands, thereby fostering a greater propensity for positive online advocacy. Brand love emerged as a significant mediating construct, partially transmitting the impact of brand experience on eWOM.

This finding underscores the pivotal role of emotional bonding in converting experiential value into favourable behavioural outcomes. The study contributes to the extant literature on experiential branding and consumer–brand relationships by validating the applicability of the S-O-R framework within a high-involvement service context. From a managerial standpoint, the findings emphasise the strategic importance of cultivating immersive brand experiences and strengthening emotional consumer–brand connections to stimulate eWOM, reinforce customer engagement and sustain long-term competitive advantage. The findings provide valuable insights for real estate marketers seeking to develop effective experiential branding strategies that foster customer advocacy in an increasingly digital environment. However, the findings are limited to Generation Y consumers in the Western Province and may be influenced by prevailing economic conditions.

Keywords**:** Brand experience, brand love, electronic word-of-mouth, Generation Y, real estate industry

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The Impact of Brand Romance on Brand Attachment With the Mediating Effect of Brand Trust in the Smartphone Industry of Sri Lanka

Fernando W.C.I.* and Adhikari A.M.S.I.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: cisuruni@gmail.com)

Introduction

In today's competitive smartphone market, sustainable advantage depends not only on product quality and technological innovation but also on strong emotional relationships with consumers. As functional differences among smartphone brands diminish, emotional branding has become important for differentiation and long-term consumer relationships. Consequently, Brand Romance, Brand Trust and Brand Attachment have gained increasing attention in the marketing literature. Brand Attachment refers to the emotional bond between consumers and brands that fosters loyalty, commitment and long-term relationships. Emotionally attached consumers are more likely to repurchase, recommend brands and resist switching. Brand Romance has emerged as an important emotional construct influencing Brand Attachment through consumers' pleasurable, exciting and psychologically engaging brand experiences. According to Patwardhan and Balasubramanian (2011), Brand Romance comprises three dimensions, namely pleasure, arousal and dominance, which collectively strengthen consumers' emotional engagement with brands.

Although previous studies have established that Brand Romance strengthens outcomes such as Brand Loyalty and Brand Attachment, the mechanism underlying this relationship remains insufficiently explained. Existing research has largely focused on direct relationships, with limited attention to Brand Trust as a mediator between Brand Romance and Brand Attachment. Brand Romance may generate positive emotional experiences, while Brand Trust can determine whether these experiences develop into enduring consumer–brand relationships. Consumer–brand relationship literature supports this proposed mediating relationship: Brand Romance can strengthen consumers' confidence in a brand and contribute to Brand Trust, which can reduce uncertainty and support stronger Brand Attachment. Thus, Brand Trust may function as a psychological mechanism linking Brand Romance to Brand Attachment, and examining it as a mediator provides a more comprehensive explanation of how Brand Romance contributes to Brand Attachment.

The smartphone industry provides a relevant context because of intense competition and increasing similarity in technological features, which make emotional differentiation important for brands. Frequent consumer–brand interactions, significant purchase decisions and expectations of product reliability and after-sales support also make Brand Trust important for sustaining long-term relationships. Understanding how emotional experiences and trust contribute to Brand Attachment can therefore provide valuable insights for smartphone marketers seeking to develop stronger and more sustainable consumer–brand relationships. Accordingly, to address the identified theoretical gap, the

primary objective of this study is to examine the impact of Brand Romance on Brand Attachment with the mediating effect of Brand Trust among smartphone users in the Western Province of Sri Lanka.

Methodology

This study adopted a quantitative, deductive research approach and an explanatory research design to examine the proposed relationships among Brand Romance, Brand Trust and Brand Attachment. A cross-sectional survey design was employed to collect data from smartphone users residing in the Western Province of Sri Lanka. Primary data were collected using a structured questionnaire comprising measurement items adapted from well-established scales in previous literature. Brand Romance was measured using the dimensions of pleasure, arousal and dominance, while Brand Trust and Brand Attachment were measured using validated constructs from prior studies. Responses were obtained on a five-point Likert scale ranging from strongly disagree to strongly agree. Convenience sampling was employed to select accessible respondents who met the eligibility criteria of being active smartphone users residing in the Western Province of Sri Lanka. A total of 392 valid questionnaires were analysed.

Statistical analyses were conducted using SPSS. Reliability was assessed through Cronbach's alpha, while validity was examined using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity. Descriptive statistics summarised respondent characteristics, whereas Pearson correlation, multiple regression and Hayes' PROCESS mediation analysis were used to test the proposed hypotheses. This methodological approach ensured reliable measurement and appropriate examination of the relationships among the study variables.

Results and Discussion

The reliability analysis indicated satisfactory internal consistency for all constructs, with Cronbach's alpha values exceeding the recommended threshold of .70. The overall measurement scale demonstrated excellent reliability ($\alpha = .927$), while KMO values confirmed adequate sampling suitability for factor analysis. Descriptive statistics revealed relatively high mean values for all variables, indicating that respondents generally held favourable perceptions of their smartphone brands. Correlation analysis demonstrated significant positive relationships among Brand Romance, Brand Trust and Brand Attachment, supporting the existence of strong emotional and trust-based consumer–brand relationships.

Multiple regression analysis revealed that Brand Romance significantly influenced Brand Attachment ($R^2 = .528$, $p < .001$). Among the three dimensions of Brand Romance, Brand Arousal exerted the strongest influence on Brand Attachment ($\beta = .456$), followed by Brand Dominance ($\beta = .239$) and Brand Pleasure ($\beta = .152$). These findings suggest that consumers who experience excitement, emotional engagement and psychological involvement with smartphone brands are more likely to develop stronger emotional attachment. The mediation analysis further demonstrated that Brand Romance significantly influenced Brand Trust ($\beta = .711$, $p < .001$), which subsequently enhanced

Brand Attachment. The indirect effect of Brand Romance on Brand Attachment through Brand Trust was statistically significant (indirect effect = 0.338), confirming that Brand Trust partially mediates the relationship between Brand Romance and Brand Attachment. This finding indicates that emotional brand experiences contribute to stronger Brand Attachment partly by strengthening consumers' confidence in the reliability and credibility of the brand.

Conclusions and Implications

This study concludes that Brand Romance significantly influences Brand Attachment among smartphone users, with Brand Trust partially mediating this relationship. Brand Arousal was the strongest predictor of Brand Attachment, highlighting the importance of emotionally engaging brand experiences in strengthening consumer–brand bonds. The findings extend the consumer–brand relationship literature by demonstrating that Brand Trust functions as a psychological mechanism linking Brand Romance and Brand Attachment, providing empirical support for Attachment Theory and the stimulus–organism–response (S-O-R) framework in the smartphone industry context.

From a managerial perspective, smartphone marketers should translate emotional branding into specific customer experiences. Since Brand Arousal was the strongest predictor of Brand Attachment ($\beta = .456$), marketers should prioritise campaigns, product launches, digital content and interactive experiences that generate excitement and engagement. Brand Trust should be strengthened through transparent information, reliable quality, consistent performance, clear warranties and responsive after-sales service. Combining emotional experiences with trust-building practices can strengthen Brand Attachment, customer retention, positive word-of-mouth and competitive advantage.

***Keywords*:** Brand attachment, brand romance, brand trust, consumer–brand relationship, smartphone industry

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Digital Dreams: Women Entrepreneurs Thriving Through Social Commerce in Central Province, Sri Lanka

Kuruppu K.A.D.T.D.*, Senevirathne Y.Y. and Fernando T.S.S.
Department of Management Studies, Faculty of Management, University of Peradeniya, Sri Lanka
*Corresponding author (email: tharukak@mgt.pdn.ac.lk)

Introduction

Women's entrepreneurship is a vital driver of economic growth, household income generation, employment creation and greater female labour force participation in developing contexts (Al-Omoush, 2024). In Sri Lanka, women play a prominent role in retail, handicrafts, food processing and services. The rise of social commerce, defined as e-commerce conducted through social media platforms such as Facebook, Instagram, WhatsApp and TikTok (Almahdi, 2021), has further expanded accessible, low-investment entrepreneurial opportunities, enabling women to balance business activities with domestic responsibilities while reaching wider markets.

Despite government initiatives such as "Digital Sri Lanka" and the Women Empowerment and Digital Inclusion (WEDI) project, substantial barriers persist. Women entrepreneurs in Sri Lanka face limited access to finance, deficits in digital infrastructure, gaps in technological literacy and entrenched gender norms, particularly in the Central Province, where geographic isolation and socio-cultural constraints intensify these challenges (Handaragama & Kusakabe, 2021; Jayarathne et al., 2023; World Bank, 2025).

Although social commerce offers flexible pathways to overcome traditional mobility and resource limitations, empirical research on its multidimensional impacts, encompassing economic independence, psychological empowerment, social recognition and decision-making autonomy, remains limited, especially within Sri Lanka's socio-culturally diverse regions. Existing studies predominantly address the performance of small and medium-sized enterprises (SMEs) in general or broad digital trends, neglecting the nuanced interplay of collaborative networks, resilience strategies and regional contextual factors (Al-Omoush, 2024).

Social commerce adoption among women entrepreneurs can be understood through several complementary theoretical perspectives that explain why individuals adopt, use and continue to engage with digital technologies. One of the most widely applied is the Technology Acceptance Model (TAM) developed by Davis (1989), which proposes that perceived usefulness and perceived ease of use are key determinants of an individual's acceptance and use of technology. In the context of women entrepreneurs, perceived usefulness may reflect the extent to which digital platforms help women reach customers, promote products, reduce transaction costs and improve business performance, while perceived ease of use may determine whether entrepreneurs with different levels of digital literacy are willing and able to use such technologies. Empirical evidence supports the relevance of TAM in entrepreneurial contexts. Crittenden et al. (2019), for example, applied TAM to 199 women micro-entrepreneurs in South Africa and found that the use of information and communication technology (ICT) was associated with self-efficacy,

social capital and empowerment. This suggests that digital adoption should be viewed not merely as technological usage but as a process that can generate broader personal and social outcomes.

Camacho and Barrios (2022), examining female digital entrepreneurs using Facebook in a developing-country context, found that social media affordances enabled women to pursue entrepreneurial objectives despite institutional and patriarchal barriers. Their findings demonstrate that features of digital platforms can support market access, customer interaction and entrepreneurial activity in ways that may not be possible through traditional business channels. This perspective is particularly relevant to the present study because platforms such as Facebook, Instagram, WhatsApp and TikTok offer women entrepreneurs multiple opportunities for marketing, networking, customer engagement and business development.

Empirical evidence from Sri Lanka further demonstrates the relationship between digital engagement and women's empowerment. De Silva and Hansson (2024), in a mixed-methods study involving 157 survey respondents and an online focus group, found that social media use contributed to women's empowerment through improved business performance. Their qualitative findings indicate that social media facilitated knowledge sharing, motivation, networking, business operations and changes in women's mindsets. The study further reported that business performance mediated the relationship between social media use and women's empowerment. Similarly, recent Sri Lankan research on women-led micro, small and medium enterprises indicates that social media can help women overcome geographical and socio-cultural boundaries, expand their markets and strengthen customer engagement.

The selection of the Central Province as the research context is justified by its distinctive socio-economic and infrastructural conditions. The region has many informal micro-enterprises, strong traditional views about women's participation in public and economic activities, and limited access to markets owing to geographical barriers. These conditions differ from those of urban areas, where digital infrastructure is more widely available. The Central Province therefore provides an important context for examining the effects of social commerce on women entrepreneurs, as it allows the study to explore how digital platforms can empower women economically while also maintaining or changing existing inequalities and power relationships. Accordingly, this study aims to develop a comprehensive qualitative understanding of the different impacts of social commerce on women entrepreneurs, including both its empowering effects and the structural challenges they continue to face. Based on this aim, three research objectives were developed: first, to examine how women entrepreneurs in the Central Province of Sri Lanka perceive and experience empowerment through their participation in social commerce; second, to investigate the influence of social commerce on the personal, social and economic dimensions of women entrepreneurs' lives; and third, to identify the challenges and barriers faced by women entrepreneurs in engaging with social commerce. The study offers evidence-based recommendations for policymakers, non-governmental

organisations (NGOs) and digital platforms to foster inclusive ecosystems that support women entrepreneurs.

Methodology

This qualitative study investigates how social commerce empowers women entrepreneurs in the Central Province by exploring their lived experiences and perceptions within specific socio-cultural contexts. The research focuses on women using low-barrier digital platforms (Facebook, Instagram, WhatsApp and TikTok) to operate home-based businesses without physical storefronts, spanning diverse sectors including handicrafts, food products, clothing, jewellery, beauty services and sustainable goods. A purposive sampling strategy was adopted to achieve maximum variation across key dimensions: age (ranging from students to senior citizens), educational background, geographic location (urban, semi-urban and rural areas), business type and duration of engagement. This approach yielded a final sample of 15 participants, at which point data saturation was reached. Data were collected through semi-structured interviews and focus groups, conducted via Zoom or face to face according to participant preference. An interview guide, grounded in the research questions and theoretical framework, was piloted with two participants for refinement. Analysis followed Braun and Clarke's (2006) six-step thematic analysis: familiarisation with the data, initial coding (inductive and deductive), theme generation, review, refinement and comprehensive reporting with rich narratives and verbatim quotations. Ethical approval was obtained from the Ethical Review Committee of the Faculty of Management, University of Peradeniya. Informed consent, confidentiality through pseudonyms, secure data storage and cultural sensitivity were prioritised throughout to protect participants' well-being and rights.

Results and Discussion

This study examined how women entrepreneurs in the Central Province experience empowerment through social commerce, analysing its multidimensional impacts on their lives alongside persistent challenges. The study drew on in-depth interviews with 15 participants from the Kandy (n = 4), Matale (n = 6) and Nuwara Eliya (n = 5) districts, who were predominantly aged 30–40 and engaged in diverse home-based ventures such as handicrafts, food products, beauty services, apparel, sustainable goods and customised gifts. The research illuminates social commerce, through platforms such as Facebook, Instagram, WhatsApp and TikTok, as a vital avenue for economic activity with minimal capital. Thematic analysis of the data yielded a framework of eight interconnected themes that collectively portray the transformative yet constrained nature of digital entrepreneurship for these women.

Theme 1, 'Empowerment and Identity Transformation', reveals social commerce as a catalyst for economic independence, psychological confidence and identity reconstruction. Participants reported a new self-perception arising from self-generated income and the management of multiple roles, shifting from traditional domestic identities to public entrepreneurial personas, such as from "the boutique lady" to "the organic vegetable lady". This aligns with broader evidence demonstrating how digital

platforms foster financial autonomy and enhanced social participation among women in developing contexts (Agarwal et al., 2023; Al-Omoush et al., 2023).

Theme 2, 'Family Dynamics and Collaborative Entrepreneurship', highlights household relationships transformed through multi-generational involvement in business operations, including spousal support with deliveries and in-laws' assistance with packing. Such collaboration enhanced intra-household bargaining power, mutual respect and joint decision-making, although tensions persisted around prioritising domestic duties.

Theme 3, 'Financial Impacts and Economic Mobility', underscores tangible contributions to household income, enabling the payment of school fees, home improvements and reinvestment in business tools. This fostered greater financial autonomy and security, with women directing their earnings towards family well-being and intergenerational mobility.

Theme 4, 'Digital Challenges and Technological Barriers', identifies obstacles related to digital literacy, device limitations, storage constraints and unreliable networks, which hinder content creation, visibility and customer engagement, particularly for rural participants using older devices.

Theme 5, 'Market and Customer-Related Challenges', encompasses difficulties in pricing handmade products, undervaluation by customers, public price competition, frequent order cancellations causing material losses, and intellectual property violations such as the theft of photographs by competitors.

Theme 6, 'Coping Strategies and Resilience', demonstrates women's adaptive responses, including quality enhancement, value-added gestures (e.g. free gifts), advance payments to reduce cancellations, watermarks for image protection, peer learning networks and consistent digital marketing informed by online resources. These bricolage strategies build trust and sustain operations amid constraints.

Theme 7, 'Social Expectations and Cultural Barriers', exposes gendered norms and community scrutiny, particularly initial criticism of women's involvement in business and additional pressures on divorced or younger participants. Over time, visible success shifted perceptions towards greater familial and social acceptance, gradually challenging patriarchal expectations.

Theme 8, 'Policy and Support System Gaps', reveals structural deficiencies, including training made inaccessible by location, language barriers (English-dominant resources), complex government schemes with poor outreach, a lack of continuous mentorship, inadequate infrastructure and the absence of platform recognition mechanisms such as credibility badges.

Collectively, these themes address the study's research objectives. Themes 1 and 2 illustrate empowerment and relational shifts; Themes 3 and 7 capture economic gains alongside evolving socio-cultural influences; and Themes 4, 5, 6 and 8 delineate barriers and resilient responses. Supported by key literature on the role of digital platforms in women's economic agency and on persistent divides (Agarwal et al., 2023; Al-Omoush et al., 2023), the findings position social commerce as a potent yet imperfect vehicle for

empowerment in the Global South. Women are moving towards greater agency as decision-makers and contributors, yet systemic technological, market, cultural and policy barriers necessitate targeted interventions if this potential is to be fully realised. This nuanced portrait advances the understanding of context-specific digital entrepreneurship dynamics in Sri Lanka.

Conclusions and Implications

This study demonstrates that social commerce serves as a transformative pathway for women's empowerment in the Central Province, fostering psychological confidence, economic independence, social recognition and the renegotiation of traditional gender roles among 15 women entrepreneurs. Through home-based digital ventures, participants achieved personal growth and an entrepreneurial identity. However, significant barriers persist, including technological limitations, market competition, socio-cultural pressures and policy gaps. The women exhibited notable resilience through creative coping strategies.

The findings underscore the need for targeted interventions, namely digital training in local languages, improved rural infrastructure, simplified government schemes, microfinance, platform-level support (e.g. "Verified Women Seller" badges) and mentorship by NGOs. With sustained institutional, technological and social support, social commerce can enable more sustainable and inclusive entrepreneurial growth.

Keywords**:** Central Province, digital economy, social commerce, women empowerment, women entrepreneurship

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A Study on the Problems Affecting the Sustainable Development of the One-Day Fishing Industry

Imesha W.K.H.C.*
University of Colombo, Sri Lanka
*Corresponding author (email: 2021ba24809@stu.cmb.ac.lk)

Introduction

The fisheries sector is one of Sri Lanka's most important primary industries, contributing significantly to employment generation, national food security and macroeconomic growth. It provides livelihoods for thousands of coastal households and is a major source of animal protein. According to the Food and Agriculture Organization of the United Nations (FAO, 2022), fisheries play a vital role in promoting sustainable livelihoods and food security, particularly in developing countries. The World Bank (2022) also highlights the sector's continued importance to Sri Lanka's rural economy despite recent economic and environmental challenges. The one-day fishing industry is a key component of Sri Lanka's marine fisheries sector. It consists of small-scale fishing operations that return to shore within 24 hours and supply fresh fish to local markets. The industry supports coastal livelihoods and local economic development but faces growing challenges to its sustainable development. Rising fuel prices, increasing operational costs, declining fish stocks, climate change, inadequate harbour facilities, poor market access and the dominance of intermediaries have reduced the profitability and productivity of fishing activities (Dodangodage, 2017; FAO, 2022). Sri Lanka's recent economic crisis has further increased the cost of fuel, fishing equipment and other essential inputs (World Bank, 2022).

Previous studies have focused mainly on the socio-economic conditions of fishing communities and the effects of environmental and economic changes on fisheries (Dodangodage, 2017; Ocloo, 2015). However, limited research has examined the combined economic, environmental and social factors affecting the sustainable development of the one-day fishing industry at the local level, particularly in the Devinuwara North Grama Niladhari Division. This study aims to address this research gap. Its main objective is to examine the problems affecting the sustainable development of the one-day fishing industry. The specific objectives are (1) to identify the major economic, environmental and social challenges; (2) to assess their impacts on fishermen's livelihoods and the sustainability of the industry; and (3) to recommend strategies and policies to promote sustainable development. The findings are expected to support policymakers, fisheries authorities and coastal communities in improving fisheries management and enhancing the livelihoods of one-day fishermen.

Methodology

This study employed a mixed-methods research design, integrating quantitative and qualitative approaches to examine the problems affecting the sustainable development of the one-day fishing industry. This approach is suitable because it combines statistical analysis with an in-depth understanding of fishermen's experiences, thereby providing a

more comprehensive interpretation of the research problem (Creswell & Creswell, 2018). The study was conducted in the Devinuwara North Grama Niladhari Division of the Devinuwara Divisional Secretariat, where one-day fishing is the primary livelihood activity.

To ensure statistical reliability and avoid sampling bias, a simple random sampling technique was employed, using as the sampling frame the official register of licensed small-scale boat owners provided by the Department of Fisheries and Aquatic Resources in Devinuwara. From this register, 52 fishermen were selected using a random number table, representing nearly half of the total active fishing population in the area. Primary data were collected through structured questionnaires, semi-structured interviews, field observations and field surveys focusing on the economic, environmental and social challenges faced by fishermen. Secondary data were obtained from academic publications, government reports, local administrative profiles and publications of the FAO and the Department of Fisheries and Aquatic Resources (Divisional Secretariat of Devinuwara, 2023; FAO, 2022).

Quantitative data were analysed using SPSS Statistics and Microsoft Excel. Descriptive statistical techniques such as frequencies, percentages, means and charts were used to summarise the major problems affecting the industry. Linear regression analysis was conducted to evaluate the mathematical relationship between seasonal catch volumes and income variations. Qualitative data from interviews and observations were analysed using thematic analysis, which helped to contextualise and explain the statistical findings.

Results and Discussion

According to the priority analysis, the major challenge faced by fishermen engaged in the one-day fishing industry is the depletion of fish resources. The respondents stated that this problem is due mainly to excessive harvesting of fish by multi-day fishing vessels and trawlers, facilitated by advances in fishing technology. Furthermore, since the onset of the economic crisis, the sharp increase in fuel prices and the rising cost of fishing equipment have become major economic challenges affecting the sustainable development of the one-day fishing industry. The main challenges affecting the sustainable development of the industry are presented below.

Table 1 indicates that unpredictable weather and climatic conditions have become one of the most significant challenges affecting the one-day fishing industry. Monsoon winds, storms and rough sea conditions have had a substantial impact on the income of one-day fishermen, as further illustrated in Table 2. The findings also reveal that the income of one-day fishermen is directly influenced by the size of their catch. During the monsoon season, strong winds, storms and high waves restrict fishing activities and reduce catches, resulting in lower incomes for fishermen. Consequently, these adverse weather and climatic conditions have emerged as a major challenge to the sustainable development of the one-day fishing industry. It can therefore be concluded that appropriate adaptation measures are essential to minimise the impacts of these environmental and climatic challenges and to promote the sustainable development of the industry.

Table 1

Problems Faced by Fishermen in the One-Day Fishing Industry According to Priority

Problem	Priority
Rapid depletion of fish stocks	1
Rising operational costs due to increasing fuel prices	2
Unfavourable market conditions	3
Unpredictable weather and climate conditions	4
Technological challenges	5
Labour shortages and workforce-related issues	6

Source: Field survey data (2026)

Table 2

Impact of Seasonal Catch Variability on Fisher Income During the Monsoon Season

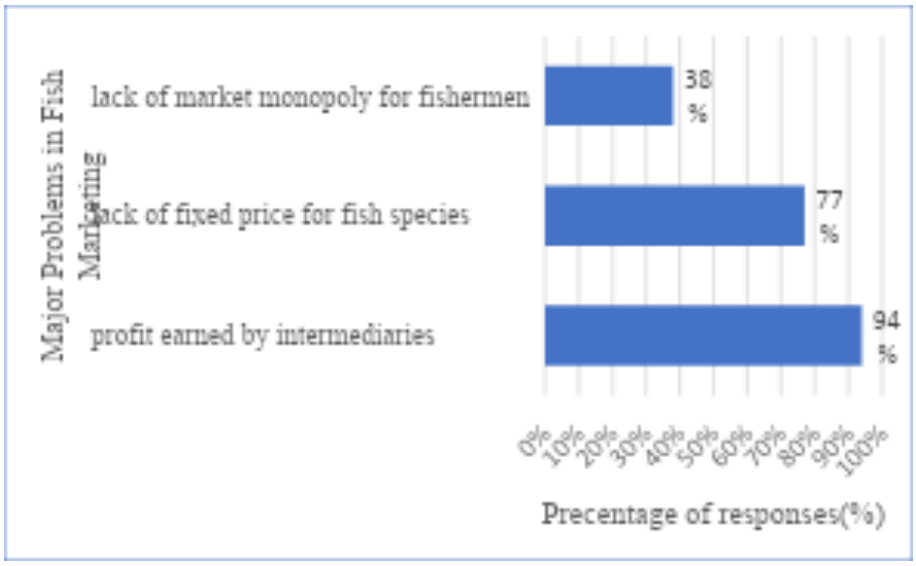
Regression Statistics	
Multiple R	0.996
R^2	0.992
Adjusted R^2	0.992
Standard error	80341.323
Observations	68

Source: Field survey data (2026)

Among the major problems affecting the sustainable development of the one-day fishing industry, issues related to fish marketing were identified as a significant challenge. Owing to the improper maintenance of the Devinuwara Harbour premises, the direct involvement of fish traders and consumers has declined. As a result, fishermen are compelled to sell their catches to intermediaries. Consequently, intermediaries earn higher incomes than fishermen, which negatively affects not only the fishing industry but also the socio-economic development and livelihood improvement of fishermen. This situation has contributed to a rapid decline in the overall progress and sustainability of the industry. These findings are presented in Figure 1.

Figure 1

Major Challenges in Fish Marketing



The findings show that the major challenge affecting the sustainable development of the one-day fishing industry is the rapid depletion of fish stocks, followed by rising fuel costs, poor market conditions and adverse weather. Regression analysis (R^2 = .992) indicates a strong positive relationship between fish catch and fishermen's income, with monsoon conditions significantly reducing catches and earnings. Poor maintenance of Devinuwara Harbour has also limited direct market access, forcing fishermen to rely on intermediaries and reducing their profits. These findings are consistent with Dodangodage (2017), FAO (2022) and the World Bank (2022), which highlight overfishing, climate change and weak market infrastructure as major constraints to the sustainability of Sri Lanka's small-scale fisheries.

Conclusions and Implications

This study concludes that the sustainable development of the one-day fishing industry in the Devinuwara North Grama Niladhari Division is affected by several economic, environmental and institutional challenges. The major challenges identified were the rapid depletion of fish stocks, rising fuel and operational costs, poor market conditions, unpredictable weather and inadequate harbour facilities. The findings also showed that fishermen's income is strongly influenced by fish catch, while dependence on intermediaries reduces their profits and weakens the industry's sustainability. The study is limited to the Devinuwara North Grama Niladhari Division and may not represent all one-day fishing communities in Sri Lanka. Future studies should include larger samples from different coastal regions and examine the impacts of fisheries policies, climate change and technological development.

The findings have important practical implications for policymakers and fisheries authorities. Strengthening fisheries resource management, improving harbour infrastructure and marketing facilities, providing fuel subsidies or financial assistance, and promoting sustainable fishing practices are essential to support the industry. In addition, improving weather forecasting services, encouraging fishermen's cooperative societies and reducing dependence on intermediaries would increase fishermen's income and enhance the long-term sustainability of the one-day fishing industry and the livelihoods of coastal communities.

***Keywords*:** One-day fishing industry, operational costs, solutions, sustainability

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The Impact of Live Streaming Marketing by Online Influencers on Consumer Purchase Intentions: The Mediating Role of Brand Trust in the Fashion Industry in Kandy, Sri Lanka

Manusha P.W.A.N.* and Wasana K.M.L.K.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: amilamanusha013@gmail.com)

Introduction

The rapid development of digital technologies and social media has significantly transformed marketing practices, with live streaming marketing emerging as an innovative strategy that facilitates real-time interaction between businesses and consumers through online influencers. This is particularly significant in the fashion industry, where visual presentation plays a critical role in influencing consumer purchasing behaviour. In this context, online influencers serve as key opinion leaders who interact with audiences, display products and offer personal recommendations, thereby shaping consumer attitudes and purchase decisions. However, despite growing engagement with live streaming content, consumers often experience uncertainty in online shopping because they cannot physically inspect products. Brand trust therefore emerges as a critical psychological mechanism that reduces perceived risk and bridges the gap between marketing exposure and purchase intention.

Most existing literature on live streaming marketing focuses on general e-commerce platforms in developed markets, with limited empirical attention to developing countries such as Sri Lanka. Furthermore, little empirical evidence is available on influencer-led fashion live streaming in the Kandy context, particularly regarding the integration of live streaming marketing dimensions, brand trust and consumer purchasing intention into a single unified model. This study addresses these gaps by examining the impact of live streaming marketing by online influencers on consumer purchase intentions, with brand trust as a mediating variable, in the fashion industry in Kandy, Sri Lanka. The primary objective is to examine the impact of live streaming marketing by online influencers on consumer purchase intention across four key dimensions (influencer expertise, post-sale service, bargaining power and live streaming schedule), incorporating the mediating role of brand trust.

Methodology

This study adopts a quantitative, deductive research approach using a cross-sectional survey design. The conceptual framework positions live streaming marketing by online influencers (influencer expertise, post-sale service, bargaining power and live streaming schedule) as the independent variable, brand trust as the mediator and consumer purchasing intention as the dependent variable. Eight hypotheses were formulated based on the theoretical foundations of Source Credibility Theory (Hovland & Weiss, 1951) and Trust Transfer Theory (Stewart, 2003).

The target population consisted of active social media users in the Kandy District, Sri Lanka, who are exposed to live streaming marketing by online fashion influencers on

platforms such as Facebook, Instagram and TikTok. Respondents were included only if they reported prior exposure to such fashion live streams. For the justification of sample size, the broader accessible population was based on active social media users in the Kandy District: the district has over 1.4 million residents (Department of Census and Statistics Sri Lanka, 2024), and approximately 34.2% of the Sri Lankan population use social media, indicating more than 470,000 social media users in the district (DataReportal, 2024). The population therefore exceeded 10,000, supporting a sample of 370 respondents based on the Krejcie and Morgan (1970) table at a 95% confidence level with a 5% margin of error. A non-probability convenience sampling technique was employed. Primary data were collected through a structured, self-administered questionnaire using a five-point Likert scale developed from established scales in prior research (Dong et al., n.d.; Wongkitrungrueng & Assarut, 2020). Data analysis was performed using SPSS, incorporating descriptive statistics, reliability analysis (Cronbach's alpha), Pearson correlation analysis, multiple regression analysis and mediation analysis using Hayes' PROCESS macro (Model 4) with 5,000 bootstrap samples.

Results and Discussion

The sample comprised 370 respondents, of whom 52.7% were female and 47.3% male. The majority (87.6%) were aged 18–34 years, and 59.7% reported monthly incomes between LKR 25,000 and LKR 50,000, indicating that the surveyed consumers were predominantly young and middle-income. Reliability analysis confirmed acceptable to excellent internal consistency across all constructs (Cronbach's alpha: influencer expertise = .866, post-sale service = .823, bargaining power = .872, live streaming schedule = .714, consumer purchasing intention = .885, brand trust = .913). The Kaiser–Meyer–Olkin measure of .826 and Bartlett's test of sphericity ($\chi^2 = 643.271$, $p < .001$) confirmed the suitability of the data for multivariate analysis.

Descriptive statistics revealed high mean scores for all variables, with brand trust recording the highest mean ($M = 4.82$, $SD = .449$), followed by consumer purchasing intention ($M = 4.68$, $SD = .543$) and influencer expertise ($M = 4.65$, $SD = .526$). Pearson correlation analysis confirmed significant positive relationships among all variables ($p < .001$). Multiple regression analysis ($R^2 = .398$, $F = 60.432$, $p < .001$) demonstrated that three of the four live streaming marketing dimensions significantly predicted consumer purchasing intention: live streaming schedule ($\beta = .342$, $p < .001$), influencer expertise ($\beta = .324$, $p < .001$) and bargaining power ($\beta = .142$, $p = .004$). Post-sale service, however, did not have a statistically significant direct impact ($\beta = -.027$, $p = .439$), leading to the rejection of H1b. This finding suggests that during live streaming events, consumers are motivated primarily by immediate and visible stimuli, such as influencer credibility, consistent scheduling and promotional incentives, rather than by post-purchase considerations.

Mediation analysis using Hayes' PROCESS macro confirmed that live streaming marketing significantly influences brand trust ($B = .550$, $p < .001$, $R^2 = .289$), supporting

H2. Brand trust, in turn, exerted a significant positive effect on consumer purchasing intention (B = .443, p < .001), supporting H3. The indirect effect of live streaming marketing on purchase intention through brand trust was significant (indirect effect = .243, Boot SE = .072, 95% CI [.119, .401]), with the confidence interval excluding zero, thereby confirming partial mediation and supporting H4. The direct effect of live streaming marketing remained significant (B = .450, p < .001), indicating that brand trust partially mediates the relationship. These findings are consistent with prior research by Wongkitrungrueng and Assarut (2020), Tjipto and Keni (2025) and Rahmi and Firman (2025), who similarly identified brand trust as a critical mediating mechanism in live streaming marketing contexts.

Conclusions and Implications

Among the surveyed consumers in Kandy, Sri Lanka, this study empirically demonstrates that live streaming marketing by online influencers has a significant positive impact on consumer purchasing intention in the fashion industry, with brand trust serving as a critical partial mediator. Live streaming schedule and influencer expertise emerged as the strongest predictors of purchase intention, underscoring the importance of consistent, well-timed broadcasts and knowledgeable presentation by influencers. Bargaining power also significantly drives purchase decisions through promotional urgency. Although post-sale service did not directly predict purchase intention in the live streaming context, it is recommended that brands reposition post-sale assurances as trust-building elements within their broader live streaming narrative.

Theoretically, this study contributes to the literature by integrating Source Credibility Theory and Trust Transfer Theory within a live streaming marketing framework, extending existing models to a developing-country context. Practically, fashion marketers in Kandy are advised to collaborate with expert influencers, maintain consistent scheduling, offer strategic real-time discounts and prioritise transparent communication to build brand trust and ultimately enhance purchase intention. Future research should broaden the geographical scope, adopt longitudinal designs, incorporate additional variables such as brand image and price sensitivity, and measure actual purchase behaviour rather than intention alone.

Keywords**:** Brand trust, consumer purchasing intention, fashion industry, influencer marketing, live streaming marketing

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Investigating Idiosyncratic Deals on Employee Retention: The Mediating Role of Hedonic Motivation – Evidence From Fashion Stores in Uva Province, Sri Lanka

Siromiya S.S.*
Independent Researcher
*Corresponding author (email: ies.shiromiya@email.com)

Introduction

Employee retention remains a significant challenge in the retail sector, particularly in fashion stores in Uva Province. Irregular and long working hours, intensive customer interaction, pressure to meet sales targets and physically demanding work contribute to low job satisfaction and high employee turnover. In response, firms have begun to adopt idiosyncratic deals (I-deals): personalised employment arrangements negotiated between an employee and an employer (Rousseau, 2005), such as flexible work schedules, task autonomy and personalised rewards (Piccolo et al., 2012). By aligning job roles with individual employees' preferences and strengths, such arrangements may ease these stressors (Hornung et al., 2011) and foster hedonic motivation, that is, the pursuit of pleasure and enjoyment in work, which shapes employees' behaviour and performance. Employees who feel that their needs and strengths are acknowledged are therefore likely to show greater job satisfaction, organisational commitment and long-term engagement, making I-deals a potential strategic tool for maintaining a stable workforce in high-turnover retail settings.

Prior studies support these links. I-deals have been associated with greater job satisfaction and organisational commitment (Piccolo et al., 2012; Rofcanin et al., 2016) and with higher employee engagement and performance (Saikrishna, 2025). In the Sri Lankan apparel sector, both extrinsic and intrinsic rewards significantly influence employee motivation (Jayawardena & Jayawardena, 2020). However, limited empirical evidence exists on how I-deals influence hedonic motivation and retention in Sri Lanka's retail sector. This study addresses this gap by examining the influence of I-deals on hedonic motivation and employee retention in fashion stores in Uva Province, Sri Lanka. Accordingly, the research objectives are to identify the impact of idiosyncratic deals on hedonic motivation, to examine the impact of idiosyncratic deals on employee retention, and to investigate the mediating role of hedonic motivation in the relationship between idiosyncratic deals and employee retention.

Methodology

Following Creswell (2014), a quantitative research approach with deductive reasoning was adopted. The quantitative approach is suitable because it enables the researcher to test the hypotheses of the study statistically using numerical data. The population of the study consisted of employees working in fashion stores in Uva Province. Fashion store employees were selected as the unit of analysis because their work mostly involves interacting with colleagues, customers and supervisors. Because of the difficulty of accessing the entire population, the researcher selected 150 employees as the sample using purposive sampling; however, 99 completed questionnaires were valid for the analysis.

The participants were identified through a field survey conducted by the researcher. The data were gathered using a self-administered structured questionnaire distributed through Google Forms, which was selected because it is user-friendly and accessible and allows the survey link to be shared through WhatsApp. The questionnaire consisted of closed-ended questions developed from an extensive literature review, and responses were measured on a five-point Likert scale. It was divided into four sections: I-deals (Section 1), hedonic motivation (Section 2), employee retention (Section 3) and demographic information (Section 4).

The data were analysed using SPSS and SmartPLS 4: demographic analysis was conducted using SPSS, and SmartPLS 4 was used for further analysis. Structural equation modelling (SEM) is considered the most suitable approach for complex analyses involving mediation and moderation (Hair et al., 2014). Furthermore, business researchers have relied increasingly on it in recent years because it is one of the most common methods for examining subjects in a management context (Hair et al., 2016). In SEM, latent variables can be endogenous or exogenous; an exogenous latent variable is considered an independent variable, as the arrows point only away from it. In this context, I-deals are therefore considered the independent (exogenous) variable. The study used reflective measurement indicators, because changes in the construct may result in changes in the indicator values.

Previous studies found that I-deals improve employee motivation, positive work experiences and employee retention. These studies further indicate that satisfying work experiences reduce employees' intention to leave the organisation. Accordingly, I-deals increase hedonic motivation and thereby enhance employee retention. On this basis, four hypotheses were developed: I-deals have a positive impact on hedonic motivation (H1); I-deals have a positive impact on employee retention (H2); hedonic motivation has a positive impact on employee retention (H3); and hedonic motivation mediates the relationship between I-deals and employee retention (H4).

Results and Discussion

The questionnaire was distributed among 150 employees, and 99 completed responses were received and considered valid for the analysis, giving a response rate of 66% and a final sample of 99 respondents. Outer loadings were examined to assess the validity and reliability of the measurement items for each construct. Indicator loadings must exceed 0.50 to confirm indicator reliability, and items with loadings below this threshold must be removed from further analysis. All outer loading values exceeded the recommended threshold of 0.50. Hair et al. (2016) indicate that multicollinearity is not an issue when variance inflation factor (VIF) values are below 5; all VIF values in this study were below 5.

To evaluate convergent validity, the average variance extracted (AVE) was examined; it indicates the variance captured by the construct from its indicators relative to the variance due to measurement error. Convergent validity is established when a construct's AVE value is 0.50 or more, indicating that it accounts for at least half of the variance of its

indicators (Fornell & Larcker, 1981; Hair et al., 2014). In the present study, all constructs achieved AVE values above 0.50, indicating adequate convergent validity. The Cronbach's alpha values were above the recommended threshold of 0.70, suggesting strong internal consistency and reliability of the measurement items.

Discriminant validity was examined to ensure that each construct was sufficiently different from the others. Following Henseler et al. (2015), it was assessed using the heterotrait–monotrait ratio (HTMT) and the Fornell–Larcker criterion. The HTMT values were below 0.9, which means that the variance common to any two constructs was less than the variance unique to each construct; this shows that the constructs measure different underlying phenomena and are sufficiently separate (Henseler et al., 2015). The Fornell–Larcker criterion requires the square root of each construct's AVE to be greater than its correlations with the other constructs, which provides evidence of the uniqueness of the constructs (Hamid et al., 2017). In this study, the diagonal value for each construct was higher than the corresponding inter-construct correlations. The discriminant validity tests thus confirmed that the measures of the study variables were unique and did not assess the same items, indicating that the constructs of the study are independent.

To investigate the impact of idiosyncratic deals on employee retention and on hedonic motivation, the path coefficients (direct effects) were analysed. Hypotheses H1, H2 and H3 received strong statistical support from the direct effects, with *p*-values below the recognised cut-off of .05; in every instance, the *p*-values were substantially below this cut-off, indicating that there is very little likelihood that the observed relationships between the variables result from random variation. H1 is accepted, revealing that idiosyncratic deal practices have a positive and significant impact on hedonic motivation. H2 is accepted, indicating that I-deals have a positive and significant impact on employee retention. H3 is also accepted: hedonic motivation has a significant and positive impact on employee retention.

The mediation analysis was conducted in SmartPLS 4 using partial least squares structural equation modelling (PLS-SEM). The specific indirect effects were investigated to evaluate the mediating role of hedonic motivation in the relationship between idiosyncratic deals and employee retention, using the original sample values, standard deviations and *t* statistics. The findings demonstrate a significant mediation effect: the mediating effect of hedonic motivation was statistically significant, indicating partial mediation of the relationship among the employees. H4 is therefore accepted.

Conclusions and Implications

The study confirms that idiosyncratic deals positively affect employee retention in fashion stores in Uva Province, with hedonic motivation as a significant mediator. Personalised work arrangements, including flexible schedules and task autonomy, enhance employees' enjoyment and satisfaction, which strengthens their commitment to the organisation. The findings indicate that managers in the retail sector should implement idiosyncratic deals and tailor them to individual employee needs, thereby fostering hedonic motivation and

reducing turnover. In practice, such strategies create a more engaged, motivated and stable workforce, which enhances organisational performance.

However, the study has limitations. Its geographic scope was limited to Uva Province, and the sample size is relatively small, which may affect the generalisability of the findings. Future studies could extend this research to other provinces of Sri Lanka or to other sectors to explore whether the positive impact of I-deals on hedonic motivation and retention extends to wider contexts.

***Keywords*:** Employee retention, fashion stores, hedonic motivation, idiosyncratic deals, Uva Province

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Exploring Digital Sincerity in TikTok Branding: Understanding Brand Believability in Aesthetic Clinics of Sri Lanka

Ranasinghe H.A.D.S.* and Hendeniya H.M.U.S.
Department of Marketing Management, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: sawbhagyadanushi@gmail.com)

Introduction

Social media, particularly TikTok, has become a major space for brand communication and consumer engagement (Zhang et al., 2024). In aesthetic medicine, clinics use TikTok to promote treatments and educate audiences, but the high-risk nature of these procedures makes credibility crucial (Ramirez et al., 2024). Digital sincerity refers to the way in which brands communicate perceived honesty, transparency and professional credibility to demonstrate genuine intentions online. Unlike authenticity, which concerns whether communication is perceived as genuine or "real", sincerity emphasises the perceived honesty and intentions behind that communication (Chmiel, 2025; Södergren, 2021). Yet research has largely treated credibility, authenticity and trust separately, and there is limited understanding of how digital sincerity operates as a distinct construct in TikTok-based healthcare branding, particularly in Sri Lanka. This study therefore examines the sincerity cues used by aesthetic clinics, how high-risk treatments are communicated, and how audiences interpret these cues in shaping digital trust and brand believability.

Methodology

This study adopted an interpretivist philosophy and an inductive approach to examine how digital sincerity is constructed and interpreted in TikTok branding by aesthetic clinics in Sri Lanka. An interpretivist stance was appropriate because the study focused on the subjective meanings attached to trust, communication and brand believability rather than on testing predefined relationships (Saunders et al., 1997). A multi-method qualitative design combined netnography and semi-structured interviews to enable triangulation and a richer contextual understanding (Kozinets & Gretzel, 2022). Data were collected from five purposively selected clinics in the Western Province with an active TikTok presence, aesthetic treatment content, publicly accessible videos and willingness to participate in interviews, representing varied follower sizes, posting activity and treatment types. TikTok content published between November 2025 and April 2026 was examined. The data comprised 25 TikTok videos, approximately 1,500 audience comments and five interviews with clinic representatives. Ethical procedures included informed consent for interviews; public comments were anonymised, and usernames and other identifying information were excluded. The data were analysed using reflexive thematic analysis (Braun & Clarke, 2006), with nine initial themes subsequently consolidated into three final themes across the datasets. This approach supported an in-depth understanding of how digital sincerity is communicated, interpreted and linked to digital trust and brand believability.

Results and Discussion

Reflexive thematic analysis generated nine initial themes across the three datasets, comprising interview data, TikTok video content and audience comments (Table 1).

Table 1

Summary of Themes and Representative Codes

Theme	Representative codes
Interview data	
Constructing Clinical Legitimacy Through Professional Expertise	Clinical authority, professional medical expertise, trust building through visibility, trust building through expertise, social proof
Strategic Openness: Revealing Enough While Protecting Brand Image	Managed transparency, selective disclosure, ethical communication, consistency of message, transparency in pricing/treatment limitations
Turning Expertise into Reassurance and Action	Simplification of medical information, educational content framing, use of expert explanations, trust building through human connection/honesty
Video data	
Performing Clinical Legitimacy Through Visible Expertise	Professional branding, professional medical expertise, trust building through visibility/expertise/realism, authentic visual presentation
Making High-Risk Care Understandable Through Managed Transparency	Transparency in procedure explanation/expected results, simplification of medical information, use of expert explanations, educational content framing
Reassurance as a Pathway from Sincerity to Treatment Confidence	Emotional reassurance, confidence in elective treatment, decision influence from content
Comment data	
Doctor Presence as the Main Trust Anchor	Trust in doctor presence/patient testimony, perceived expertise/trustworthiness, social proof influence
Seeking Clarity Before Accepting the Content	Desire for more transparency, price inquiry behaviour, safety concern, fear or anxiety, booking intention
Negotiating Believability Through Reassurance, Approval and Doubt	Emotional reassurance, admiration of results, positive brand perception, relatability, scepticism towards claims/visuals, negative brand perception

These themes were subsequently consolidated into three final integrated themes: Strategic Transparency as a Performance of Credibility, Negotiating Trust Through Visible Clinical Authenticity, and Emotional Reassurance as Digital Risk Management. Overall, the findings indicate that digital sincerity in TikTok branding is shaped through these three interconnected processes. Strategic transparency demonstrates how clinics manage clinical information while maintaining credibility; visible clinical authenticity shows how expertise, doctor presence and authentic presentation make professional credibility observable; and emotional reassurance demonstrates how communication reduces uncertainty and supports treatment confidence. Audiences evaluate these cues through information seeking, approval and doubt, which influences trust and brand believability. These findings are consistent with previous studies that identify transparency, authenticity and professional expertise as key determinants of trust in digital healthcare communication (Chmiel, 2025; Södergren, 2021).

Furthermore, the findings support Source Credibility Theory (Ohanian, 1990), which conceptualises source credibility in terms of expertise, trustworthiness and attractiveness. Digital sincerity adds to this perspective not as a separate credibility dimension but as a contextualised communicative process through which these source qualities are performed and interpreted on TikTok. In this study, expertise became visible through doctor-led explanations and professional cues, trustworthiness through managed transparency and selective disclosure, and attractiveness through approachable, relatable and emotionally reassuring communication. The findings thus extend Source Credibility Theory by showing that, in short-form healthcare environments, credibility depends not only on source attributes but also on how these qualities are made visible to and interpreted by audiences.

Conclusions and Implications

This study concludes that digital sincerity is a strategic communication process through which aesthetic clinics establish brand believability on TikTok. It arises not from isolated elements such as transparency, authenticity or expertise but from their complementary use, which enables clinics to communicate professional credibility while sustaining audience engagement. Audiences actively evaluate these cues before developing digital trust; trust is negotiated through ongoing assessment rather than formed through passive exposure.

The study provides context-specific evidence on digital sincerity in Sri Lankan aesthetic healthcare branding, a scarcely researched area. It extends Source Credibility Theory by showing that credibility in short-form healthcare communication depends not only on perceived expertise and trustworthiness but also on how these qualities are communicated and interpreted in digital interactions.

In practical terms, clinics should feature practitioners visibly, provide clear information on treatment risks and pricing, and use authentic audience engagement to strengthen trust and support informed treatment decisions. The study is limited to five clinics in the Western Province and to TikTok alone, which may limit transferability to other sectors, contexts or platforms; moreover, audience interpretations came from public comments that could not be probed in the way that interviews can. Future research should examine other platforms, healthcare settings and cultural contexts, using larger samples and alternative methods.

Keywords**:** Aesthetic healthcare, brand believability, digital sincerity, Source Credibility Theory, TikTok marketing

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The Impact of Multisensory Marketing on Customer Loyalty in Badulla District's Food and Beverage Industry

Manike R.M.P.P.* and Wasana K.M.L.K.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: prabuddhinipiyumali05@gmail.com)

Introduction

The food and beverage (F&B) industry has become highly competitive globally, driven by changing consumer lifestyles and the expansion of tourism. Customers now seek experiential and emotional benefits beyond functional value, which has elevated multisensory marketing (engaging sight, sound, smell, taste and touch) as a strategic approach to creating memorable experiences (Krishna, 2012). This is particularly relevant to the F&B industry, where food presentation, background music, aroma, texture and taste collectively shape consumer perceptions (Sudarnice et al., 2025).

Customer loyalty is a critical factor in long-term business success because loyal customers are more likely to make repeat purchases, recommend businesses to others through positive word of mouth and maintain long-term relationships with brands (Desveaud et al., 2024). Previous literature reviews found that sensory experience has a strong impact on the development of loyalty owing to its ability to evoke emotion and create perceived value (Sudarnice et al., 2025). Nevertheless, most existing research has considered individual sensory factors in isolation and has not examined the combined effects of all five senses on customer loyalty. Furthermore, empirical evidence on multisensory marketing is lacking in the Sri Lankan context, particularly in regional destinations such as Badulla District.

Based on the theoretical framework of Attachment Theory (Bowlby, 1982), this research explores the effect of multisensory marketing on customer loyalty in the F&B sector in Badulla District. According to the theory, attachment to a service provider develops through positive emotions arising from sensory inputs, which increases customer loyalty. The primary objective is to examine the impact of multisensory marketing on customer loyalty in the F&B industry of Badulla District. The specific objectives are to evaluate the distinct impacts of visual, auditory, olfactory, tactile and gustatory stimuli on loyalty. The study tests five hypotheses: H1a (visual), H1b (auditory), H1c (olfactory), H1d (tactile) and H1e (gustatory), each proposing that the respective sensory stimulus has a significant positive impact on customer loyalty.

Methodology

The study employed a quantitative, descriptive, cross-sectional survey design based on a positivist philosophy and deductive reasoning, which was appropriate for measuring the effects of sensory marketing on loyalty among consumers who had visited F&B establishments in Badulla within the past two years. A sample size of 384 respondents was determined using Krejcie and Morgan's (1970) table for unknown populations, and primary data were collected through convenience sampling across diverse dining venues.

The measurement instrument was a structured questionnaire using a five-point Likert scale (Chen et al., 2021).

The questionnaire was divided into two parts, covering demographic data and the measurement items for the constructs under investigation. The independent variable, multisensory marketing, was measured through five aspects: visual, auditory, olfactory, tactile and gustatory. The dependent variable, customer loyalty, was measured using five items. All measurement items were rated on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree).

The data were analysed using SPSS. Internal consistency reliability was confirmed by Cronbach's alpha (multisensory marketing overall $\alpha = .930$, sub-dimensions $\alpha = .742$ to .910; customer loyalty $\alpha = .872$). Construct validity was verified through exploratory factor analysis, with the Kaiser–Meyer–Olkin measure of sampling adequacy (KMO = .978) and Bartlett's test of sphericity ($\chi^2 = 2{,}451.62$, $p < .001$) confirming factorability, and all factor loadings exceeding .60. Multicollinearity diagnostics revealed tolerance values between .35 and .68 and variance inflation factor (VIF) values between 1.47 and 2.85 (well below the threshold of 5.0), ruling out multicollinearity concerns. Hypotheses were tested using Pearson correlation and multiple linear regression analyses.

Results and Discussion

Descriptive statistics indicated high consumer agreement regarding the presence and appreciation of multisensory stimuli ($M = 4.06$, $SD = 0.58$) and customer loyalty ($M = 4.02$, $SD = 0.61$). Among the sensory dimensions, visual stimuli registered the highest mean evaluation ($M = 4.09$, $SD = 0.64$), emphasising the paramount importance diners place on plate presentation, interior decor and ambient aesthetics. Pearson correlation analysis demonstrated statistically significant positive associations between all five sensory dimensions and customer loyalty ($p < .001$). Auditory stimuli exhibited the strongest bivariate correlation with customer loyalty ($r = .829$, $p < .001$), followed by visual ($r = .804$, $p < .001$), tactile ($r = .741$, $p < .001$), gustatory ($r = .712$, $p < .001$) and olfactory stimuli ($r = .658$, $p < .001$).

Multiple linear regression analysis revealed that the overall model was statistically significant, $F(5, 378) = 250.31$, $p < .001$, explaining 76.8% of the variance in customer loyalty ($R^2 = .768$, adjusted $R^2 = .765$). All five sensory dimensions exerted a statistically significant positive effect on customer loyalty, thereby supporting all five hypotheses. Auditory stimuli had the strongest effect ($\beta = .274$, $t = 6.42$, $p < .001$), supporting H1b, followed by visual stimuli ($\beta = .243$, $t = 5.81$, $p < .001$), supporting H1a; tactile stimuli ($\beta = .153$, $t = 3.89$, $p < .001$), supporting H1d; gustatory stimuli ($\beta = .125$, $t = 3.24$, $p = .001$), supporting H1e; and olfactory stimuli ($\beta = .084$, $t = 2.18$, $p = .030$), supporting H1c.

These findings corroborate and extend prior empirical work. The predominant influence of auditory stimuli aligns with Krishna (2012) and Hultén (2011), demonstrating that ambient acoustic curation, background music tempo and volume significantly govern consumer dwell time, relaxation and emotional receptivity. In tourism-centric areas such as Ella, where travellers seek immersive leisure, acoustics play a transformative

atmospheric role. Visual cues emerged as the second strongest predictor, consistent with Sudarnice et al. (2025) and Chen et al. (2021), confirming that visual appeal serves as the initial evaluative anchor for service quality and engagement driven by social media. Tactile, gustatory and olfactory cues also contributed significantly, highlighting that customer loyalty is nurtured most effectively when sensory cues operate synergistically rather than in isolation.

Conclusions and Implications

The empirical findings suggest that multisensory marketing exerts a meaningful and positive influence on customer loyalty in Badulla District's food and beverage industry across visual, auditory, olfactory, tactile and gustatory touchpoints. Auditory stimuli emerged as the most potent predictor, followed by visual, tactile, gustatory and olfactory cues. The results demonstrate that cultivating customer loyalty requires a coordinated sensory environment rather than fragmented, unintegrated stimuli. From a theoretical perspective, the findings align with the core premises of Attachment Theory (Bowlby, 1982), suggesting that harmonious multisensory experiences elicit favourable emotional responses that strengthen consumers' emotional bonds with dining establishments, ultimately reinforcing repeat patronage and positive recommendation behaviour. By studying the combined impact of the synergistic sensory experience in a developing-country setting, this research fills an important gap both theoretically and practically. In tourism-oriented regions such as Ella, these sensory approaches allow businesses to differentiate themselves on factors other than price. The research also provides practical recommendations on the allocation of resources so that businesses can make the most effective investments in sensory aspects.

It should be noted, however, that the results cannot be generalised, because of the study's cross-sectional nature and regional focus. The cross-sectional design and reliance on convenience sampling within a single district constrain the generalisability of the findings. Future research should consider longitudinal assessments, probability sampling designs and the inclusion of explicit psychological mediators (such as brand attachment and perceived value) across diverse regional hospitality markets.

Keywords**:** Attachment theory, customer loyalty, food and beverage industry, multisensory marketing

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The Effect of Visual Merchandising on Impulsive Buying: The Mediating Role of Customer Emotions with Special Reference to the Apparel Stores

Nisansala A.H.C.C.* and Wasana K.M.L.K.
Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: chamodinisansalaa@gmail.com)

Introduction

The apparel retail sector serves as a cornerstone of the Sri Lankan economy, contributing approximately 7% of the national gross domestic product (GDP) and generating over USD 5.5 billion in export earnings in 2023, while directly employing over 350,000 individuals (Export Development Board, 2024). The domestic retail industry contributes 14% of GDP, with apparel retail becoming increasingly competitive as both local and international brands expand their presence across the country (The apparel retail sector serves as a cornerstone of the Sri Lankan economy, n.d.). This intense competition compels retailers to adopt innovative in-store strategies, particularly visual merchandising, to differentiate themselves and influence consumer purchase decisions at the point of sale (Mehta & Chugan, 2013).

Visual merchandising serves as a powerful "silent selling" tool that attracts customers and stimulates unplanned purchases through aesthetically appealing store environments. Within the Stimulus–Organism–Response (S-O-R) theory (Mehrabian & Russell, 1974), visual merchandising elements function as environmental stimuli that evoke emotional responses, ultimately shaping impulsive buying behaviour (Ramaabya & Makgosa, 2025). Impulse buying, characterised by unplanned and spontaneous purchase decisions, is typical of the clothing retail business. It plays a crucial role in revenue generation, as nearly half of total sales in retail outlets result from impulsive purchases (Franjković & Dujak, 2022).

However, limited empirical research has examined the psychological mechanisms through which visual merchandising elements translate into impulsive buying, particularly in the Sri Lankan context. Previous Sri Lankan studies have confirmed that visual merchandising significantly affects impulse buying, yet the mediating role of customer emotions remains under-researched, especially in the apparel retail context of Kandy District (Sachitra & Konara, 2023). The COVID-19 pandemic has fundamentally altered consumers' emotional responses, necessitating updated empirical investigations that capture these evolving dynamics (Ramaabya & Makgosa, 2025). This study addresses these gaps by examining the impact of visual merchandising on impulsive buying, with customer emotions as a mediating variable, focusing on apparel stores in Kandy District. A quantitative approach was employed, with primary data collected from 384 consumers through structured questionnaires. The findings contribute to both academic knowledge and practical retail strategies, providing actionable insights for apparel retailers seeking evidence-based approaches to enhance store environments and stimulate impulsive purchases.

Methodology

This study adopts a positivist research philosophy with a deductive approach and a quantitative methodological choice to examine the impact of visual merchandising on impulsive buying, with customer emotions as a mediating variable, in apparel stores in Kandy District, Sri Lanka. Grounded in S-O-R theory (Mehrabian & Russell, 1974), the research follows a structured, theory-testing framework in which predetermined hypotheses are empirically tested through numerical data collection and statistical analysis, enabling objective measurement and generalisation of results.

The target population comprises all consumers visiting and purchasing apparel in apparel stores within Kandy District. As the exact population size is unknown and no complete sampling frame exists, convenience sampling, a non-probability technique, was employed to select respondents who were easily accessible and willing to participate. The sample size of 384 respondents was determined from Krejcie and Morgan's (1970) sample size determination table, assuming a 95% confidence level and a 5% margin of error for a large population.

A structured, self-administered questionnaire employing a five-point Likert scale was used to collect primary data, measuring visual merchandising across eight dimensions (lighting, store colour, fixtures and fittings, signage, product presentation, display, shelf health, and cleanliness), customer emotions (positive and negative), and impulsive buying. The questionnaire was personally administered to customers leaving apparel stores in Kandy District over a period of 4–6 weeks.

Data analysis was conducted using SPSS version 26.0 and encompassed descriptive statistics (frequencies, means, and standard deviations), reliability testing (Cronbach's α), validity assessment (Kaiser–Meyer–Olkin [KMO] measure and Bartlett's test), Pearson correlation analysis, simple and multiple linear regression, and mediation analysis using the Baron and Kenny (1986) approach at a significance level of $p < .05$. Anonymity, voluntary participation, and confidentiality were strictly maintained, thereby ensuring adherence to ethical research principles.

Results and Discussion

The study analysed data from 384 apparel store customers in Kandy District, who were predominantly female (83.3%) and aged 29–38 years (52.6%). Reliability and validity tests confirmed excellent internal consistency (Cronbach's $\alpha > .90$ for all constructs) and adequate sampling adequacy (KMO > .50, $p < .001$). Univariate analysis revealed positive perceptions across all variables (means of approximately 4.0 on the five-point scale), with negative skewness indicating favourable respondent attitudes.

Bivariate correlations demonstrated strong positive relationships among all variables (r = .766 to .968, $p < .01$). Simple linear regression confirmed that visual merchandising strongly predicts impulsive buying ($R^2 = .937$, $\beta = .968$, $p < .001$) and customer emotions ($R^2 = .879$, $\beta = .938$, $p < .001$), while customer emotions strongly predict impulsive buying ($R^2 = .920$, $\beta = .959$, $p < .001$).

Multiple regression identified signage as the strongest predictor (β = .293), followed by shelf health (β = .236), display (β = .182), store colour (β = .142), product presentation (β = .111), and cleanliness (β = .084). Lighting and fixtures and fittings were not significant predictors, consistent with the findings of Ramaabya and Makgosa (2025) during COVID-19, suggesting that contextual factors may diminish their effectiveness.

Mediation analysis confirmed that customer emotions partially mediate the relationship between visual merchandising and impulsive buying, with 41.5% of the total effect transmitted through emotional responses (indirect effect = 0.416, 95% CI [0.278, 0.546]). This validates S-O-R theory in the Sri Lankan apparel context, demonstrating that visual merchandising (stimulus) evokes emotional responses (organism) that drive impulsive buying (response). The findings address the research gap by empirically establishing the psychological mechanism through which store environments translate into unplanned purchases, providing both theoretical contributions to the consumer behaviour literature and practical insights for apparel retailers in Kandy District.

Conclusions and Implications

The study concludes that visual merchandising significantly affects impulsive buying through the partial mediation of customer emotions in apparel stores in Kandy District, Sri Lanka. All main hypotheses were supported, validating S-O-R theory. Signage and shelf health emerged as the strongest drivers, while lighting and fixtures showed no significant unique effects. Customer emotions partially mediated the relationship, transmitting 41.5% of the total effect.

In practical terms, apparel retailers should prioritise signage, shelf health, creative displays, and appealing colour schemes while avoiding over-investment in lighting and fixtures. Managers must deliberately evoke positive customer emotions through friendly staff, pleasant music, comfortable temperatures, and welcoming atmospheres, as visual improvements alone are insufficient.

In theoretical terms, the study extends S-O-R theory to an emerging economy context, empirically validating emotions as a key organism variable. It provides a validated measurement framework for future research, contributing to the consumer behaviour literature by identifying which specific visual merchandising dimensions most effectively drive impulsive buying in apparel retail settings.

***Keywords*:** Apparel retail, customer emotions, impulsive buying, visual merchandising

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Self-Identity and Students' Tuition Class Choice in Ratnapura, Sri Lanka

Sewwandi H.A.S.* and Cooray N.H.K.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: sashima.sew@gmail.com)

Introduction

Private tuition has become an integral component of the Sri Lankan education system, particularly among students preparing for higher education. Growing academic competition, limited university admission opportunities and an increasing emphasis on educational achievement have contributed to the expansion of the private tuition sector (Bray, 2010; UNESCO, 2021). Consequently, tuition classes have developed beyond supplementary academic support and increasingly operate within a competitive educational marketplace characterised by teacher reputation, branding, social media visibility and differentiated educational services (Bray & Kwo, 2014).

Existing research has primarily explained participation in private tuition through examination pressure, academic achievement, affordability, accessibility, parental influence and teacher quality (Bray & Lykins, 2012; Dang & Rogers, 2008; Zhang & Bray, 2021). Although these studies provide important insights into shadow education, comparatively limited attention has been given to the psychological and identity-related meanings underlying students' selection of tuition classes. The consumer behaviour literature suggests that individuals may select services and experiences that correspond to their self-concepts, social identities and desired future selves (Arnould & Thompson, 2005; Belk, 2013). Tuition class selection may therefore represent not only a functional educational decision but also an identity-related choice.

Within Sri Lanka, previous research has largely emphasised academic, social, economic and structural influences on private tuition, while self-identity remains underexplored as a determinant of tuition class choice. Addressing this gap, the present study views students as active educational consumers whose choices may reflect their identities and aspirations. Accordingly, the study aims to examine how self-identity influences students' tuition class choices in the Ratnapura District, with particular attention to success-driven and socially connected learning environments, affordability and scheduling flexibility, and prestige-oriented marketing and tutor reputation.

Methodology

This study adopted a qualitative research approach, guided by an interpretive paradigm and inductive research logic, to explore the meanings and experiences that students associated with tuition class selection. An exploratory research design was employed to develop an in-depth understanding of how self-identity was reflected in students' educational decision-making.

The study involved 10 Advanced Level students aged 16–18 years who attended tuition classes in the Ratnapura District. Participants from different educational streams were selected through purposive sampling on the basis of their direct experience of the

phenomenon under investigation. Data were collected through semi-structured interviews conducted in Sinhala, which enabled participants to express their experiences and perspectives comfortably. The interviews were manually transcribed and translated where necessary.

Data were analysed using reflexive thematic analysis (RTA), following Braun and Clarke (2022). An inductive coding process was applied, allowing codes and patterns to develop from participants' accounts rather than from predetermined theoretical categories. NVivo was used to support data organisation and coding. The analysis generated three major themes: student identity and success-oriented tuition choice; social and communication influences on tuition class selection; and teacher and practical factors in tuition class choice. Following theme development, Self-Concept Theory, Social Identity Theory and Consumer Culture Theory were applied as interpretive lenses to deepen the understanding of the findings.

Results and Discussion

The findings demonstrated that students' tuition class choices were shaped by an interaction of identity-related, social, teacher-related and practical considerations rather than solely by academic necessity. Three major themes illustrate how students interpreted tuition classes in relation to their learner identities, social environments, educational aspirations and practical circumstances.

The first theme, Student Identity and Success-Oriented Tuition Choice, revealed that students evaluated tuition environments according to their learner identities, academic ambitions and future aspirations. Several participants described themselves as competitive, hard-working or achievement-oriented. One participant stated, "Yes, I am a competitive student. I want to be at the top of the class," while another expressed a clear future aspiration: "I really want to be a lawyer." Competition also operated as a source of motivation, as reflected in the statement, "When those people get marks, I feel like getting marks too. Then I get more interested and feel like studying." These findings are consistent with previous shadow-education research identifying examination performance, competition and higher-education aspirations as important drivers of participation in private tuition (Bray & Lykins, 2012; Dang & Rogers, 2008; Zhang & Bray, 2021). However, this study extends these explanations by showing that such environments may also reinforce students' current and desired learner identities, consistent with Self-Concept Theory (Belk, 2013; Escalas & Bettman, 2005).

The second theme, Social and Communication Influences on Tuition Class Selection, demonstrated the importance of friends, siblings, parents and digital communication. One participant explained, "My friends influenced me the most when choosing a tuition class," while another described using TikTok and YouTube to observe teaching styles before selecting a teacher. Family members also provided recommendations based on their previous educational experiences. Although these findings correspond with previous research emphasising social influence in educational decision-making, participants did not simply follow recommendations. Instead, they evaluated social information according

to their own goals and learning preferences. This supports Social Identity Theory while highlighting the interaction between social influence and individual agency.

The third theme, Teacher and Practical Factors in Tuition Class Choice, showed that teacher reputation, experience, teaching quality and demonstrated results contributed to students' perceptions of credibility. One participant explained, "A teacher does not just become popular. Over time, a teacher becomes popular with experience," while another preferred "a class with stable results." Although previous tuition research similarly emphasises teacher quality and academic outcomes, the present findings indicate that teacher reputation also carried symbolic meanings associated with competence, confidence and success. This interpretation is consistent with Consumer Culture Theory (Arnould & Thompson, 2005). Nevertheless, affordability, accessibility, travel convenience and timetable compatibility remained important, indicating that aspirational preferences were negotiated against practical realities.

Overall, the findings extend established explanations of shadow education by demonstrating that academic, social, teacher-related and practical considerations may also acquire identity-related meanings, positioning tuition class selection as both a functional educational decision and an identity-related process.

Conclusions and Implications

The study concludes that self-identity represents an important dimension of students' tuition class selection within the secondary education sector in the Ratnapura District. Participants' accounts demonstrated that tuition choices extended beyond supplementary academic support and were associated with learner identity, academic ambition, future aspirations, social relationships, perceptions of teachers and practical circumstances.

The principal contribution of this study is its extension of existing explanations of private tuition in Sri Lanka by examining tuition class selection from an identity perspective. While previous research has primarily emphasised examination performance, affordability, accessibility, teacher quality and social influence, this study demonstrates how these considerations may also carry personal and symbolic meanings for students. The integration of Self-Concept Theory, Social Identity Theory and Consumer Culture Theory therefore provides a complementary understanding of tuition class selection as both a functional educational decision and an identity-related process.

The findings also offer practical implications for tuition providers. Greater attention to learning culture, teaching approaches, teacher credibility, student experience, social support, affordability, accessibility and scheduling may enable tuition services to respond more effectively to students' diverse circumstances and aspirations. However, these implications should be interpreted within the qualitative and context-specific nature of the study. Future research across different geographical and educational contexts could further examine the broader relevance of these findings.

Keywords**:** Consumer culture theory, self-identity, shadow education, social identity theory, tuition class selection

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Volatility Dynamics and Forecasting Accuracy of the Sri Lankan Rupee Exchange Rate

Vithanage P.T., Bandara A.L.J.* and Herath H.M.L.K.
Department of Agribusiness Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka
*Corresponding author (email: janithb@wyb.ac.lk)

Introduction

Exchange rates are vital to global economic health, shaping trade, capital flows and monetary policy. For Sri Lanka, a small open economy, fluctuations in the Sri Lankan rupee (LKR) carry significant consequences. The LKR interacts primarily with the US dollar (USD), euro (EUR), pound sterling (GBP), Japanese yen (JPY) and Australian dollar (AUD), reflecting Sri Lanka's main trading partners and sources of remittances, investment and tourism. As an exporter of tea and rubber and an importer of fuel and capital goods carrying substantial foreign debt, Sri Lanka depends on exchange rate stability: depreciation boosts exports but raises import costs, fuels inflation and worsens debt burdens. The 2010–2025 period spans Sri Lanka's post-crisis recovery, the COVID-19 pandemic and the 2022 debt crisis, when the rupee lost over 80% of its value against the dollar within months, triggering hyperinflation and an International Monetary Fund (IMF) bailout (Ravinthirakumaran et al., 2019).

Empirical research on LKR dynamics remains limited, particularly research that jointly models volatility persistence, cross-currency transmission and forecasting performance within one framework; existing studies examine these aspects in isolation, without an integrated basis for understanding LKR volatility. This is the research problem addressed here. By integrating volatility modelling, causal analysis and a forecasting comparison across five currency pairs over 15 years spanning Sri Lanka's most severe crisis, this study offers a fuller account of LKR exchange rate behaviour than prior single-model studies. It pursues three objectives: (i) to examine LKR volatility and causality using generalised autoregressive conditional heteroscedasticity (GARCH) models and Granger causality tests; (ii) to compare the forecasting accuracy of the autoregressive integrated moving average (ARIMA) and Ornstein–Uhlenbeck (OU) models; and (iii) to analyse the effects of inflation, interest rates and gross domestic product (GDP) using autoregressive distributed lag (ARDL) bounds testing.

Methodology

The study utilises daily exchange rate data from the Central Bank of Sri Lanka (CBSL) covering May 2010 to December 2025, yielding 5,718 trading-day observations per currency pair for USD/LKR, EUR/LKR, GBP/LKR, JPY/LKR and AUD/LKR. Missing values for trading days were filled by spline interpolation. All series were transformed into daily logarithmic returns to stabilise the variance, and stationarity was confirmed by the augmented Dickey–Fuller (ADF) test (Khan et al., 2019).

For the mean equation, optimal autoregressive moving average models, ARMA(p,q), were identified by a grid search minimising the Akaike information criterion (AIC) over

p, $q \leq 5$. ARIMA(1,1,1) was used for the forecasting comparison to accommodate the persistent trending behaviour during the 2022 crisis and recovery period.

Volatility was modelled using autoregressive conditional heteroscedasticity, ARCH(1), GARCH(1,1) and Glosten–Jagannathan–Runkle, GJR-GARCH(1,1), specifications, estimated with Student's *t*-distributed innovations. The GARCH(1,1) conditional variance is

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

where ($\alpha_1 + \beta_1$) measures persistence. For asymmetric pairs, GJR-GARCH was employed:

$$\sigma_t^2 = \omega + \alpha_1 u_{t-1}^2 + \gamma_1 u_{t-1}^2 I_{t-1} + \beta_1 \sigma_{t-1}^2$$

where $I_{t-1} = 1$ when $u_{t-1} < 0$ (Engle & Bollerslev, 1986).

Short-run dynamic interdependencies were examined with pairwise Granger causality tests and a vector autoregression model, VAR(p = 2), with forecast error variance decomposition (FEVD) quantifying each variable's contribution to the forecast error variance. Forecasting accuracy was compared between ARIMA(1,1,1) and the OU mean-reverting process using the root mean square error (RMSE) over an out-of-sample period from October 2024 to December 2025 (approximately 439 days). The ARDL bounds testing approach (Pesaran et al., 2001) was used to examine long-run relationships between GARCH-based conditional volatility and GDP growth, inflation and interest rates. All analyses were performed using RStudio (v4.5.2).

Results and Discussion

Table 1 presents the descriptive statistics of the daily logarithmic returns for the five bilateral LKR exchange rates from May 2010 to December 2025. Mean returns are positive but close to zero, indicating marginal average depreciation of the LKR. All series are right-skewed, with USD/LKR recording an exceptional skewness of 13.01, reflecting the asymmetric pressure on the rupee during the 2022 crisis. Excess kurtosis substantially exceeds 3 for all pairs, confirming leptokurtic distributions and motivating Student's *t* GARCH estimation. ADF tests confirm stationarity at the 1% level ($p < .01$). These distributional properties indicate that conventional normal-variance models would systematically understate LKR tail risk, particularly for USD/LKR, and they justify the Student's *t* GARCH specification adopted throughout the remainder of the analysis.

Table 1

Descriptive Statistics of Logarithmic Returns for LKR Bilateral Exchange Rates

Currency	Mean	Median	Min	Max	Std. dev.	Skewness	Kurtosis
USD/LKR	0.000175	0.000000	−0.04016	0.12719	0.003604	13.012	409.34
EUR/LKR	0.000162	0.000066	−0.04746	0.13113	0.005311	4.226	94.29
GBP/LKR	0.000159	0.000046	−0.05396	0.12661	0.005653	2.871	70.02
JPY/LKR	0.000083	0.000040	−0.04918	0.12354	0.005659	3.318	65.66
AUD/LKR	0.000126	0.000085	−0.07322	0.11883	0.006382	2.005	45.13

Table 2 presents the ARMA model selection results. USD/LKR is best captured by ARMA(2,1), with the lowest AIC (−45,732.81), while the most parsimonious model for EUR/LKR is ARMA(2,0). GBP/LKR, JPY/LKR and AUD/LKR share the ARMA(2,1) structure, suggesting correlated LKR depreciation dynamics. Residual variance is smallest for USD/LKR (0.0000129) and largest for AUD/LKR (0.0000375). Diagnostics confirmed significant residual autocorrelation and ARCH effects, motivating GARCH-class modelling. The recurring ARMA(2,1) structure across four pairs suggests that LKR depreciation is driven largely by a common domestic factor, most plausibly the supply–demand pressure on the rupee itself, rather than by currency-pair-specific shocks, reinforcing the case for unified modelling.

Table 2

ARMA Model Selection Results Based on AIC

Currency	Best model	AIC	BIC	Log-likelihood	σ^2
USD/LKR	ARMA(2,1)	−45732.81	−45699.81	22871.41	0.0000129
EUR/LKR	ARMA(2,0)	−44307.53	−44280.92	22157.76	0.0000251
GBP/LKR	ARMA(2,1)	−43491.61	−43458.36	21750.81	0.0000290
JPY/LKR	ARMA(2,1)	−43381.23	−43347.98	21695.61	0.0000291
AUD/LKR	ARMA(2,1)	−42010.14	−41976.88	21010.06	0.0000375

Note. σ^2 = estimated residual variance; AIC = Akaike information criterion; BIC = Bayesian information criterion.

Table 3 presents the coefficients of the best-fitting GARCH models: GJR-GARCH(1,1) for USD/LKR and EUR/LKR, and symmetric GARCH(1,1) for GBP/LKR, JPY/LKR and AUD/LKR. Near-unit-root persistence ($\alpha_1 + \beta_1 \approx 0.999$) across all pairs reflects near-integrated GARCH (IGARCH) behaviour arising from the 2022 debt collapse. The USD/LKR asymmetry parameter ($\gamma_1 = -0.1448$, $p < .001$) shows that negative shocks generate less volatility than positive shocks, the opposite of the leverage effect observed in equity markets, which is consistent with the anticipation of CBSL intervention. JPY/LKR shows the highest ARCH coefficient (0.6509) but the lowest GARCH coefficient (0.3481), reflecting transient volatility arising from the yen's safe-haven dynamics. Diagnostics confirm an adequate fit for USD/LKR, although persistent ARCH effects in the other pairs suggest a need for higher-order specifications. In practical terms, shocks from fuel-price spikes, political events or debt-restructuring news dissipate slowly, so hedges set during calm periods offer limited protection once turmoil begins.

Table 3

Estimated Coefficients of the Best-Fit GARCH Models (Student's t Innovations)

Currency	Model	α_0 (ω)	α_1 (ARCH)	β_1 (GARCH)	γ_1 (asym.)	Shape (ν)	$\alpha_1 + \beta_1$	AIC
USD/LKR	GJR-GARCH(1,1)	–	0.535^{***}	0.537^{***}	-0.145^{***}	4.327	0.999	−2.554
EUR/LKR	GJR-GARCH(1,1)	–	0.251^{***}	0.772^{***}	-0.046^{*}	4.947	0.999	0.706
GBP/LKR	GARCH(1,1)	–	0.264^{***}	0.735^{***}	–	5.335	0.999	0.759
JPY/LKR	GARCH(1,1)	0.0291	0.6509^{***}	0.3481^{***}	–	3.953	0.999	0.8584
AUD/LKR	GARCH(1,1)	–	0.2128^{***}	0.7862^{***}	–	5.544	0.999	1.2128

Note. γ_1 is reported only for GJR-GARCH models. Persistence = $\alpha_1 + \beta_1$ for GARCH(1,1) and $\alpha_1 + \beta_1 + \gamma_1/2$ for GJR-GARCH(1,1). $^{*}p < .05$. $^{***}p < .001$.

A VAR(2) model confirmed joint significance across all five equations ($p < .001$), with R^2 ranging from 5.95% (USD) to 12.80% (EUR), consistent with the low predictability of daily returns. All characteristic roots lie within the unit circle (maximum root = 0.4778), confirming structural stability. Table 4 presents the Granger causality results. USD/LKR unidirectionally Granger-causes all four other rates ($p < .001$), confirming the dominant causal role of the US dollar. FEVD at the 10-period horizon shows that USD innovations account for 44.73%, 41.71%, 40.82% and 32.99% of the forecast error variance in EUR/LKR, GBP/LKR, JPY/LKR and AUD/LKR, respectively.

Table 4

VAR(2)-Based Granger Causality Test Results

Dependent variable	Null hypothesis	*F*-statistic	*p*
USD/LKR	AUD, GBP, EUR, JPY do not Granger-cause USD	2.665	< .01
AUD/LKR	USD, GBP, EUR, JPY do not Granger-cause AUD	10.582	< .001
GBP/LKR	USD, AUD, EUR, JPY do not Granger-cause GBP	13.383	< .001
EUR/LKR	USD, AUD, GBP, JPY do not Granger-cause EUR	13.733	< .001
JPY/LKR	USD, AUD, GBP, EUR do not Granger-cause JPY	11.489	< .001

Table 5 compares the out-of-sample RMSE of ARIMA(1,1,1) and the OU model. ARIMA outperforms OU for four pairs (AUD, GBP, EUR and JPY), with RMSE reductions of 42–57%. The exception is USD/LKR, for which OU achieves superior accuracy (RMSE = 22.83 vs. 81.99), a 72.2% reduction, reflecting stronger mean-reverting characteristics anchored by CBSL managed-float interventions and the IMF stabilisation programme following the 2022 crisis (Hina & Qayyum, 2015). This divergence shows that no single forecasting model performs universally well: liquid pairs are better captured by autoregressive dynamics, whereas the heavily managed USD/LKR pair is better represented by a mean-reverting process anchored to policy intervention, a distinction relevant to firms selecting a forecasting approach according to their currency exposure.

Table 5

Out-of-Sample RMSE Comparison: OU Model vs. ARIMA(1,1,1)

Currency	OU model RMSE	ARIMA(1,1,1) RMSE
USD/LKR	22.835	81.994
AUD/LKR	15.836	7.332
GBP/LKR	42.570	20.286
EUR/LKR	46.689	27.058
JPY/LKR	0.186	0.079

In the ARDL bounds tests, all *F*-statistics (range: 0.325–2.179) fell below the lower-bound critical value of 3.65 at the 10% level, indicating no long-run cointegrating relationship between LKR volatility and the macroeconomic variables for any currency pair. The absence of cointegration is attributable to the small annual sample ($N = 16$), the severe structural break created by the 2022 crisis (inflation: 49.7%; interest rate: 28.5%; GDP: −7.8%) and possible I(2) behaviour in inflation. Nevertheless, the signs of the error-correction terms (ECT) for USD, GBP and JPY are negative (−0.072, −0.049 and −0.159), indicating the theoretically correct direction of error correction. VAR-based Granger causality confirms that the interest rate Granger-causes USD and AUD volatility ($p < .05$) and that GDP growth Granger-causes EUR and JPY volatility ($p < .05$), with strong contemporaneous explanatory power in ordinary least squares (OLS) regressions (R^2 = .788–.893).

Conclusions and Implications

This study examined the volatility dynamics, causal interdependencies and forecasting accuracy of the Sri Lankan rupee against five major currencies from May 2010 to December 2025. GARCH-class models confirmed near-integrated volatility persistence ($\alpha_1 + \beta_1 \approx 0.999$) across all pairs, with GJR-GARCH capturing asymmetric shocks for USD/LKR and EUR/LKR. VAR-based Granger causality established unidirectional USD/LKR dominance, explaining up to 44.73% of the EUR/LKR forecast error variance. ARIMA(1,1,1) outperformed the Ornstein–Uhlenbeck model for four pairs (RMSE reduction: 42–57%), while OU proved superior for USD/LKR, reflecting IMF-anchored mean reversion. The ARDL analysis found no long-run cointegration, although short-run causality confirms that interest rates and GDP growth influence LKR volatility.

These findings carry three main implications. Theoretically, a single-equation approach cannot capture LKR dynamics, since volatility persistence, causal spillovers and macro-financial linkages interact simultaneously and must be modelled jointly. For policy, unidirectional USD dominance suggests that the stabilisation efforts of the CBSL would benefit from monitoring USD-specific shocks and from pair-specific rather than uniform intervention. For practice, especially in agriculture, near-integrated persistence implies unpredictable export earnings for tea, rubber and coconut producers; USD dominance underscores the need for hedging instruments for plantation stakeholders; and, since no single model forecasts best, GARCH- and ARIMA/OU-based forecasts should inform agribusiness pricing and procurement to mitigate exposure.

***Keywords*:** Autoregressive integrated moving average, exchange rate volatility, generalised autoregressive conditional heteroscedasticity, Sri Lankan rupee, vector autoregression model

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Exploring Entrepreneurial Leadership Styles and Opportunity Identification Among Micro-Entrepreneurs in the North Central Province

Maddumage M.O.W.* and Cooray N.H.K.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: omalwihangamaddumage@email.com)

Introduction

Entrepreneurship is widely recognised as a key driver of economic development, employment generation, innovation and regional resilience, particularly in resource-constrained economies (Acs et al., 2018). In Sri Lanka, micro-entrepreneurs make a significant contribution to rural livelihoods and local economic development, especially in the North Central Province (NCP). However, despite operating under similar environmental and resource constraints, entrepreneurs differ considerably in their ability to identify and exploit strategic business opportunities, suggesting that entrepreneurial success depends on internal capabilities as well as on external resources (Baron, 2006; Shane & Venkataraman, 2000). Although entrepreneurial leadership and opportunity identification have been widely studied, few studies have examined this relationship in rural micro-enterprises, and most have used quantitative approaches.

Guided by the resource-based view (RBV; Barney et al., 2001), this study addresses these contextual and methodological gaps by exploring how entrepreneurial leadership styles support opportunity identification among micro-entrepreneurs in the North Central Province of Sri Lanka. Specifically, the study aimed to explore the different leadership styles practised by micro-entrepreneurs in the NCP and to examine how these leadership styles function as intangible drivers in identifying strategic opportunities. The findings demonstrate that entrepreneurial leadership functions as a valuable intangible strategic asset that facilitates opportunity identification and sustainable business development in resource-constrained rural contexts.

Methodology

To explore how entrepreneurial leadership styles support opportunity identification among micro-entrepreneurs in the North Central Province of Sri Lanka, this study adopted an interpretivist research philosophy and an inductive research approach. The interpretivist approach was the more appropriate because the study sought a deeper understanding of the subjective experiences, perceptions and leadership behaviours of entrepreneurs in their natural business context. In line with this philosophical stance, the inductive approach enabled the researcher to generate context-specific insights from the participants' real-life experiences rather than to test predetermined hypotheses. Accordingly, a qualitative exploratory research design was used to investigate this phenomenon, which has not received sufficient empirical attention in the resource-limited rural micro-enterprise sector.

Ten micro-entrepreneurs representing diverse business sectors across the NCP were selected through purposive sampling. Participants were selected on the basis of predefined inclusion criteria relevant to the study, including their status as micro-entrepreneurs and

sufficient entrepreneurial experience to provide information relevant to the research objectives. Primary data were collected through semi-structured interviews conducted entirely in Sinhala, enabling participants to express their experiences naturally and in depth. Data saturation was reached after the tenth interview, as no substantially new themes emerged from the subsequent analysis. Reflexive thematic analysis (Braun & Clarke, 2006) was used to analyse the data, with NVivo software used to organise and code the data systematically. Through this formal analysis process, the researcher was able to identify recurring patterns in the challenges faced by entrepreneurs, their leadership practices and the role of leadership as an intangible strategic asset in identifying new opportunities.

Results and Discussion

The findings revealed that micro-entrepreneurs in the North Central Province operate amid environmental uncertainty, financial constraints, operational challenges and limited institutional support. Despite such obstacles, successful entrepreneurs demonstrated high resilience by combining transformational, democratic and servant leadership practices to sustain their operations and identify new opportunities. Transformational leadership promoted strategic vision, innovation and business diversification, while democratic leadership fostered collaborative decision-making and knowledge sharing. Servant leadership, in turn, strengthened employee commitment, stakeholder trust and long-term relationships.

The key finding of this study is that these leadership styles do not operate independently. Instead, they collectively operate as a highly valuable "intangible strategic asset", which enables entrepreneurs to interpret environmental changes, manage limited resources effectively, identify market opportunities and transform challenges into strategic opportunities. This finding extends previous research by confirming that the combined use of these leadership styles creates a unique strategic capability to identify opportunities in rural micro-enterprises.

Consistent with the RBV, the findings demonstrate that entrepreneurial leadership extends beyond a managerial function and operates as a valuable internal capability that enhances opportunity identification, organisational resilience and sustainable business development. Overall, the study provides qualitative evidence that entrepreneurial leadership functions as a strategic mechanism for transforming environmental constraints into strategic business opportunities, thereby contributing to the long-term sustainability of rural micro-enterprises.

Conclusions and Implications

This study concludes that entrepreneurial leadership serves as a critical "intangible strategic asset" for identifying strategic business opportunities in resource-limited rural environments. Successful micro-entrepreneurs do not rely solely on one leadership style but dynamically combine transformational, democratic and servant leadership practices to overcome environmental challenges and transform them into business opportunities. This further extends the RBV by showing that leadership is not merely a managerial

function but a valuable internal capability that creates sustainable competitive advantage through the identification of new opportunities.

According to these findings, developing the leadership capabilities of entrepreneurs is as important as providing financial and physical resources. Therefore, entrepreneurship development programmes should provide leadership training, training in opportunity identification and strategic thinking, and mentoring services in addition to financial support. It is essential that policymakers prioritise programmes that strengthen these intangible capabilities in order to enhance entrepreneurs' resilience, business sustainability and regional economic development, especially in resource-poor environments.

Figure 1

Empirical Model of Entrepreneurial Leadership



The empirical model developed through this study (Figure 1) illustrates that entrepreneurial leadership is a critical bridge between environmental challenges and strategic business opportunities. The model demonstrates how the above leadership styles work together to overcome obstacles and achieve successful and sustainable entrepreneurship. Overall, this study contributes directly to the entrepreneurship and RBV literature by providing a specific explanation of how leadership influences business success and the identification of new opportunities in resource-limited rural micro-enterprises.

Keywords**:** Entrepreneurial leadership, micro-entrepreneurs, North Central Province, opportunity identification, resource-based view

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The Impact of Sustainable Packaging on Brand Loyalty With Special Reference to the Food and Beverage Industry in Ampara District, Sri Lanka Among Generation Z

Jowdath Aadhil M.Z.* and Wasana K.M.L.K.
Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: msjaathil@gmail.com)

Introduction

Environmental issues, increasing packaging waste and global warming have compelled firms to embrace sustainability in business. Sustainable packaging has become a critical part of the operations of food and beverage businesses because of its minimal environmental impact and favourable reputation among consumers (Ketelsen et al., 2020). Sustainable packaging involves the use of recyclable, reusable and biodegradable materials without affecting the quality and safety of products (Duarte et al., 2024). With growing environmental awareness among the public, especially Generation Z, concern about the environmental impact of purchases is increasing. Generation Z is considered an environmentally conscious consumer segment that tends to favour brands with authentic sustainability efforts. Sustainable packaging helps to improve brand perceptions, reduce environmental impact and gain competitive advantage. Organisations therefore use sustainable packaging to build customer relationships and gain competitive advantage (Karunarathne et al., 2025; Ketelsen et al., 2020). Brand loyalty reflects a consumer's commitment to purchase a preferred brand repeatedly and to maintain a favourable relationship with it (Oliver, 1999).

Previous studies have reported that sustainable packaging positively influences consumers' purchase intentions, perceived value, environmental concern and attitudes towards environmentally responsible products (Boz et al., 2020; Swarnika & Rathnasiri, 2022). However, limited research has examined the relationship between consumer constructs related to sustainable packaging and brand loyalty among Generation Z consumers in the Sri Lankan food and beverage industry, particularly in Ampara District. Therefore, this study examines the relationships of perceived value, willingness to pay, environmental concern and attitude towards sustainable packaging with brand loyalty among Generation Z consumers in Ampara District, Sri Lanka.

Methodology

This study used a quantitative explanatory research design guided by a deductive research approach. A cross-sectional survey was conducted to examine the relationships between the consumer constructs related to sustainable packaging and brand loyalty among Generation Z consumers in the food and beverage industry in Ampara District, Sri Lanka. The quantitative approach is considered appropriate because it enables the researcher to examine relationships among variables using numerical data and statistical techniques. The deductive approach further supports hypothesis testing based on existing theories and previous empirical studies related to sustainable packaging and brand loyalty. The target population comprised Generation Z consumers who purchase food and beverage products

in Ampara District. A convenience sampling technique was employed owing to accessibility and resource constraints, particularly the difficulty of obtaining a complete sampling frame of Generation Z consumers in Ampara District. A sample of 384 respondents was selected on the basis of the sample size determination guidelines of Krejcie and Morgan (1970).

Primary data were collected using a structured questionnaire with items measured on a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). The measurement items for perceived value, willingness to pay, environmental concern and attitude towards sustainable packaging were adapted from Duarte et al. (2024), while the measurement items for brand loyalty were adapted from Oliver (1999). The data were screened for completeness and analysed using SPSS. The reliability of the measurement scales was assessed using Cronbach's alpha, with values ranging from .850 to .928, indicating satisfactory internal consistency. Construct validity was assessed using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity, with a KMO value of .885 and a significant Bartlett's test ($p < .001$), supporting the suitability of the data for factor analysis.

Results and Discussion

The findings revealed a significant positive relationship between the examined consumer constructs related to sustainable packaging and brand loyalty among Generation Z consumers in the food and beverage industry in Ampara District, Sri Lanka. Correlation analysis indicated a strong positive relationship between sustainable packaging and brand loyalty ($r = .866$, $p < .001$). The multiple regression model was statistically significant, $F(4, 379) = 331.270$, $p < .001$, explaining 77.8% of the variance in brand loyalty ($R^2 = .778$; adjusted $R^2 = .775$).

The variance inflation factor (VIF) values ranged from 2.539 to 4.355, indicating that multicollinearity was within acceptable levels. Among the examined constructs, willingness to pay showed the strongest positive influence on brand loyalty ($\beta = .468$, $p < .001$), followed by attitude towards sustainable packaging ($\beta = .260$, $p < .001$), perceived value ($\beta = .133$, $p = .009$) and environmental concern ($\beta = .109$, $p = .017$). These findings indicate that Generation Z consumers are more likely to remain loyal to food and beverage brands that adopt environmentally responsible packaging practices.

These findings are broadly consistent with previous studies suggesting that environmentally responsible packaging practices and positive consumer perceptions can contribute to favourable brand-related outcomes (Boz et al., 2020; Duarte et al., 2024). They are also broadly consistent with selected aspects of the Theory of Planned Behaviour, particularly the role of consumer attitudes in shaping behavioural responses (Ajzen, 1991). However, the present study does not test the complete Theory of Planned Behaviour model. The analysis also determined the relative impact of each of these variables on brand loyalty, thereby identifying which of the four variables has the greatest impact on Generation Z consumers' loyalty towards food and beverage brands.

Conclusions and Implications

On the basis of the findings, the examined consumer constructs related to sustainable packaging demonstrated significant positive associations with brand loyalty among Generation Z consumers in the food and beverage industry in Ampara District, Sri Lanka. Perceived value, willingness to pay, environmental concern and attitude towards sustainable packaging were significantly associated with brand loyalty, with willingness to pay demonstrating the strongest association among the examined constructs. These findings suggest that consumer perceptions of and responses to sustainable packaging may be important considerations for food and beverage brands seeking to strengthen customer loyalty. Hence, sustainable packaging may be regarded as an effective marketing strategy for food and beverage organisations seeking to develop good customer relationships. The study contributes context-specific evidence to the literature on sustainable marketing and brand loyalty by examining these relationships among Generation Z consumers in the Sri Lankan food and beverage context.

From a practical perspective, food and beverage organisations may consider integrating environmentally responsible packaging into their broader branding and customer relationship strategies. Communicating the value and environmental benefits of sustainable packaging may help to strengthen favourable consumer perceptions and loyalty-related outcomes. Moreover, the research has implications for policymakers and environment-related non-governmental organisations seeking to promote sustainable consumption and to persuade enterprises to implement sustainable packaging strategies. The findings should be interpreted in light of the study's limitations, including its focus on Generation Z consumers in Ampara District and the use of convenience sampling, which limits the generalisability of the findings. Future research could examine sustainable packaging and brand loyalty in other sectors, regions and target audiences.

Keywords**:** Brand loyalty, food and beverage industry, Generation Z, Sri Lanka, sustainable packaging

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Exploring Spatial Vulnerability in Public Transportation Spaces

Thathsarani M.M.D.* and Cooray N.H.K.
Department of Marketing Management, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: dinurithathsarani2002@gmail.com)

Introduction

Public transportation is vital for supporting daily mobility and social participation, particularly in developing countries, where a large proportion of the population depends on public transport services. The bus system remains the most common form of transportation in Sri Lanka and provides affordable and accessible transport for work, education, healthcare and other essential activities. Beyond its functional role, public transport operates as a consumption and social space in which people navigate environments, interact with one another and experience their daily lives. However, these experiences are not the same for all users. Women frequently experience discomfort, fear and a lack of control during travel, largely owing to sexual harassment and safety concerns (Rajaguru, 2018).

While women's safety and sexual harassment in public transport have been studied, there is limited research on how the resulting feelings of powerlessness and tension actively produce spatial vulnerability, particularly in the Sri Lankan context (Clark, 2021). Most previous studies have focused on prevalence rates and behavioural outcomes rather than on the interaction between space, environment and perception, and few include qualitative insights that capture women's lived experiences.

This study addresses that gap by exploring how spatial dynamics, sexual harassment and safety concerns contribute to spatial vulnerability among female consumers travelling along the Colombo–Anuradhapura bus corridor. The study seeks to explore the sources of spatial vulnerability of women in public transportation spaces, to explore coping strategies in response to spatial vulnerability and to understand the role of community and social support in reducing spatial vulnerability.

Methodology

This study was guided by an interpretivist philosophy and an inductive approach to explore women's experiences of spatial vulnerability in public transportation spaces. An interpretivist approach was appropriate because the research is concerned with understanding the subjective meanings, perceptions and lived experiences associated with spatial vulnerability rather than with measuring an objective reality (Saatcioglu & Ozanne, 2013). A qualitative research design was used to explore in-depth experiences of, emotional responses to and coping behaviours in relation to spatial vulnerability (Baker et al., 2007). Data were collected through in-depth semi-structured interviews with 10 female passengers aged between 18 and 30 years who travelled on the Colombo–Anuradhapura bus corridor and were selected through purposive sampling. Interviews were conducted in Sinhala, both face to face and via Zoom. The data were analysed using reflexive thematic analysis as described by Braun and Clarke (2006). Coding was carried

out in NVivo, and related codes were then iteratively grouped, reviewed and refined to create meaningful themes.

Results and Discussion

The analysis generated four major themes: sources of spatial vulnerability, experience of spatial vulnerability, individual responses to spatial vulnerability and collective responses to spatial vulnerability. Three sources of spatial vulnerability emerged from the data.

Spatial dynamics emerged as one of the primary sources of spatial vulnerability experienced by women in public transportation spaces. Factors such as overcrowding and sleep-related risk actively generate spatial vulnerability. As one participant explained, "Our buses are very crowded … it creates situations where there is a chance of unwanted or intentional rubbing. They start saying things like, 'this bus is too crowded, where are we supposed to move?' and it becomes a chance for them." This illustrates that overcrowding is not only a physical inconvenience but an active spatial dynamic. Sexual harassment was another source of spatial vulnerability experienced by women in public transportation spaces. Sexual harassment, including physical touching, inappropriate leaning and rubbing, and non-verbal harassment, actively generates spatial tension, which in turn produces vulnerability. Safety concerns, including poor lighting, repeated exposure to familiar "route harassers" and the resurfacing of childhood experiences of harassment, formed a further source that created feelings of insecurity, showing that vulnerability can be both situational and carried forward over time (Clark, 2021).

As a result of these sources, women experienced spatial vulnerability through a range of feelings, including fear, discomfort, insecurity and helplessness, when confronted with vulnerable situations. In response, women employed a range of individual coping strategies, including avoiding male proximity, physical displacement, protective positioning and defensive eye contact owing to fear of social or digital exposure. These behavioural and cognitive coping mechanisms are in line with the findings of Echeverri and Salomonson (2019) that women often rely on individual strategies in public transportation environments where institutional protection is limited.

At the collective level, responses from fellow passengers, drivers and conductors were largely passive, with bystanders often witnessing incidents without intervening. One participant said, "At that moment, I felt a strong sense of helplessness. I wished someone was there to help me. I felt like I had no one with me at that time, so I felt very helpless." Another participant said, "At that time, there were boys sitting in the nearby seats, and they were all just watching, but they did not say anything or react. Only the two of us were left in that situation." These narratives show that the silence of the community was interpreted not merely as inaction but as a social signal that harassment was often normalised as an ordinary feature of commuting.

Overall, the findings show that spatial dynamics, sexual harassment and safety concerns within public transportation shape women's experiences of vulnerability through feelings of powerlessness and insecurity, and that a lack of community support further increases vulnerability.

Conclusions and Implications

This study extends the construct of spatial vulnerability into the previously unexamined context of public transportation as a consumption space. Prior to this study, spatial vulnerability was understood as tension existing within social spaces such as commercial retail environments, public parks, housing and digital spaces. What was not known was whether public transportation, as a distinct type of consumption space, also carries such tension. The findings confirm that public transportation space already carries the forms of tension described by Saatcioglu and Corus (2016).

The study further found that this tension is increased by the absence of community support within public transportation space. Baker et al. (2005, p. 136) argue that most people cope with vulnerable conditions, especially when social support is provided. The findings confirm this directly: when even minimal support was offered by a fellow passenger, women's feelings of powerlessness were noticeably reduced. Creating safer public transportation spaces therefore requires the development of a culture of shared responsibility, in which passengers, transport employees, authorities and the wider community actively contribute to preventing and responding to experiences of spatial vulnerability.

Accordingly, targeted recommendations are proposed to strengthen community involvement and active protection within public bus transportation spaces. These include implementing a social marketing campaign to encourage active bystander intervention by educating passengers on how to support victims safely and challenge harassment; strengthening service quality through gender-sensitive customer service training for bus drivers and conductors to improve their awareness and response capabilities; and implementing social marketing initiatives to reduce victim-blaming attitudes that discourage women from reporting harassment or seeking support after experiencing it. This study is limited to a single long-distance bus corridor, relies on self-reported experiences that may be affected by recall bias and excludes the perspectives of other actors such as male passengers, conductors and drivers.

Keywords**:** Community apathy, consumption space, public transportation, spatial vulnerability, women's safety

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The Impact of Social Media Influencers' Reputation Signals on Consumer Purchase Intention: The Mediating Role of Parasocial Relationships With Influencers in the Context of Beauty Brands in the Western Province of Sri Lanka

Jayawardhan J.G.H.B.* and Hendeniya H.M.U.S.
Department of Marketing Management, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: rasikak565@gmail.com)

Introduction

The rapid growth of social media has established influencers as a core element of digital marketing strategies (Belanche et al., 2021), particularly in the beauty industry, where consumers rely heavily on influencer reviews and recommendations before making a purchase (Lou & Yuan, 2019; Sokolova & Kefi, 2020).

The effectiveness of influencer marketing is shaped by influencers' reputation signals, namely communication skills, perceived expertise, perceived authenticity, and influence (persuasiveness). Source Credibility Theory holds that credible, expert sources strengthen consumer trust and purchase intention (Ohanian, 1990), while clear communication and persuasive delivery further build message acceptance and opinion leadership (Lou & Yuan, 2019). Beyond credibility, consumers often develop parasocial relationships with influencers, a one-sided emotional attachment formed despite the absence of genuine reciprocity (Horton & Wohl, 1956), which increases trust and receptivity towards recommendations (Chung & Cho, 2017).

Although influencer marketing is expanding in Sri Lanka, evidence on how reputation signals affect purchase intention through parasocial relationships remains limited, especially in the beauty industry. This study focuses on the Western Province, Sri Lanka's most populous province and leading commercial hub, which has a high concentration of beauty retail brands and digitally active consumers (Department of Census and Statistics, 2021). Grounded in stimulus–organism–response (S-O-R) theory (Mehrabian & Russell, 1974), in which reputation signals are the stimulus, parasocial relationships the organism, and purchase intention the response, this study addresses the following question: what effect do social media influencers' reputation signals have on consumer purchase intention, and to what extent do parasocial relationships mediate this effect for beauty brands in the Western Province of Sri Lanka?

Methodology

This study adopted a quantitative, positivist design with a deductive approach and a cross-sectional survey. The target population comprised social media users in the Western Province who follow beauty influencers; 384 respondents were selected by purposive sampling and surveyed using a structured questionnaire with previously validated five-point Likert-scale items. Reputation signals were operationalised as a multidimensional construct (communication skills, expertise, authenticity, and influence); parasocial relationships were measured using established parasocial-interaction items; and purchase intention was measured as the self-reported likelihood of purchase. Data were analysed

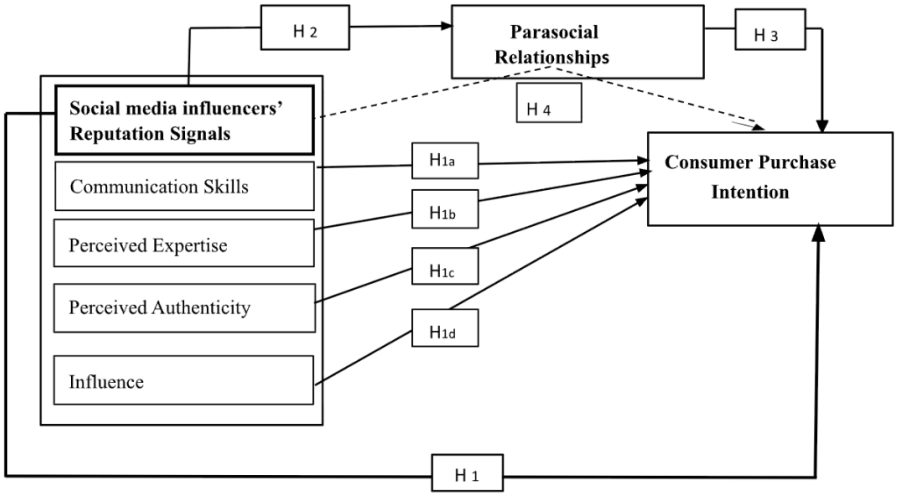
in SPSS Version 26, and reliability and validity were confirmed using Cronbach's alpha, the Kaiser–Meyer–Olkin (KMO) measure, and Bartlett's test. Pearson correlation and multiple regression analyses tested the proposed relationships, and the PROCESS macro (Model 4; Hayes, 2022) tested mediation, with the significance of the indirect effect determined using a 95% bootstrap confidence interval (BootCI).

In this study, influencer reputation signals are operationalised through four dimensions: communication skills, perceived expertise, perceived authenticity, and influence (persuasiveness). Communication skills represent the influencer's ability to deliver clear and engaging messages, while perceived expertise reflects knowledge and competence regarding beauty products. Perceived authenticity refers to the extent to which followers perceive influencer recommendations as genuine and trustworthy, whereas influence represents the persuasive ability to shape consumer attitudes and purchase decisions. Parasocial relationships are measured through consumers' perceived emotional attachment and connection to influencers, while purchase intention represents consumers' willingness to purchase beauty products recommended by influencers.

Figure 1 presents the conceptual framework, in which reputation signals and their four underlying dimensions are hypothesised to affect purchase intention both directly and indirectly through parasocial relationships.

Figure 1

Conceptual Framework of the Study



Accordingly, the following hypotheses were tested. H1: Social media influencers' reputation signals have a significant positive impact on consumer purchase intention. H1a–H1d: Communication skills, perceived authenticity, perceived expertise, and influence (persuasiveness), respectively, have a significant positive impact on consumer purchase intention. H2: Reputation signals have a significant positive impact on parasocial relationships with influencers. H3: Parasocial relationships have a significant

positive impact on consumer purchase intention. H4: Parasocial relationships mediate the relationship between reputation signals and consumer purchase intention.

Results and Discussion

Reliability and validity were strong (Cronbach's α = .921; KMO > .6; Bartlett's test, $p <$ .001). Pearson correlations among all variables were significant and positive ($p < .01$): reputation signals correlated strongly with purchase intention ($r = .845$) and with parasocial relationships ($r = .883$), and parasocial relationships correlated with purchase intention ($r = .720$). Reputation signals significantly predicted purchase intention ($R^2 = .579$, $F = 130.225$, $p < .001$), supporting H1; among the four dimensions, influence was the strongest predictor (β = .269), followed by communication skills (β = .239), authenticity (β = .182), and expertise (β = .169; all $p < .01$), supporting H1a–H1d. Reputation signals also significantly predicted parasocial relationships (β = .883, $R^2 = .780$, $p < .001$), supporting H2, and parasocial relationships in turn predicted purchase intention (β = .720, $p < .001$), supporting H3.

The mediation analysis (PROCESS macro, Model 4; Hayes, 2022) confirmed partial mediation: both the direct effect ($B = .565$, $p < .001$) and the indirect effect ($B = .273$, $SE = .057$, 95% BootCI [.165, .387]) were significant, supporting H4. The significance of the bootstrapped indirect effect is established by this confidence interval rather than by a *p*-value (Hayes, 2022). All hypotheses were supported, consistent with S-O-R theory and prior research (Chung & Cho, 2017; Lou & Yuan, 2019; Sokolova & Kefi, 2020; Taher et al., 2022), and the findings extend this literature to the Sri Lankan beauty industry.

Conclusions and Implications

This study found that social media influencers' reputation signals significantly and positively affect consumer purchase intention for beauty brands in the Western Province of Sri Lanka, both directly and indirectly through parasocial relationships, which partially mediate this effect. Influence (persuasiveness) was the strongest contributing dimension, followed by communication skills, authenticity, and expertise.

Theoretically, the study extends S-O-R theory to the beauty industry in an emerging economy. Practically, beauty brands should prioritise influencers with strong persuasive ability and communication skills while fostering authentic, engaging content that builds parasocial connections. The study is limited by its geographic focus, cross-sectional design, and purposive sampling; future research should extend this model to other regions and examine additional factors such as consumer trust and electronic word-of-mouth.

***Keywords*:** Beauty brands, consumer purchase intention, parasocial relationships, reputation signals, social media influencers

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The Impact of Product Placement Advertising on Consumer Purchase Intention of Gen Z With the Mediation of Brand Recall: Special Reference to the Automobile Industry in the Western Province, Sri Lanka

Kumari R.* and Hendeniya H.M.U.S.
Department of Marketing Management, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: rasikak565@gmail.com)

Introduction

The effectiveness of traditional advertising has increasingly been challenged by advertising clutter, ad-skipping technologies, and the growing use of streaming platforms, which enable consumers to avoid conventional advertisements (Gamage et al., 2023; Grzyb et al., 2018). Consequently, product placement advertising has emerged as an alternative promotional strategy that integrates brands into entertainment content and provides a less intrusive form of marketing communication (Russell, 2002; Soba & Aydin, 2013). This strategy is particularly relevant to the automobile industry, as automobiles are a prominent product category featured in motion pictures and other entertainment content (Davtyan et al., 2021). Generation Z is an important target group because of its high engagement with films, series, and streaming content and its greater tendency to avoid conventional advertising formats (Ghanem et al., 2024; Puspanathan et al., 2024).

Previous research indicates that the effectiveness of product placement can depend on specific placement characteristics. The present study conceptualises Product Placement Advertising through plot connection, product prominence, and movie actor presence. Plot connection represents the extent to which the placed automobile is meaningfully connected to the storyline; product prominence reflects the extent to which the placed product attracts audience attention through its visibility and presentation; and movie actor presence refers to the involvement of an actor or character with the placed product.

Although previous studies have examined product placement and purchase intention and have identified brand recall as an important cognitive mechanism, empirical evidence concerning the mediating role of brand recall in the relationship between product placement advertising and purchase intention among Generation Z consumers in the Sri Lankan automobile industry remains limited (Canoza et al., 2025; Gamage et al., 2023; Puspanathan et al., 2024). Furthermore, existing Sri Lankan research has not adequately addressed the combined effect of the three placement dimensions, Generation Z, the automobile industry, and brand recall as a mediator within the Western Province. Therefore, this study aims to examine the impact of Product Placement Advertising and its three dimensions (plot connection, product prominence, and movie actor presence) on consumer purchase intention among Generation Z consumers, and the mediating role of brand recall, in the automobile industry in the Western Province of Sri Lanka.

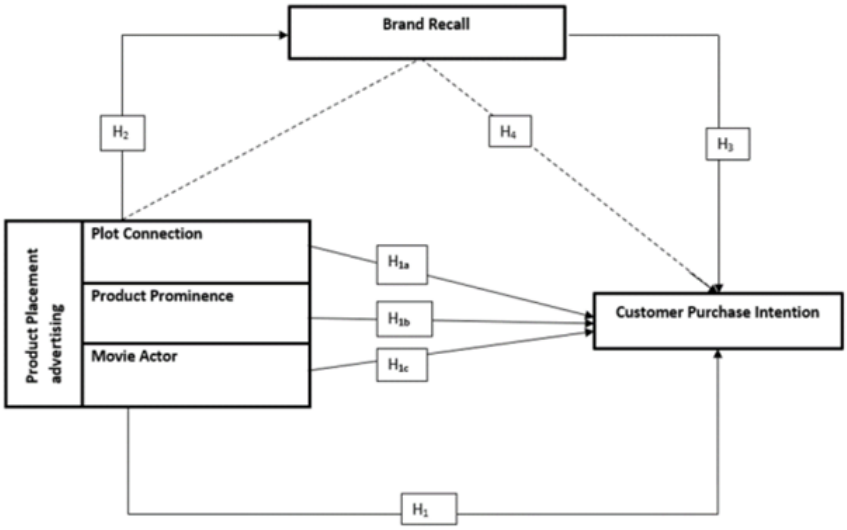
Methodology

The study adopted a positivist philosophy and a deductive approach using an explanatory, quantitative, cross-sectional survey design. This approach was considered appropriate

because the study sought to test empirically the hypothesised relationships among Product Placement Advertising, its dimensions, brand recall, and consumer purchase intention using numerical data and statistical techniques (Saunders et al., 2019). The research framework (Figure 1) positioned Product Placement Advertising as the independent variable, represented by plot connection, product prominence, and movie actor presence; brand recall as the mediating variable; and consumer purchase intention as the dependent variable. The hypotheses examined the direct effects of Product Placement Advertising and its dimensions on purchase intention, the effect of Product Placement Advertising on brand recall and of brand recall on purchase intention, and the mediating effect of brand recall.

Figure 1

Conceptual Framework



The target population consisted of Generation Z consumers aged 18–24 years residing in the Western Province of Sri Lanka who had been exposed to product placement in films or streaming content related to the automobile industry. Since no complete sampling frame was available for this population, a non-probability convenience sampling technique was employed, whereby respondents were selected on the basis of their accessibility and willingness to participate. A total of 400 questionnaires were distributed, and 386 valid responses were retained after screening. Data were collected through a structured online questionnaire using a five-point Likert scale. The measurement items for the three Product Placement Advertising dimensions were adapted from validated scales reported by Bruner (2009), while brand recall and consumer purchase intention were measured using validated scales from Puspanathan et al. (2024).

Results and Discussion

The measurement scales demonstrated strong internal consistency, with an overall Cronbach's alpha of .905, while construct validity was supported by an overall Kaiser–Meyer–Olkin (KMO) value of .961 and a significant Bartlett's test ($p < .001$). The multiple regression results demonstrated that plot connection, product prominence, and movie actor presence jointly explained 57.3% of the variance in consumer purchase intention ($R^2 = .573$, $F = 170.856$, $p < .001$). All three dimensions had significant positive effects. Movie actor presence was the strongest predictor ($\beta = .407$, $p < .001$), followed by product prominence ($\beta = .236$, $p < .001$) and plot connection ($\beta = .226$, $p < .001$). These findings indicate that the presence and association of actors with placed automobile brands may be particularly influential in shaping Generation Z consumers' purchase intentions, while the visibility and meaningful integration of the automobile within the storyline also contribute significantly.

At the composite construct level, Product Placement Advertising significantly predicted consumer purchase intention ($\beta = .752$, $R^2 = .566$, $p < .001$) and brand recall ($\beta = .804$, $R^2 = .646$, $p < .001$). Brand recall also significantly predicted consumer purchase intention ($\beta = .790$, $R^2 = .624$, $p < .001$). These results are consistent with previous evidence showing that product placement can strengthen brand-related memory and purchase responses, and that brand recall represents an important mechanism connecting product placement exposure with purchase intention (Canoza et al., 2025; Puspanathan et al., 2024).

The mediation analysis further revealed a significant total effect of Product Placement Advertising on purchase intention (effect = 0.727, $p < .001$). Product Placement Advertising significantly predicted brand recall ($\beta = .786$, $p < .001$), while brand recall significantly predicted purchase intention when controlling for product placement ($\beta = .518$, $p < .001$). The direct effect remained significant after brand recall was introduced (effect = 0.320, $p < .001$), and the indirect effect through brand recall was also significant (effect = 0.407, 95% CI [0.316, 0.497]). Since both the direct and indirect effects were significant, brand recall partially mediates the relationship between Product Placement Advertising and consumer purchase intention. This finding is consistent with Puspanathan et al. (2024), who identified a similar mediating role of brand recall among moviegoers, and supports evidence that memory-related responses can contribute to purchase-related outcomes among Generation Z consumers.

Conclusions and Implications

The findings demonstrate that Product Placement Advertising significantly influences Generation Z consumers' purchase intention in the Sri Lankan automobile context, both directly and through brand recall. The significant effects of plot connection, product prominence, and movie actor presence confirm that the effectiveness of product placement is determined not solely by exposure but also by how the brand is integrated, presented, and associated with actors within entertainment content. Among the three dimensions, movie actor presence emerged as the strongest predictor, highlighting the

importance of credible and engaging actor–brand associations in automobile product placement.

The significant partial mediation by brand recall provides an important theoretical contribution by demonstrating that memory-related processing is one mechanism through which product placement influences purchase intention, while the remaining direct effect suggests that other responses to product placement may also contribute to purchase intention. From a managerial perspective, automobile marketers and advertising practitioners should design placements that simultaneously enhance visibility, meaningful storyline integration, and memorable actor–brand associations rather than relying solely on product exposure. Strengthening brand recall through strategically designed placements may help automobile brands remain accessible during consumers' subsequent purchase consideration.

The study is limited to Generation Z consumers in the Western Province and uses a cross-sectional, non-probability convenience sample; therefore, the findings should be interpreted within this contextual scope. Future studies could extend the geographical coverage to other regions of Sri Lanka, examine other consumer segments and industries, and incorporate additional mediating or moderating variables to further explain product placement effectiveness.

***Keywords*:** Automobile industry, brand recall, consumer purchase intention, Generation Z, product placement advertising

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The Psychological Impact of Using AI Chatbots to Discuss Mental Health among State University Students

Werellagama W.M.R.A.U.* and Senarath T.U.S.
Department of Information Systems, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: amashawerellagama@email.com)

Introduction

The increasing prevalence of mental health concerns among university students, together with the rapid development of artificial intelligence (AI), has created new opportunities for technology-mediated emotional support. According to the World Health Organization, mental health is a state of well-being in which individuals can cope with life's stresses, realise their abilities, learn and work productively, and contribute to their communities. In this study, mental health concerns are examined through four psychological dimensions: Emotional Relief, Self-Expression and Openness, Stress or Anxiety Levels, and Emotional Intelligence. Emotional Intelligence refers to the capacity to perceive, understand, manage, and constructively use emotions (Salovey & Mayer, 1990; Wong & Law, 2002). International evidence indicates a substantial mental health burden among university students, with reported prevalence rates of depression at 49%, anxiety at 75%, and stress at 73% among first-year undergraduates (Auerbach et al., 2023).

The mental health burden is also evident in the Sri Lankan higher education context. Abayaratna et al. (2023), in a cross-sectional study of University of Ruhuna undergraduates, reported elevated stress, anxiety, and depression associated with academic pressure and insufficient institutional support. Students may also face financial hardship and barriers to professional support, including stigma, cost, the limited availability of qualified professionals, and reluctance to disclose personal difficulties in face-to-face settings. AI chatbots have therefore emerged as an accessible alternative, offering 24/7 availability, anonymity, and a perceived non-judgemental environment (Alsayed et al., 2024; Chin et al., 2023).

However, AI chatbots also raise concerns regarding response quality and reliability, emotional dependence, and their inability to fully replicate human interaction and professional psychological support (Al-Zahrani, 2025; Amer et al., 2024). Despite growing interest in AI-based emotional support, empirical evidence concerning its psychological impact remains limited within the Sri Lankan higher education context. Therefore, this study aimed to examine the psychological impact of using AI chatbots as a medium for expressing mental health concerns among state university students in Sri Lanka. Four objectives examined Emotional Relief, Self-Expression and Openness, Stress or Anxiety Levels, and Emotional Intelligence, with four corresponding hypotheses (H1–H4).

Methodology

A positivist, deductive, quantitative cross-sectional survey design was employed, guided by the Stimulus–Organism–Response (S-O-R) framework (Mehrabian & Russell, 1974).

Primary data were collected via a structured online questionnaire distributed to undergraduates across all 17 state universities in Sri Lanka. The target population comprised 198,106 students (University Grants Commission, 2022). The unit of analysis was the individual undergraduate student. Using Morgan's (1970) table at a 95% confidence level and a 5% margin of error, the required sample size was 384. The sample was proportionally distributed across universities, with respondents recruited through convenience and snowball sampling. Of the 392 responses received, 19 from non-users of AI chatbots were excluded via a filter question, yielding 373 valid responses for inferential analysis.

The independent variable, AI Chatbot Usage, was operationalised through four dimensions: Usage Patterns, Usage Purpose, Emotional Disclosure, and Reliance (Chin et al., 2023; Hua et al., 2025; Rackoff et al., 2025). The dependent variables were Emotional Relief, operationalised as the perceived reduction in emotional burden after interactions with AI chatbots; Self-Expression and Openness, operationalised as the comfort and willingness to disclose personal thoughts and feelings; Stress or Anxiety Levels, operationalised as perceived psychological tension, worry, and the ability to cope with academic and personal demands; and Emotional Intelligence, operationalised as the perceived ability to understand, regulate, and use emotions effectively, adapted from Wong and Law (2002). All items were measured on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Data were analysed using IBM SPSS Statistics (Version 27) through Cronbach's alpha (reliability), the Kaiser–Meyer–Olkin (KMO) measure, Bartlett's test of sphericity and average variance extracted (AVE) (validity), descriptive statistics, Pearson correlation, and simple linear regression. Hypotheses were tested at $p < .05$.

Results and Discussion

The findings demonstrated statistically significant relationships between AI Chatbot Usage and all four psychological dimensions. The strongest relationship was observed between AI Chatbot Usage and Emotional Relief ($r = .808$, $p < .001$), with AI Chatbot Usage explaining 65.3% of the variance in Emotional Relief ($R^2 = .653$). This suggests that students who reported greater engagement with AI chatbots also tended to report greater perceived emotional relief after expressing their concerns.

A strong positive relationship was also identified between AI Chatbot Usage and Self-Expression and Openness ($r = .749$, $p < .001$). The regression model indicated that AI Chatbot Usage explained 56.2% of the variance in this construct ($R^2 = .562$). This suggests that students who engage more with AI chatbots tend to report greater openness in expressing their thoughts, feelings, and personal concerns. The strong positive relationship between AI Chatbot Usage and Self-Expression and Openness may be associated with the perceived privacy and reduced fear of judgement when communicating with AI systems. A similar potential for chatbots to facilitate emotional expression and support has been identified in previous research (Amer et al., 2024; Chin et al., 2023).

AI Chatbot Usage demonstrated a strong negative relationship with Stress or Anxiety Levels ($r = -.775$, $p < .001$). The corresponding regression model explained 60.1% of the variance in Stress or Anxiety Levels ($R^2 = .601$). Thus, greater AI chatbot usage was associated with lower reported levels of stress and anxiety among the respondents. However, because the study employed a cross-sectional design, this finding should be interpreted as an association rather than as evidence that AI chatbot usage directly causes a reduction in stress or anxiety.

The relationship between AI Chatbot Usage and Emotional Intelligence was positive and statistically significant but comparatively weaker ($r = .512$, $p < .001$). AI Chatbot Usage explained 26.3% of the variance in Emotional Intelligence ($R^2 = .263$). The comparatively lower explanatory power indicates that emotional intelligence may depend substantially on other factors, including interpersonal relationships, social experiences, emotional learning, and real-world interactions.

These results indicate that AI chatbots may provide meaningful short-term emotional support by facilitating emotional expression, perceived emotional relief, and stress management. However, the findings should not be interpreted as evidence that AI chatbots are superior to, or can replace, professional counselling. The positive outcomes observed in this cross-sectional study represent respondents' reported experiences and do not establish the long-term effectiveness of AI chatbots as mental health interventions. This distinction is particularly important because AI systems may produce inaccurate or hallucinated information and cannot consistently replicate professional judgement, human empathy, or the contextual understanding required for complex psychological concerns.

Conclusions and Implications

The study concludes that AI Chatbot Usage is significantly associated with Emotional Relief, Self-Expression and Openness, Stress or Anxiety Levels, and Emotional Intelligence among state university students in Sri Lanka. The strongest association was observed with Emotional Relief, while Emotional Intelligence demonstrated the weakest relationship among the four psychological outcomes. This pattern suggests that AI chatbots may be more effective in providing immediate emotional support than in developing the deeper emotional competencies that typically emerge through sustained interpersonal interaction.

Nevertheless, the findings should be interpreted within the scope of the study. The research does not establish that AI chatbots provide effective long-term counselling or that they can substitute for trained mental health professionals. In particular, the comparatively weaker relationship with Emotional Intelligence reinforces the importance of human interaction and broader interpersonal experiences in emotional development. Therefore, AI chatbot-based support should be positioned as a complementary form of emotional support rather than as a substitute for professional mental health services.

The findings have practical implications for universities, AI developers, mental health professionals, and policymakers. Universities may provide students with clear guidance

on the appropriate and responsible use of AI chatbots while maintaining accessible professional counselling services. AI chatbot developers should strengthen privacy protection, transparency, safety mechanisms, response accuracy, and safeguards against harmful or misleading outputs. Importantly, the use of AI chatbots for counselling-related purposes without appropriate training, professional oversight, or safety mechanisms may expose users to risks arising from inaccurate responses, AI hallucinations, inappropriate guidance, and excessive dependence. Therefore, policymakers and relevant institutions should consider developing evidence-based standards and guidelines governing the responsible use of AI chatbots in mental health-related contexts. Such measures can help to maximise the potential short-term benefits of AI while ensuring that professional human support remains central to the management of serious psychological concerns.

Keywords**:** Artificial intelligence chatbots, emotional intelligence, mental health, self-expression, university students

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Determinants of the Privacy Paradox in Cloud Storage Usage among Sri Lankan Undergraduates

Dewmini A.M.T.* and Ratnayake R.M.G.H.N.
Department of Information Systems, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: dewminitharu07@gmail.com)

Introduction

Cloud storage platforms such as Google Drive, Dropbox, and OneDrive now underpin how university students store, share, and collaborate on academic and personal data, making trustworthy cloud adoption integral to the sustainable digital transformation of higher education. This dependence exposes students to privacy risks, and evidence from Sri Lanka indicates that limited knowledge and data privacy concerns constrain effective use (Hettige et al., 2020). A substantial body of research documents individuals who express strong privacy concerns yet continue to disclose information and forgo protective measures, a discrepancy termed the privacy paradox (Kokolakis, 2017). The Antecedents–Privacy Concerns–Outcomes (APCO) framework offers a parsimonious lens on this behaviour by modelling how antecedent factors shape privacy concerns, which in turn drive behavioural outcomes (Smith et al., 2011). Recent research reveals that attitude instability and cognitive resource limitations influence privacy disclosure (Zhu et al., 2025), while studies in developing countries show that privacy risk awareness correlates with protective behaviours, although institutional transparency and digital literacy remain critical moderators. Systematic reviews confirm that users often exhibit inconsistent privacy behaviours despite expressing concerns (Taufik & Juhana, 2025).

Three gaps motivated this study. First, empirical evidence on the paradox originates predominantly from Western, East Asian, and Middle Eastern contexts, leaving South Asian settings such as Sri Lanka underexplored (Connolly et al., 2025). Second, cloud storage used for academic purposes has received limited attention despite hosting sensitive data (Hettige et al., 2020). Third, prior studies typically test determinants in isolation rather than integrating social and cognitive antecedents within one APCO-based model (Bartol et al., 2023). Recent research has emphasised the need for context-specific investigations that account for cultural and institutional factors influencing privacy perceptions in developing countries (Taufik & Juhana, 2025). Accordingly, this study examined how peer influence (PI), self-efficacy in privacy management (SE), privacy awareness (PA), and trust in cloud providers (TCP) shape privacy concerns (PC) and privacy protective behaviours (PPB) among Sri Lankan undergraduates. The study hypothesised that peer influence positively affects privacy concerns (H1) and protective behaviours (H6); that self-efficacy (H2), privacy awareness (H3), and trust (H4) negatively affect privacy concerns; that privacy concerns positively affect protective behaviours (H5); and that trust negatively affects protective behaviours (H7).

Methodology

The study adopted a positivist philosophy, a deductive approach, and an explanatory, cross-sectional survey strategy (Bartol et al., 2023). The target population comprised 198,106 undergraduates enrolled in 17 state universities of Sri Lanka. In the absence of a complete sampling frame, convenience sampling was employed across all universities. A self-administered online questionnaire yielded 403 valid cases, exceeding the Krejcie–Morgan minimum of 384. Validated five-point Likert scales adapted from prior research (e.g. Chen & Chen, 2015) measured the six constructs.

Data were analysed using partial least squares structural equation modelling (PLS-SEM) in SmartPLS 4 (Hair et al., 2017). The measurement model demonstrated strong psychometric properties: outer loadings (0.797–0.933), Cronbach's alpha (0.870–0.950), composite reliability (0.911–0.961), average variance extracted (AVE; 0.720–0.854), and heterotrait–monotrait (HTMT) ratios below 0.85. Variance inflation factor (VIF) values (1.015–3.294) ruled out collinearity. One-tailed tests at $\alpha = .05$ assessed the structural model through bootstrapping with 5,000 subsamples. Harman's single-factor test showed that a single factor accounted for approximately 31% of the variance, below the 50% threshold. Anonymity and informed consent were maintained.

Results and Discussion

Undergraduates reported low privacy concerns ($M = 2.09$) and low protective behaviours ($M = 2.14$), while the antecedents scored higher ($M = 3.67$–3.74). This low-to-low pattern is the opposite of a privacy paradox, in which high concern coexists with low protection. It aligns with research in developing countries in which students exhibit moderate awareness but limited understanding of institutional data protection policies (Taufik & Juhana, 2025). Table 1 summarises the hypothesis tests.

Table 1

Results of Hypothesis Testing

Hypothesis	Path	β	*t*-statistic	*p*-value	Decision
H1	PI → PC	−0.052	0.738	.461	Not supported
H2	SE → PC	−0.165	2.012	.044	Supported
H3	PA → PC	−0.176	2.137	.033	Supported
H4	TCP → PC	0.247	3.614	< .001	Not supported[a]
H5	PC → PPB	0.450	9.368	< .001	Supported
H6	PI → PPB	−0.017	0.351	.726	Not supported
H7	TCP → PPB	−0.202	3.875	< .001	Supported

Note. One-tailed tests with bootstrapping using 5,000 subsamples. PI = peer influence; SE = self-efficacy in privacy management; PA = privacy awareness; TCP = trust in cloud provider; PC = privacy concerns; PPB = privacy protective behaviours. [a]The effect is significant but positive, contrary to the hypothesised negative direction.

Privacy concerns exerted the strongest effect in the model, significantly increasing protective behaviours ($\beta = 0.450$, $f^2 = 0.269$), confirming the central APCO proposition (Smith et al., 2011). This attitude–behaviour consistency indicates that concerns and behaviours align: students who worry act on that worry, and low protection reflects low

concern. This is consistent with research showing that privacy risk awareness positively influences protective behaviours (Taufik & Juhana, 2025).

Trust played a dual role. Contrary to H4, trust significantly increased privacy concerns (β = 0.247), suggesting a "trust but verify" orientation, while simultaneously reducing protective behaviours directly (β = −0.202), a complacency effect whereby students delegate data protection to the platform. The indirect path through concerns was significant (β = 0.111, p = .001), yielding competitive mediation (Zhao et al., 2010). Privacy awareness (β = −0.176) and self-efficacy (β = −0.165) significantly lowered concerns, indicating that informed users hold calibrated concerns (Chen & Chen, 2015), although the effects were small (f^2 = 0.010). Peer influence affected neither concerns nor behaviours. Beyond possible cultural contingency (Connolly et al., 2025), a valence mismatch is likely to have attenuated these estimates.

The model explained 25.7% of the variance in protective behaviours, with acceptable fit (standardised root mean square residual [SRMR] = 0.045, normed fit index [NFI] = 0.908). The antecedents explained only 4.9% of the variance in privacy concerns. This weak prediction is theoretically consequential: the antecedents-to-concerns component of the APCO model barely functions, implying that unmeasured factors such as breach experience, regulatory awareness, and privacy disposition shape concern formation.

Conclusions and Implications

This study extends the APCO framework to cloud storage usage in South Asian higher education in three ways. First, Sri Lankan undergraduates exhibit an aligned low-to-low pattern instead of a paradox, challenging the universal applicability of the privacy paradox phenomenon. Second, the competitive mediation finding reveals that trust operates through opposing mechanisms, namely complacency and informed concern, which the original APCO model does not account for. Third, the weak prediction of privacy concerns (R^2 = 0.049) demonstrates that the antecedents-to-concerns pathway is weaker in developing country settings, suggesting that cultural and institutional factors moderate APCO relationships.

In practical terms, universities should embed digital privacy modules in orientation programmes, provide privacy-setting checklists, and publicise students' rights under Sri Lanka's Personal Data Protection Act No. 9 of 2022. Universities should also develop clear data governance procedures and educate all students about their data rights. Effective privacy protection models require user consent, clear objectives, and transparency (Taufik & Juhana, 2025). Given the cognitive mechanisms identified by Zhu et al. (2025), privacy education should address both the emotional and the cognitive aspects of privacy decision-making. Five limitations bound these conclusions: convenience sampling, the cross-sectional design, self-reported behaviour, the mismatch in the peer-influence instrument, and the mismatch between the paradox framing and the observed pattern. Future research should employ probability sampling, longitudinal designs, behavioural measures, and additional antecedents such as breach experience and regulatory awareness.

***Keywords*:** APCO model, cloud storage, privacy concerns, privacy paradox, privacy protective behaviours

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User Acceptance of Passenger Information Systems Among Daily Train Commuters in Western Province

Pathirana K.P.R.S.* and Bandara K.M.P.G.A.J.
Department of Information Systems, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: rasikapathirana25@gmail.com)

Introduction

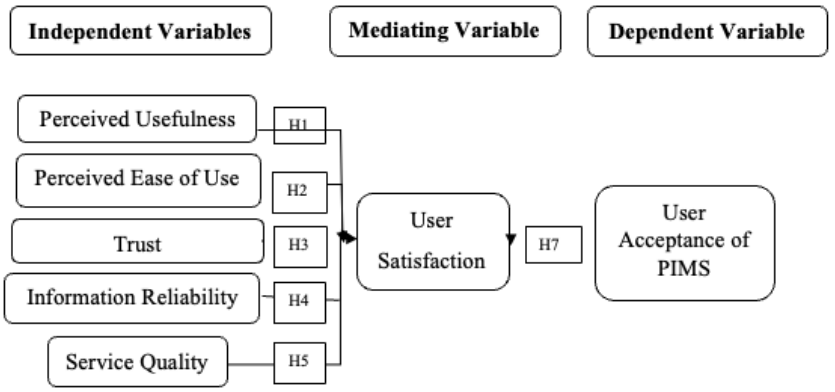
Railway transport is a socio-economic lifeline in Sri Lanka, yet it suffers from persistent unreliability. In 2023, only 34.11% of trains operated on time, while over 51% experienced delays exceeding ten minutes (Sri Lanka Railways, 2023). In this volatile environment, digital Passenger Information Systems (PIMS), such as the *Ratawata Dumriya Mageenge Nila Samuhaya* (RDMNS) and e-ticketing applications, have become practical coping mechanisms for daily commuters. While prior research by De Silva and Manel (2023) established a clear need for PIMS and other studies proposed technological prototypes (Mihiranga et al., 2021), a significant gap exists in understanding the actual behavioural acceptance of currently operational platforms. This study shifts the focus from hypothetical concepts to the empirical evaluation of active systems through the lens of daily users in the Western Province. A critical issue addressed is the trust gap caused by discrepancies between station announcements and real-time digital data (Perera et al., 2023). By integrating the Technology Acceptance Model (TAM), the Unified Theory of Acceptance and Use of Technology (UTAUT), and the Information Systems Success Model (ISSM), this research aims to identify the key factors influencing user acceptance. The primary objective is to evaluate how perceived usefulness, ease of use, trust, information reliability, and service quality drive adoption, and specifically to determine the mediating role of user satisfaction in this process.

Methodology

The study adopted a quantitative, cross-sectional survey design with an explanatory strategy to quantify the causal mechanisms of PIMS adoption (Creswell, 2009). The conceptual framework (Figure 1) integrates TAM, UTAUT, and ISSM to examine seven hypotheses (H1–H7) regarding the direct and mediating drivers of user acceptance. Data were collected from 386 daily train commuters in the Western Province using convenience sampling at major railway hubs and through digital forums, exceeding the minimum sample size recommended by Krejcie and Morgan (1970). A 35-item questionnaire on a five-point Likert scale, adapted from validated instruments (Davis, 1989; Venkatesh et al., 2003) and reviewed by experts, served as the primary data-collection tool. Construct validity was confirmed by exploratory factor analysis (Kaiser–Meyer–Olkin [KMO] measure = .949), and internal reliability was established with Cronbach's alpha values exceeding .70.

Figure 1

Conceptual Framework Illustrating the Direct and Mediating Relationships Between System Attributes, User Satisfaction, and User Acceptance



Note. H6 represents the mediating effect of User Satisfaction on the relationship between each independent variable and User Acceptance.

Data were analysed using descriptive and inferential statistical techniques. Multiple linear regression was employed to test the direct relationships between the independent variables, user satisfaction, and user acceptance (H1–H5, H7). Additionally, mediation analysis using a bootstrapping procedure with 5,000 resamples was conducted to evaluate the indirect, mediating role of user satisfaction (H6). This statistical approach ensures high power and robust handling of non-normal behavioural data.

Results and Discussion

Demographic analysis of the 386 daily train commuters revealed that 85.7% were aged 18–44 years and 83.9% commuted primarily for work or education, reflecting a highly time-sensitive user base reliant on real-time travel information. Descriptive statistics showed strong positive perceptions across all constructs, with mean scores exceeding 4.00 on the five-point Likert scale. Multiple linear regression analysis established that the overall model significantly explained 43.3% of the variance in User Acceptance ($F(5, 380) = 58.15$, $p < .001$, $R^2 = .433$, adjusted $R^2 = .426$). As summarised in Table 1, all seven hypotheses (H1–H7) were statistically supported. Among the independent variables, Trust ($\beta = .687$, $t = 16.68$, $p < .001$) and Information Reliability ($\beta = .682$, $t = 15.55$, $p < .001$) were the strongest predictors of User Satisfaction, demonstrating that data credibility and accuracy outweigh technical novelty in Sri Lanka's volatile transit environment. Furthermore, User Satisfaction proved to be the most powerful direct determinant of User Acceptance ($\beta = .774$, $t = 17.07$, $p < .001$). Bootstrap mediation analysis (5,000 resamples) confirmed that User Satisfaction significantly and partially mediates the relationships between all independent variables and User Acceptance, as all 95% bias-corrected confidence intervals (CIs) excluded zero (e.g., Trust → User Satisfaction → User Acceptance: indirect effect = 0.507, 95% bootstrap CI [0.410, 0.605]). These findings

confirm that digital PIMS adoption in Sri Lanka is an experiential, satisfaction-driven response to managing daily commute uncertainty.

Table 1

Summary of Hypotheses Testing Results

Hypothesis	Relationship	Path coefficient (β)	*t*	*p*	Result
H1	Perceived Usefulness → User Satisfaction	.611	13.561	< .001	Accepted
H2	Perceived Ease of Use → User Satisfaction	.674	16.184	< .001	Accepted
H3	Trust → User Satisfaction	.687	16.682	< .001	Accepted
H4	Information Reliability → User Satisfaction	.682	15.546	< .001	Accepted
H5	Service Quality → User Satisfaction	.682	16.898	< .001	Accepted
H6	User Satisfaction mediates the relationship between the independent variables and User Acceptance	0.473–0.514*		[0.374, 0.622]*	Accepted
H7	User Satisfaction → User Acceptance	.774	17.073	< .001	Accepted

Note. β represents standardised regression coefficients; $p < .001$ for all direct paths. *For H6, values represent the range of indirect effects and 95% bias-corrected bootstrap confidence intervals across all five mediated paths.

Conclusions and Implications

This study confirms that PIMS acceptance among Western Province commuters is driven by experiential evaluations rather than by technology alone. While usefulness and ease of use contribute to satisfaction, trust and information reliability are the primary predictors in Sri Lanka's volatile transit setting. User satisfaction partially mediates these relationships, converting system attributes into behavioural adoption. In practical terms, railway authorities and developers must prioritise real-time data accuracy, credibility, and synchronisation with station announcements to bridge trust gaps. Interface features providing instant delay alerts can further improve utility for daily commuters. Future research should expand beyond the Western Province using longitudinal or mixed-methods approaches to explore moderating factors such as age and digital literacy.

***Keywords*:** Multiple regression, passenger information systems, Sri Lanka Railways, technology acceptance, user satisfaction

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Managing the Negative Impacts of Overtourism Through Sustainable Tourism Practices: A Case Study of Ella

Dilshan M.M.G.A.* and Dayangana K.T.L.U.S.
Department of Tourism and Hospitality Management, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: asankadilshangamage@email.com)

Introduction

Tourism is widely recognised as a catalyst for economic development, employment generation and intercultural exchange. However, when growth occurs rapidly and without adequate planning or management, destinations may experience overtourism, a condition marked by overcrowding, environmental degradation, infrastructure overload and tensions between visitors and host communities (Gössling et al., 2018; Milano et al., 2019). Recent scholarship shows that overtourism is no longer limited to Europe; destinations in Asia and the Global South are increasingly vulnerable because of fragile ecosystems, limited infrastructure and weak governance capacity (Dodds & Butler, 2019; Peeters et al., 2018).

Ella, Sri Lanka, illustrates these dynamics clearly. The destination has experienced rapid visitor growth alongside traffic congestion, inadequate waste and sewage management, unplanned construction, rising living costs and pressure on public services. Although sustainable tourism frameworks are often proposed as remedies, there is limited empirical research that directly connects overtourism with practical sustainable interventions in the Sri Lankan context. Much of the existing literature, developed mainly in European settings, does not adequately reflect the socio-ecological and governance constraints that shape overtourism outcomes in Ella (Butler, 1980; World Tourism Organization, 2018).

Recent studies have begun to examine overtourism and post-pandemic recovery in Sri Lanka and Asia. Abeyanayake (2025) documents how overcrowding and management deficits threaten ecological integrity in protected areas, Fernando (2023) highlights tensions between economic recovery and environmental protection in nature-based tourism, and Zhang and Kumar (2025) stress the need for infrastructure upgrades, visitor-flow management and product diversification. Building on these insights, this study investigates overtourism in Ella with three objectives: first, to identify its drivers and its environmental, socio-cultural and economic impacts; second, to document stakeholder perceptions; and third, to assess feasible sustainable tourism practices for long-term resilience.

Methodology

This study adopted an interpretivist philosophy and an inductive approach to gain a deeper understanding of stakeholder perceptions and experiences of overtourism and sustainable tourism practices in the Ella tourism area. A qualitative case study design was chosen, as Ella represents a destination undergoing rapid tourism expansion and increasing tourism influence (Saunders et al., 2019).

The sample comprised 15 purposively selected respondents with direct knowledge or experience of tourism in Ella, consistent with Patton's (2015) guidance on purposive sampling. Participants included three tourism business operators, four local authority representatives, four foreign tourists, two residents/taxi drivers, one tour guide and one academic specialising in tourism and hospitality at Uva Wellassa University of Sri Lanka. Semi-structured interviews were conducted within the Ella tourism area, each lasting 30–45 minutes, in either English or Sinhala depending on participant preference. Interviews were recorded with consent, transcribed and supplemented by field observations of tourism activities, visitor congestion and environmental conditions. Ethical considerations included informed consent, confidentiality and voluntary participation.

Thematic analysis, following Braun and Clarke's (2006) framework, was employed to identify recurring patterns and themes systematically within participants' responses. This approach ensured a structured interpretation of the qualitative data, highlighting the key issues and practices relevant to overtourism and sustainable tourism in the Ella tourism area.

Results and Discussion

Five interconnected themes emerged from the thematic analysis of the 15 stakeholder interviews: environmental impacts, socio-cultural impacts, economic impacts, tourism management and governance challenges, and sustainable tourism practices for overtourism. The results show that overtourism in Ella is not merely the result of an increased number of tourists but is also linked to the way in which rapid tourism growth is managed in the destination. These pressures were found to be interdependent and linked to governance weaknesses, infrastructure constraints, community change, economic dependency and environmental pressures, and together they challenge the long-term sustainability of the destination.

The environmental indicators highlighted inadequate waste collection and disposal, poor sewage management, garbage accumulation, unplanned and unauthorised construction, loss of green spaces and natural beauty, changes in land use, traffic congestion, and a lack of parking and transport facilities as key issues in Ella. The results indicate that tourism development has outpaced the ecological and physical infrastructure available to accommodate it, which is consistent with previous studies on overtourism and destination capacity (Gössling et al., 2018; Koens et al., 2018; Milano et al., 2019).

The socio-cultural and economic findings show both positive and negative impacts of tourism development. The positive relationship between tourists and the local community was manifested in hospitality, friendliness, assistance and cultural interaction, and tourism has motivated local people to shift from traditional agriculture to tourism jobs and businesses. However, changes in lifestyles and community practices were also identified. Economically, tourism has generated employment, entrepreneurship and income opportunities and has improved livelihoods. Nevertheless, high dependence on tourism, a high cost of living, overcharging and weak price regulation, among other factors, were seen as important challenges. The results therefore show that tourism is a significant

economic opportunity for the local community, but that it also creates social and economic vulnerabilities that must be managed.

The results also revealed that weak institutional management and tourism governance are key factors affecting overtourism in Ella. Participants identified several issues that affected planning: poor planning, lack of monitoring, inconsistent regulation, unauthorised planning, inadequate infrastructure planning, lack of awareness and insufficient coordination between stakeholders. Importantly, the study shows that the quality of destination management and governance, and not only the volume of tourists, plays an important role in shaping overtourism in Ella.

With regard to addressing these challenges, four elements of sustainable tourism practice were found to be important, namely environmental sustainability, infrastructure development, stakeholder collaboration and long-term tourism planning. Participants highlighted the need to improve waste collection, disposal and segregation; to promote environmental protection and regulatory action; to enhance roads, transport infrastructure and parking facilities; and to improve cooperation among local communities, government institutions and tourism operators. Furthermore, tourism diversification and visitor-management measures were recognised as crucial for spreading tourist flows and easing the burden on overcrowded locations. Overall, the results indicate the need for an integrated, sustainable destination-management approach that reconciles tourism growth with environmental protection, community well-being and the economic sustainability of the tourism sector in Ella.

Conclusions and Implications

The study brings together the interrelated environmental, socio-cultural, economic and governance issues that have emerged from overtourism in Ella and that threaten its long-term sustainability. Although tourism contributes to employment, income generation and business creation, poor waste management, environmental degradation, infrastructure pressure, community change, pricing problems, weak institutional management and a lack of coordination among stakeholders have contributed to the negative impacts of rapid tourism growth. Sustainable destination management must therefore be integrative rather than based solely on the growth of tourist numbers.

The results are relevant to tourism policymakers, local governments, destination managers, tourism operators and local communities. Attention should be given to strengthening waste-management and environmental protection systems, roads, parking facilities and development regulations, and to adopting effective visitor-management and tourism-diversification strategies. Enhanced cooperation among institutions, the community, the tourism industry and other stakeholders is also crucial. These measures can help to balance tourism development, environmental protection, social health and economic sustainability, ensuring the long-term sustainability of Ella as a tourist destination.

Keywords**:** Destination management, Ella, overtourism, sustainable tourism, sustainable tourism practices

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Community Readiness, Participation and Challenges in Tourism Development in Loolkandura: Towards a Community-Based Integrated Approach

Kavindi G.J.O.* and Abeywickrama K.T.N.P.
Department of Tourism and Hospitality Management, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: onethrakavindi@gmail.com)

Introduction

Loolkandura, the birthplace of commercial Ceylon tea, is located in Kandy District and possesses significant historical, cultural, natural and plantation resources. Despite its favourable location within a major tourist hub and its rich resource base, tourism activity remains limited and is weakly connected with local livelihoods, community participation and coordinated destination planning. The continuing recovery of international tourism further highlights the need to diversify destinations and develop distinctive, experience-based tourism products (UN Tourism, 2025). Tea tourism has particular potential in Sri Lanka, although the segment remains insufficiently developed as a structured tourism product (Kumari et al., 2023).

Tourism can contribute to livelihood generation and local economic opportunities when destinations are developed in a way that involves communities meaningfully (Alam, 2025). Community-based tourism (CBT) and Empowerment Theory emphasise participation, ownership, capacity building and equitable benefit sharing; however, CBT initiatives may remain constrained by weak institutional support, limited coordination and weak integration with wider tourism systems (Giampiccoli & Saayman, 2018; Goodwin, 2017; Tasci et al., 2019; Tosun, 2000). In response, the Community-Based Integrated Approach (CBIA) applied in this study integrates three interdependent dimensions: destination resources, community involvement and stakeholder participation. Its theoretical contribution lies in extending the community-centred logic of CBT and Empowerment Theory by explicitly connecting community participation with the strategic utilisation of destination resources and with the institutional and private-sector collaboration required to create participation opportunities and development support.

Accordingly, this extended abstract focuses on two objectives: first, to understand how community involvement in tourism-related activities can be enhanced in Loolkandura; and second, to identify the key challenges affecting tourism development in Loolkandura. The study therefore examines the gap between community interest and actual participation, and the enabling conditions required to translate local readiness into meaningful tourism involvement.

Methodology

The study adopted an interpretivist philosophy, an inductive approach and a qualitative case-study strategy with a cross-sectional time horizon. The research was conducted in Loolkandura, Kandy District, Sri Lanka. The population comprised community members, estate management personnel and local tourism officers/operators, and the unit of analysis was the individual participant. Thirteen participants were purposively selected: five

community members, five estate management representatives and three local tourism officers/operators. Participants were selected on the basis of their knowledge, experience and involvement in tourism-related activities in and around Loolkandura.

Primary data were collected through semi-structured, face-to-face interviews during May 2026. Each interview lasted approximately 10–20 minutes and was conducted in Sinhala or English. Interviews were audio-recorded with the participants' permission and transcribed. Sampling was concluded when data saturation was reached, as indicated by the absence of substantially new themes or meaningful insights in subsequent interviews. The transcribed interviews were analysed manually using the six-phase thematic analysis process described by Naeem et al. (2023): familiarisation, coding, generating themes, reviewing themes, defining and naming themes, and writing up. Meaningful segments were coded according to the research objectives, and related codes were grouped into themes and sub-themes. Coding decisions and the analytical process were documented manually. Trustworthiness was strengthened through credibility, transferability, dependability and confirmability procedures, including data triangulation across stakeholder groups, member checking, contextual description, documentation of procedures, reflexive journaling and the use of participant quotations.

Results and Discussion

Regarding the first objective, concerning how community involvement in tourism-related activities can be enhanced, three themes emerged: community interest, community readiness and community participation. Community interest was reflected in positive attitudes towards visitors and in economic motivation, including expectations of income generation and business opportunities. Community readiness was reflected in a willingness to participate, interest in future tourism programmes and confidence in working with tourism stakeholders. These findings indicate that the community is not resistant to tourism; rather, there is an underlying willingness to engage when suitable opportunities and support are available. This is consistent with recent rural tourism literature identifying favourable resident attitudes and expectations of income, employment and entrepreneurship as important foundations for participation (Cordova-Buiza et al., 2025), while Yachin (2025) emphasises that rural tourism engagement can develop when communities are supported to recognise opportunities and participate as entrepreneurs.

However, actual participation remained limited compared with the expressed interest and readiness. Existing community involvement included food and beverage activities, small shops, vegetable farming, three-wheeler transportation and tea-plucking interactions. Potential forms of involvement included selling tea products, guiding, homestays and village tours. Thus, the central finding is a readiness–participation gap: willingness exists, but opportunities, skills and enabling conditions are insufficient to convert readiness into broader participation. From a CBT and empowerment perspective, this suggests that empowerment requires more than positive attitudes; communities need practical opportunities, tourism awareness, language and guiding skills, entrepreneurship support

and access to resources. The finding therefore extends the application of CBT and Empowerment Theory in Loolkandura by showing how community readiness is shaped by the wider destination and institutional environment.

Regarding the second objective, concerning the key challenges affecting tourism development, three themes emerged: infrastructure deficiencies, limited stakeholder involvement, and community capacity and resource constraints. Infrastructure deficiencies included damaged roads, poor accessibility, limited public transportation, and inadequate accommodation, restaurants, sanitation and parking. These deficiencies restrict the conversion of tourism resources into accessible and marketable visitor experiences and are consistent with recent evidence that inadequate rural infrastructure can restrict the benefits of community-based tourism (Cordova-Buiza et al., 2025).

Limited stakeholder involvement emerged as the most critical challenge. Participants identified limited private investment and financial support, weak public-sector support, inadequate tourism planning and promotion, delays in administrative approvals and coordination problems. These findings indicate that tourism development cannot depend on community participation alone; it requires coordinated action among estate management, government and tourism institutions, private investors and local tourism actors. Recent research similarly identifies policy, industry, communication and stakeholder barriers as constraints on sustainable CBT development (Cordova-Buiza et al., 2025; Liang et al., 2024). Furthermore, community capacity and resource constraints included language barriers, gaps in tourism and business knowledge, limited training, lack of capital and limited investment ability, consistent with evidence on educational, expertise and financial barriers to community participation (Gohori & van der Merwe, 2024; Reindrawati, 2023).

Taken together, the findings for the two objectives demonstrate that the principal issue is not simply community unwillingness or the absence of tourism potential. Rather, community interest and readiness are constrained by enabling conditions. Infrastructure deficiencies reduce destination readiness; weak stakeholder involvement limits institutional, promotional and investment support; and capacity and financial constraints limit the community's ability to establish and expand tourism activities. This supports the CBIA logic that destination resources, community involvement and stakeholder participation must operate together. The study therefore addresses a theoretical gap by demonstrating, within a plantation-based destination, how the community-centred foundations of CBT and Empowerment Theory require integration with destination-resource utilisation and stakeholder coordination to translate readiness into meaningful participation and development.

Conclusions and Implications

The findings indicate that the Loolkandura community demonstrates positive attitudes towards tourism, economic motivation and readiness to participate, but that actual participation remains relatively limited. Existing involvement is concentrated in small-scale products and services, while guiding, homestays, village tours, tea-based enterprises

and other community-led experiences represent potential areas for greater participation. The study also identifies weak stakeholder involvement, infrastructure deficiencies, and community capacity and financial constraints as the principal challenges affecting tourism development.

The implications are specific to the Loolkandura case and the perspectives of the 13 purposively selected participants. Theoretically, the findings indicate that CBT and Empowerment Theory can be strengthened by considering the destination-resource and stakeholder conditions that enable community participation. On the basis of the findings, three priority actions are recommended. First, structured opportunities for community participation should be created through guiding, homestays, local food and products, village experiences and tea-related enterprises. Second, community capacity should be strengthened through language, tourism, customer-service, guiding and entrepreneurship training, together with appropriate financial support mechanisms. Third, stronger coordination should be established among government and tourism authorities, estate management, private-sector actors and the community to address infrastructure, investment, promotion and administrative barriers.

These implications do not imply statistical generalisation beyond the study context, which is limited by its single-case focus on Loolkandura, its small purposive sample, its reliance on participant perceptions and the cross-sectional nature of the fieldwork. Future research should examine the proposed integrated approach in other plantation and rural destinations, involve broader stakeholder samples and investigate how community participation and destination development change over time.

Keywords**:** Community participation, community-based integrated approach, destination development, Loolkandura, tourism development challenges

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Influence of Video Gaming Behaviour Among Adolescents

Wickramasinghe W.G.L.* and Gamini V.K.N.
Department of Information Systems, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: gayathrilakmini2001@gmail.com)

Introduction

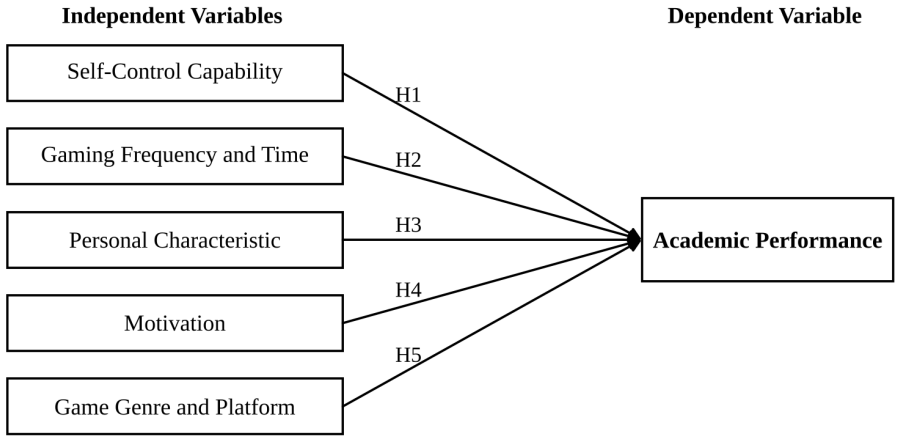
Play has long been considered an essential part of childhood, supporting physical and mental well-being. However, with the advancement of digital technology and the widespread use of the internet, smartphones, and social media, video gaming has become increasingly popular and, over the last two decades, one of the most common recreational activities worldwide, especially among adolescents and college students (Lala et al., 2024). Video games are event-based mathematical software models used for digital interactive recreational activity on electronic devices. Several authors have identified both positive and negative impacts of video gaming on academic performance. Positive impacts of video gaming include improved problem-solving skills, improved communication skills, and enhanced creativity (Drummond & Sauer, 2014). Negative impacts of video gaming include addiction, the promotion of violence, mental health challenges, and harm to academic performance (Granic et al., 2014). Some authors argue that there is no correlation between video gaming and academic performance. Owing to the limited number of studies and the contradictions between these arguments, some authors have recommended further research on the influence of video gaming behaviour on academic performance among adolescents (Alanood & Mark, 2024; Hassan & Tejnia, 2022). Moreover, most studies on the impact of video games on academic performance have been conducted in Western countries, and only limited studies have been conducted in developing countries (Wahid & Hassan, 2023), including Sri Lanka. Therefore, the main objective of this research was to examine the influence of video gaming behaviour on academic performance among adolescents, specifically the association between video gaming and the academic performance of school students in the Kurunegala Municipal area.

Methodology

The population of this quantitative study comprised approximately 4,936 General Certificate of Education Advanced Level (GCE A/L) students in schools within the Kurunegala Municipal Council area. Primary data were collected from 357 students across five selected schools during the first two weeks of July 2025 using snowball sampling. A pre-tested, structured, 32-item online survey questionnaire on a five-point Likert scale was used. The link to the online questionnaire was distributed via WhatsApp through teachers and student representatives. The unit of analysis was the individual student. Based on a review of the existing literature, the conceptual framework shown in Figure 1 was formulated.

Figure 1

Conceptual Framework of the Study



Data were analysed using IBM SPSS Statistics (Version 25.0). Descriptive statistics (frequencies, percentages, means, and standard deviations) were used to describe the study variables. In addition, Pearson's correlation was used to assess the strength and direction of the relationships between the study variables. Multiple linear regression was then used to determine how well the independent variables predicted the dependent variable while controlling for the other predictors. Statistical significance was set at $p < .05$.

Results and Discussion

The internal consistency of the six variables was assessed using Cronbach's alpha. As Table 1 shows, the Cronbach's alpha values ranged from .737 (Game Genre and Platform) to .804 (Motivation), exceeding the commonly recommended minimum threshold of .7. These results indicate that all six constructs demonstrate acceptable to good internal consistency, confirming that the items used to measure each construct are sufficiently reliable for subsequent statistical analysis.

Table 1

Reliability Test

Variable	No. of items	Cronbach's α
Game Genre and Platform (GGP)	3	.737
Gaming Frequency and Time (GFT)	3	.791
Motivation (MOT)	3	.804
Self-Control Capability (SCC)	4	.772
Personal Characteristics (PCH)	4	.776
Academic Performance (APE)	5	.745

Source: SPSS output (2025)

The hypotheses were then tested using correlation and multiple regression analyses. H1 was supported by both analyses: the results indicated significant positive relationships between video game genre and platform and adolescents' academic performance, with *p* values of .001 and .030. Thus, both factors significantly and positively influence academic performance among adolescents in five urban schools in Kurunegala District. H2 was not supported: video gaming frequency and duration did not significantly affect adolescents' academic performance; despite a significant correlation, regression analysis found no significant effect among students in five urban schools in Kurunegala. H3 was supported, showing a significant positive relationship between adolescents' video gaming motivation and academic performance, based on correlation ($p < .001$) and regression ($p = .048$) analyses in five urban schools. H4 was supported, with significant correlation and regression results ($p < .001$): adolescents' self-control over video gaming positively influences academic performance, highlighting self-control as an important factor in academic achievement. The fifth hypothesis (H5) was also supported, confirming that adolescents' personal gaming characteristics significantly and positively influence academic performance, as evidenced by correlation and regression analyses ($p < .001$). Accordingly, it can be confirmed that this variable has a positive effect on the academic performance of adolescents in the five urban schools of Kurunegala District.

Conclusions and Implications

The findings show that adolescents' personal characteristics related to video gaming have a significant and positive influence on their academic performance. Both correlation and multiple regression analyses produced statistically significant results ($p < .001$), confirming H1 and H3–H5. This suggests that adolescents' individual characteristics and gaming-related behaviours play an important role in shaping their academic outcomes.

The researchers emphasise the importance of balanced video gaming habits among adolescents and suggest arranging parental guidance workshops. Adolescents should manage their gaming time alongside studying, sleeping, and other responsibilities. Parents and schools should guide students, raise awareness of excessive gaming, and encourage effective time management. Adolescents should choose games that support skills such as problem-solving and critical thinking. The researchers also suggest that future research should examine factors such as gaming duration, game types, parental involvement, motivation, and study habits to better understand how gaming affects academic performance.

***Keywords*:** Academic performance, addiction, adolescent, parental monitoring, student achievement

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Importance of Learning Histology and Embryology in the Medical Curriculum: Student Perspectives on Future Careers

Magamage S.D.[1,*], Muthunayaka M.B.N.[1], Wijesinghe A.G.K.R.[1], Hakmanage N.M.[2] and Kumarasinghe N.[3]
[1]*Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Saliyapura, Anuradhapura, Sri Lanka,* [2]*Faculty of Computing and Technology, University of Kelaniya, Sri Lanka,* [3]*Faculty of Medicine, Sir John Kotelawala Defence University, Rathmalana, Colombo, Sri Lanka*
*Corresponding author (email: sdmagamage2002@gmail.com)

Introduction

In medical education, certain subjects are taught before medical undergraduates receive any clinical exposure because of their importance in laying a sound foundation for clinical training and future careers. Histology and human embryology belong to this category, and students are well exposed to their theoretical aspects during the preclinical period. With regard to human embryology in particular, medical curriculum developers have long been uncertain whether to incorporate this subject into the preclinical curriculum or into some other period of the medical curriculum (Carlson, 2002). In the Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, the embryology curriculum has been incorporated into the anatomy curriculum as a separate sub-region of anatomy. However, the authentic learning of these subjects extends beyond the preclinical period. Experiences gained during clinical training may therefore influence students' preferences as well as their perception of the importance of learning histology and human embryology prior to clinical practice. Through research activities, curriculum developers have made case scenarios related to certain developmental abnormalities available to students, so that they can learn the theoretical facts together with practical knowledge (Scott et al., 2013). This indicates how curricula could be modified to be delivered to preclinical students with greater influence and effectiveness.

Histology, the study of bodily tissues, involves extensive study to identify types of tissue on the basis of the characteristic features that distinguish them from other tissue types in the body and the modifications that occur in tissues to support their function efficiently. Human embryology covers the complex process by which the entire human body, made up of over 10 trillion cells, develops from a single cell, the "zygote", which seemingly contains only the information carried from the maternal and paternal sides. Only a small glimpse of these areas is taught during the preclinical period.

Understanding students' perspectives on the applicability of these subjects during clinical training may help optimise curriculum design and strengthen the integration of basic and clinical sciences. Therefore, this study aimed to assess medical students' perceptions of the importance of learning histology and embryology in clinical settings and for their future medical careers. The specific objectives were, first, to assess how patient exposure changes students' perception of the importance of learning (PIL) for two subjects, histology and human embryology; second, to determine the association between preference and PIL for each subject following clinical exposure; third, to assess students' overall satisfaction with the effort they invested in learning histology and embryology during the preclinical period; and fourth, to explore whether students' experiences

following clinical exposure could provide insights to enhance junior students' appreciation of the importance and clinical relevance of histology and embryology during the preclinical period.

Methodology

Data were collected from six consecutive batches of the Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka: four undergraduate batches and two senior batches of students who had already graduated from the university. The inclusion criterion was experience of clinical practice in a hospital setting. Informed consent was obtained from each participant, and the objectives of the study were explained beforehand.

The questionnaire was developed with reference to similar research conducted in different regions of the world (Carneiro et al., 2023; Sume, 2022; Teshome, 2022). The semi-structured, self-administered online questionnaire was created using Google Forms. It comprised two main sections: the first consisted of nine questions on the socio-demographic and background information of the participants, and the second consisted of five questions addressing the main objective, namely how the preference for histology and human embryology and the perception of the importance of learning these subjects change after a certain amount of clinical training.

Data obtained through Google Forms were entered into IBM SPSS Statistics 20 for statistical analysis. Both descriptive and inferential statistical analyses were carried out. Descriptive statistics were used to summarise the data set, and frequency analysis was carried out to obtain an overall impression of the change in preference and PIL for these subjects with patient exposure. The chi-square test was used to examine the dependence between two pairs of categorical variables: the change in the PIL of histology (variable 1) and the change in preference for histology with patient exposure (variable 2), and the change in the PIL of human embryology (variable 3) and the change in preference for human embryology with patient exposure (variable 4).

Results and Discussion

A total of 177 responses were collected. Changes in preference and PIL following clinical exposure are presented in Figure 1 for human embryology and in Figure 2 for histology, demonstrating the observed association between the two variables ($p < .001$ for both subjects).

Figure 1

Embryology PIL–Preference Change

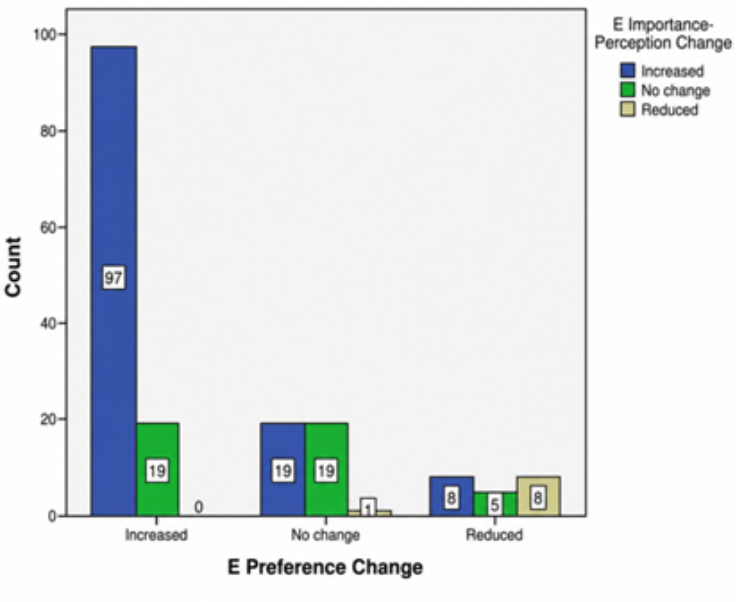
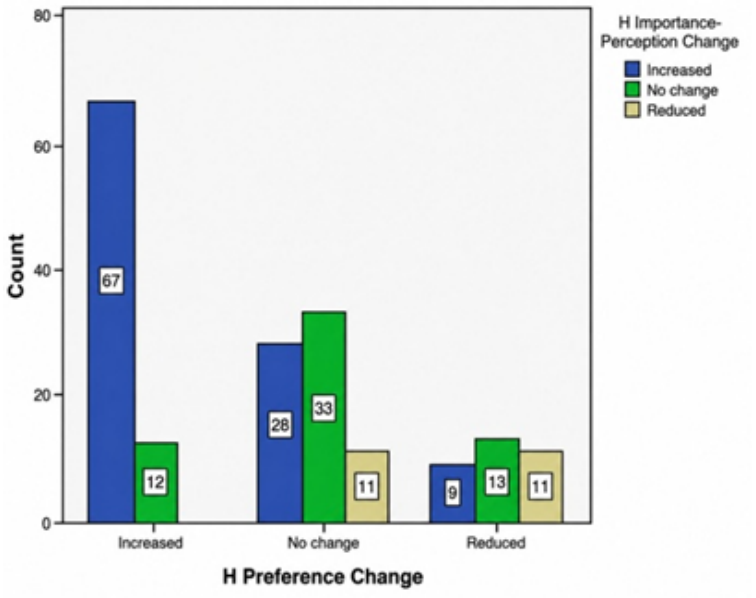


Figure 2

Histology PIL–Preference Change



Regarding satisfaction with the effort invested during the preclinical period, participants were categorised as satisfied, dissatisfied and wishing they had invested more effort, or dissatisfied and wishing they had invested less effort. Only 38% of students reported

satisfaction with their effort in histology and 35% with their effort in embryology. Among those who were dissatisfied, the majority indicated that they wished they had invested more effort, while a smaller proportion felt that they had invested more than necessary.

Conclusions and Implications

Once students begin interacting with patients, changes in PIL and preference are dependent on each other for both subjects, or a common factor has a significant influence on both. The majority of students are not satisfied with the effort they put into learning these two subjects. Therefore, in addition to emphasising during the teaching–learning process how these subjects can influence patients' lives, and thereby awakening students' enthusiasm and responsibility towards learning them properly, junior students should be given insight into how the majority of senior students found their effort in learning these subjects during the preclinical period less than satisfying. This may stimulate junior students who are still learning histology and human embryology to learn these subjects more efficiently and responsibly.

Keywords**:** Histology, human embryology, preference and perception regarding the importance of learning

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Knowledge, Attitude and Practice of MDI Technique Among Asthmatic Patients Attending the Respiratory Clinic, Teaching Hospital Anuradhapura

Ahamed M.F.[1,*], Bandara B.A.A.S.[1], Anuththara W.A.S.[1], Akshara T.[1], Bahji S.A.[1], Ahamed A.A.A.[1], Bandara M.M.T.C.[2] and Shuja M.I.M.[3]

[1]Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka, [2]Department of Respiratory Medicine, Teaching Hospital Anuradhapura, Sri Lanka, [3]Department of Physiology, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka

*Corresponding author (email: fiyasahamed686@gmail.com)

Introduction

Asthma is a chronic inflammatory airway disease characterised by bronchial hyper-responsiveness, causing recurrent wheezing, shortness of breath, chest tightness and coughing. It affects an estimated 300–334 million people worldwide, a figure that was projected to reach 400 million by 2025. Although mortality has declined in some regions, asthma remains a major public health challenge because of its high morbidity and healthcare costs, particularly in low- and middle-income countries. In Sri Lanka, the burden is significant, with 7,160 asthma-related deaths reported in 2017.

Inhalation therapy is the main treatment for asthma, as it delivers medication directly to the lungs, providing rapid action while minimising systemic side effects compared with oral medications. The most widely used device is the metered-dose inhaler (MDI), introduced in 1956. However, effective treatment depends greatly on the patient's ability to use the inhaler correctly. Studies show that up to 90% of patients make one or more serious errors in MDI technique. Incorrect technique can result in inadequate drug delivery, poor disease control, increased hospital admissions and unnecessary financial costs. Therefore, assessing the knowledge, attitude and practice of correct MDI technique among adult asthma patients attending a tertiary care clinic in Anuradhapura is important in order to identify gaps in patient education and self-management.

Methodology

A descriptive cross-sectional study with a follow-up component was conducted among adult asthma patients attending the Respiratory Clinic at Teaching Hospital Anuradhapura, Sri Lanka. Patients aged 18 years or older who had been diagnosed with asthma, had used an MDI for at least three months and provided written informed consent were eligible for inclusion. Consecutive sampling was used to recruit 114 participants.

Data were collected using a pre-tested, structured questionnaire to assess socio-demographic characteristics and knowledge, attitudes and practices regarding MDI use, together with a standardised 10-item observational checklist, based on the Global Initiative for Asthma (GINA), National Institutes of Health (NIH) and Australian National Asthma Council guidelines, to evaluate inhaler technique. Health-related quality of life was assessed using the EuroQol EQ-5D-5L instrument. Following the baseline assessment, participants received standardised education and a demonstration of the correct MDI technique, and quality of life was reassessed after three months among

participants who consented to follow-up; these findings will be presented in a separate paper.

Data were analysed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics were used to summarise participant characteristics and study variables. Associations between categorical variables were assessed using the chi-square test or Fisher's exact test, while correlations were evaluated using Pearson's or Spearman's correlation coefficients, as appropriate. Multivariable logistic regression was performed to identify determinants of correct MDI technique, with statistical significance set at $p < .05$.

Results and Discussion

A preliminary analysis was conducted on the data collected from 114 asthmatic patients. The sample consisted predominantly of females (69.3%, $n = 79$) compared with males (30.7%, $n = 35$). The majority of the participants were elderly, with 57.0% ($n = 65$) aged above 60 years. When stratified by sex, older adults aged above 60 years represented the largest subcategory for both males (62.9%, $n = 22$) and females (54.4%, $n = 43$). Regarding education, 56.1% ($n = 64$) had studied up to secondary education (Grades 6–11). Detailed sociodemographic frequencies are presented in Table 1.

Table 1

Sociodemographic Characteristics of the Sample Stratified by Gender (N = 114)

Variable	Subcategory	*n* (%)
Education level	No formal education	11 (9.6%)
	Primary education (up to Grade 5)	15 (13.2%)
	Secondary education (Grades 6–11)	64 (56.1%)
Male	18–24 years	3 (8.6%)
	25–44 years	4 (11.4%)
	45–60 years	6 (17.1%)
	Above 60 years	22 (62.9%)
Female	18–24 years	1 (1.3%)
	25–44 years	8 (11.4%)
	45–60 years	27 (34.2%)
	Above 60 years	43 (54.4%)

The chronicity of the condition was notable: 56.1% ($n = 64$) of the sample had suffered from asthma for more than 5 years, a proportion that was consistent across males (57.1%) and females (55.7%). Long-term reliance on respiratory therapy was evident, as 76.3% ($n = 87$) had used an MDI for over 12 months. The prevailing treatment regimen was a combination of short-acting β_2-agonist (SABA), inhaled corticosteroid (ICS) and long-acting β_2-agonist (LABA) inhalers (SABA + ICS + LABA; 84.2%, $n = 96$), with 89.5% ($n = 102$) requiring daily administration. SABA-only use was observed in 10 patients (8.8%); these patients should be reviewed at subsequent clinic visits, as SABA-only therapy is not recommended and an ICS-containing controller should be considered where appropriate. These clinical characteristics are detailed in Table 2.

Regarding spacer use, 34 participants (29.8%) reported using an MDI with a spacer, while 80 (70.2%) used the MDI without a spacer. Among participants aged above 60 years, 18 (32.1%) used a spacer, whereas 38 (67.9%) used the MDI without a spacer.

Table 2

Clinical History and Inhaler Profiles (N = 114)

Variable	Subcategory	*n* (%)
Duration of asthma	Below 1 year	10 (8.8%)
	1–5 years	40 (35.1%)
	Above 5 years	64 (56.1%)
Duration of inhaler usage	> 3 months	14 (12.7%)
	> 6 months	13 (11.4%)
	> 12 months	87 (76.3%)
Type of MDI	SABA	10 (8.8%)
	ICS + SABA	8 (7.0%)
	SABA + ICS + LABA	96 (84.2%)
Frequency of inhaler use	Daily	102 (89.5%)
	When needed	12 (10.5%)
Spacer use	MDI with spacer	34 (29.8%)
	MDI without spacer	80 (70.2%)

Note. SABA = short-acting β_2-agonist; ICS = inhaled corticosteroid; LABA = long-acting β_2-agonist.

Observation of individual technical manoeuvres highlighted the specific steps driving overall technique failure (Table 3). While basic preparatory gestures such as removing or replacing the cap (90.4%) and holding the device upright (95.6%) were largely performed correctly, severe execution errors emerged during respiratory coordination. Only 25.4% of patients exhaled slowly and fully away from the mouthpiece prior to actuation ($p <$ .001). Furthermore, only a minority completed a slow, deep inhalation to full lung capacity (40.4%, $p = .039$) or waited the requisite minute between consecutive puffs (39.5%, $p = .025$). Table 3 lists the complete performance checklist.

Table 3

Performance Verification Across Individual MDI Technique Checklist Steps (N = 114)

Checklist step	Correct, *n* (%)	Incorrect, *n* (%)	*p*
1. Removes mouthpiece cap	103 (90.4%)	11 (9.6%)	< .001
2. Shakes inhaler vigorously (5–10 times)	89 (78.1%)	25 (21.9%)	< .001
3. Holds inhaler upright (canister up, mouthpiece down)	109 (95.6%)	5 (4.4%)	< .001
4. Exhales slowly and fully away from mouthpiece	29 (25.4%)	85 (74.6%)	< .001
5. Seals lips firmly around mouthpiece (no biting)	92 (80.7%)	22 (19.3%)	< .001
6. Begins slow, deep inhalation and simultaneously actuates the canister	59 (51.8%)	55 (48.2%)	.708
7. Continues slow, deep inhalation to full lung capacity (≈ 3–5 s)	46 (40.4%)	68 (59.6%)	.039
8. Holds breath for 5–10 seconds after inhalation	55 (48.2%)	59 (51.8%)	.708
9. Waits ≥ 1 minute before second puff (if prescribed)	45 (39.5%)	69 (60.5%)	.025
10. Replaces mouthpiece cap after use	111 (97.4%)	3 (2.6%)	< .001

The overall categorisation derived from the critical steps confirmed a pervasive problem in the quality of inhaler use: 71.9% (n = 82) of the total population demonstrated an inefficient MDI technique, while only 28.1% (n = 32) achieved an efficient MDI technique. Cross-tabulation by duration of inhaler use demonstrated that this pattern persisted uniformly, irrespective of the length of therapy (Table 4).

Table 4

Critical Step Outcome Mapping: Overall Efficiency vs. Inhaler Usage Experience

Group	Efficient MDI technique, *n* (%)	Inefficient MDI technique, *n* (%)
Total population	32 (28.1%)	82 (71.9%)
Duration of inhaler usage > 3 months	3 (21.4%)	11 (78.6%)
Duration of inhaler usage > 6 months	4 (30.8%)	9 (69.2%)
Duration of inhaler usage > 12 months	25 (28.7%)	62 (71.3%)

Conclusions and Implications

The final data assessment confirms a major "technique gap" among asthmatic patients, with 71.9% displaying an inefficient metered-dose inhaler technique. Strikingly, the breakdown by duration of use demonstrates that experience does not self-correct technique: 71.3% of individuals who had used an MDI for over a year still exhibited flawed execution.

The step-by-step checklist locates this breakdown not in simple physical handling (such as removing or replacing caps) but in the more demanding control of breathing, specifically proper preparatory exhalation (74.6% incorrect) and the maintenance of a slow, prolonged inhalation (59.6% incorrect).

These findings imply that unreinforced clinical counselling may fail over time. Therefore, targeted education and practical demonstrations should be provided to ensure correct inhaler technique, with regular assessment and reinforcement during follow-up visits. An MDI with a Volumatic spacer should be recommended for older adults, particularly those who have difficulty coordinating inhalation with actuation. Patients should be encouraged to use their inhalers as instructed, with individual difficulties identified and addressed. Written or pictorial instructions can be provided to reinforce correct technique, while healthcare professionals and caregivers should be trained to educate and support patients in the proper use of inhalers. Additionally, patients using SABA alone should be identified and their treatment reviewed at subsequent clinic visits, as SABA-only therapy is not recommended in the latest guidelines, even for infrequent exacerbations; an ICS-containing controller should be considered where clinically appropriate. These measures may improve drug delivery, treatment outcomes and quality of life while reducing the avoidable burden on emergency and outpatient healthcare services.

***Keywords*:** Asthma, attitude, inhalation technique, knowledge, metered-dose inhalers

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Localised Non-Traumatic Ocular Nodules of Potential Trematode Aetiology in Children: A Clinico-Epidemiological Study From Anuradhapura, Sri Lanka

Kodithuwakku P.[1,*], Weerakoon H.[2], Wijayasiriwardana W.[3], Asanthi J.[3], Gam Hewage P.G.[3], Widanage G.J.N.[3], Wickramasinghe S.[4], Silva A.[1] and Weerakoon K.[1]

[1]Department of Parasitology, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka, [2]Department of Biochemistry, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka, [3]Teaching Hospital, Anuradhapura, Sri Lanka, [4]Department of Parasitology, Faculty of Medicine, University of Peradeniya, Sri Lanka

*Corresponding author (email: piyumikodithuwakku017@gmail.com)

Introduction

Globally, parasitic infections remain a major public health concern, particularly in low- and middle-income countries, where they contribute substantially to the burden of disease (Piperaki & Tassios, 2016). Ocular nodules can result from a wide range of infectious and non-infectious aetiologies, leading to diverse ocular pathological manifestations. Among infectious aetiologies, ocular trematode infections (OTIs), a specific subtype caused by trematodes, can lead to a spectrum of pathological consequences (Watson et al., 2018). OTIs can be broadly divided into those with and those without nodule formation. Patients can also develop ocular redness, irritation and foreign body sensation (Arya et al., 2016; Vedhanayaki & Rathinam, 2020). OTIs are accidental and typically occur through direct contact with trematode cercariae or metacercariae or through the consumption of raw or undercooked freshwater fish or crustaceans that contain infectious larvae. Thus, a strong association has been noted between the occurrence of human OTIs and exposure to aquatic environments, particularly freshwater sources. Untreated infections can progress to severe complications, including glaucoma, cataract and visual impairment (Arya et al., 2016; Vedhanayaki & Rathinam, 2020).

OTIs show a geographic concentration in specific tropical and subtropical regions of Asia, Africa and North America (Tantawy, 2025). In Sri Lanka, the first documented case was reported in 1956, followed by a second case in 2009. Two distinct trematode species causing ocular infections in children were identified in a recent case series (Durette-Desset et al., 1958; Mallawarachchi et al., 2023; Rajapakse et al., 2009). Although ocular nodules suspected to be of trematode aetiology have been noted in recent years in Anuradhapura District, an area with many freshwater reservoirs, OTIs remain an under-researched public health concern in the region. Hence, this study evaluated the clinico-epidemiological characteristics of localised non-traumatic ocular nodules of presumed trematode aetiology in children in Anuradhapura District, Sri Lanka.

Methodology

This ongoing descriptive cross-sectional study was commenced in October 2024 at the ophthalmology unit of Teaching Hospital Anuradhapura (THA). All patients with suspected OTIs were included following clinical confirmation by the consultant ophthalmologist. Socio-demographic data, clinical history and exposure details were collected using an interviewer-administered questionnaire and the patients' medical records. For patients who underwent surgical excision of the lesion as part of routine

clinical management, tissue samples were collected for histopathological and molecular analyses. A sample from the excised nodule was used for histopathological examination with haematoxylin and eosin (H&E) staining. Histopathological evaluation was performed by the consultant histopathologist at THA. Ethical approval was obtained from the Ethics Review Committee of the Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka.

Results and Discussion

From October 2024 to June 2026, 57 children who presented with localised non-traumatic ocular nodules clinically suspected to be OTIs were recruited. The mean age was 9.8 ± 3.1 years (range: 3–16 years), and most were male (*n* = 41, 71.9%). Notably, all the patients reported either regular use of open water sources for bathing and washing (*n* = 46, 80.7%) or prior exposure to open water sources (*n* = 11, 19.2%) before the onset of symptoms. The most frequently used open water sources were irrigation canals (*n* = 40, 70.1%), lakes (*n* = 15, 26.3%) and rivers (*n* = 2, 3.5%). Seasonality in the use of water sources was reported by 31.6% (*n* = 18). Notably, 84.2% (*n* = 48) of those who reported using open water sources also used them for activities related to farm animals, particularly cows.

The monthly distribution of the reported cases suggested potential seasonality, with a higher concentration of cases during the dry season, when water levels in reservoirs in Anuradhapura are typically reduced. Case numbers were low at the beginning of the year, from January to March (*n* = 4), followed by a gradual increase from April (*n* = 8) and a peak in May (*n* = 14). Elevated case numbers continued during June (*n* = 5), July (*n* = 6) and August (*n* = 7), after which a gradual decline was observed, with fewer cases reported towards the end of the year. Several water sources were identified from the exposure histories of affected individuals. Jaya Ganga (Yoda Ela) was the most frequently reported water source, accounting for 20 cases (35%), followed by the Rajanganaya canal (*n* = 6, 10.5%), Malwathu Oya (*n* = 4, 7%) and Nachchaduwa lake (*n* = 4, 7%). Although certain water sources were repeatedly reported, exposure sites were distributed across different regions of Anuradhapura District rather than being confined to a single locality. The frequent reporting of Jaya Ganga (Yoda Ela) may reflect either a greater level of exposure among children or environmental conditions favourable for disease transmission.

All patients except two presented with a unilateral episcleral nodule. One participant had multiple nodules in the same eye (1.75%). Six patients (10%) reported recurrences at intervals ranging from one week to seven years. Eye redness was the most frequently reported symptom, followed by the episcleral nodule (*n* = 55, 96.4%). More than 90% (*n* = 53) noticed redness as the first symptom, followed by the development of the episcleral nodule. Pain (*n* = 17, 29.8%), photophobia (*n* = 13, 22.8%) and tearing (*n* = 11, 19.2%) were the most common associated symptoms. Foreign body sensation (*n* = 5, 8.7%), itching (*n* = 5, 8.7%) and eye discharge (*n* = 1, 1.8%) were reported less frequently. Further, 28.1% (*n* = 16) reported that their symptoms were triggered by prolonged exposure to direct sunlight. Some participants (*n* = 7, 12.2%) reported using traditional

medicines prior to seeking clinical care. Commonly used eye-cleansing practices were washing with a pomegranate leaf decoction and washing the eyes with water infused with jasmine flowers.

Hospital management of these nodules involved medical and surgical approaches. Initially, all patients were managed medically with topical corticosteroids, antibiotics, non-steroidal anti-inflammatory drugs (NSAIDs) and lubricants, resulting in resolution in 59.6% (n = 34) of cases. The remaining patients underwent surgical excision of the nodules (n = 23, 40.3%). Histopathological assessment of the excised nodules after H&E staining revealed a mixed inflammatory response in all patients.

Conclusions and Implications

This study identifies a cluster of paediatric ocular nodules with epidemiological features suggestive of freshwater-associated trematode infection in Anuradhapura. The observed association with freshwater exposure and the seasonal clustering highlight the need for increased clinical awareness and further investigation to support the prevention and control of this emerging condition. Further molecular evaluation will be pivotal in confirming the causative species.

Keywords**:** Clinico-epidemiology, ocular nodules, parasitic eye infections, trematode eye infections

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Enterobiasis Among Primary School Children in Anuradhapura District, Sri Lanka

Jayakody N.[1,*], Gordon C.[3], Collinson N.[3], Silva A.[2], Wickramasinghe N.[4], Wickramasinghe S.[5], Wijayasekara A.[1], Karunarathne C.[6], De Silva N.[7] and Weerakoon K.[2]

[1]*Department of Parasitology, Faculty of Medicine, Wayamba University of Sri Lanka, Sri Lanka,* [2]*Department of Parasitology, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka,* [3]*Department of Infection and Inflammation, QIMR Berghofer Medical Research Institute, Brisbane, Australia,* [4]*Department of Community Medicine, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka,* [5]*Department of Parasitology, Faculty of Medicine, University of Peradeniya, Sri Lanka,* [6]*Department of Physiology, Faculty of Medicine, Wayamba University of Sri Lanka, Sri Lanka,* [7]*Department of Parasitology, Faculty of Medicine, University of Kelaniya, Sri Lanka*

*Corresponding author (email: jayakodynalini@wyb.ac.lk)

Introduction

Enterobiasis, caused by *Enterobius vermicularis*, is a faeco-orally transmitted human intestinal nematode infection (HINI) acquired through the ingestion of infective eggs from contaminated hands, clothing, bedding and environmental surfaces (Centers for Disease Control and Prevention, 2024a). Other common HINIs include *Ascaris lumbricoides*, *Trichuris trichiura*, hookworms and *Strongyloides stercoralis*. Among these, *A. lumbricoides*, *T. trichiura* and hookworms are collectively known as soil-transmitted helminths (STHs) because their life cycles require a mandatory development period in soil (Centers for Disease Control and Prevention, 2024b). In contrast, *E. vermicularis* is transmitted directly from person to person without an obligatory soil phase. Enterobiasis affects approximately 200 million people worldwide, with the highest burden in Asia, where prevalence among children ranges from 5% to 50% (Lashaki et al., 2023). Around one-third to one-half of infected individuals remain asymptomatic, while others experience perianal pruritus, sleep disturbance, irritability, nocturnal enuresis and impaired concentration (Centers for Disease Control and Prevention, 2024a). Owing to efficient person-to-person transmission and the prolonged environmental survival of infective eggs, recurrent infections are common, particularly in households and schools (Centers for Disease Control and Prevention, 2024a). Persistent infection may adversely affect sleep quality, school performance, psychosocial well-being and overall quality of life (Leung et al., 2025).

Despite its public health importance, enterobiasis remains under-recognised because the reference diagnostic method, the Scotch tape method, is not routinely incorporated into large-scale epidemiological surveys (Shoup, 2001). Furthermore, *E. vermicularis* is not included in the World Health Organization (WHO) deworming surveillance framework, which mainly targets STHs (World Health Organization, 2021). School-based deworming programmes and improvements in sanitation over the past decades have resulted in a marked decline in STH infections in Sri Lanka. The last national STH survey, conducted in 2017 using the Kato–Katz (KK) technique among primary schoolchildren (PSC), reported an overall STH prevalence of 0.97%, including only 0.21% in Anuradhapura District (Ediriweera et al., 2019), which led to the discontinuation of routine school-based

deworming in several low-intensity districts, including Anuradhapura (Ministry of Health, 2018).

In contrast, epidemiological data on enterobiasis in Sri Lanka remain limited and are largely derived from regional studies conducted among schoolchildren in the Western and Central Provinces, particularly in plantation and other socioeconomically disadvantaged communities, where reported prevalence estimates have ranged from approximately 20% to over 40% (Jayakody et al., 2024). However, published data from Anuradhapura District are lacking. Furthermore, molecular studies investigating the detection and prevalence of *E. vermicularis* remain scarce globally (Jayakody et al., 2026). Therefore, this study aimed to determine the prevalence of enterobiasis among PSC in Anuradhapura District using both microscopic methods and quantitative polymerase chain reaction (qPCR), and to evaluate the true prevalence of enterobiasis, coinfections and associated factors.

Methodology

A school-based cross-sectional study was conducted from January to November 2023 among PSC aged 5–11 years (Grades 1–5) in Anuradhapura District, Sri Lanka. Children were recruited from 19 state schools representing five educational zones using multistage stratified cluster sampling. The study assessed the prevalence of HINIs using microscopic and molecular diagnostic methods. An interviewer-administered questionnaire was completed with the caregivers of participating children to collect information on sociodemographic characteristics, knowledge, attitudes and practices (KAP) related to HINIs, and deworming history. Ethical approval for the study was obtained from the Ethics Review Committee of the Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka (ERC/2021/89). Written informed consent was obtained from the caregivers of all participating children prior to enrolment.

Stool and perianal samples were collected following standardised instructions provided to caregivers. All stool-based diagnostic methods, including direct wet smears (DWS), the formalin-ether concentration technique (FECT), KK, agar plate culture (APC) and qPCR, were performed in triplicate. Scotch tape samples were examined for *E. vermicularis* eggs. DNA was extracted from stool samples for species-specific qPCR assays for HINIs. Microscopic examinations were performed independently by experienced microscopists blinded to the results of the other diagnostic methods, with discordant findings reviewed by the principal investigator, and 10% of samples underwent repeat quality assessment. Participants were considered microscopy-positive if parasite stages were detected in at least one replicate by any relevant diagnostic method. Samples were considered qPCR-positive if amplification occurred in at least two of three replicates, with an average cycle threshold (Ct) < 35 and a Ct standard deviation ≤ 1.

Prevalence estimates were calculated as percentages. Associations between enterobiasis status and KAP were assessed with chi-square or Fisher's exact tests, as appropriate. Coinfections were identified using the combined results of all diagnostic methods. Sensitivity and specificity were calculated using a composite reference standard (CRS)

derived from all diagnostic tests. These metrics were calculated from 2 × 2 contingency tables of true positives, true negatives, false positives and false negatives.

Results and Discussion

The study included 626 PSC with a mean age of 7.9 years (*SD* = 1.44), of whom 354 (56.5%) were boys. Overall, 215 (34.3%) were positive for *E. vermicularis* infection. Detection varied markedly by diagnostic method. Stool-based microscopy showed very low detection rates: DWS (0.2%, *n* = 1), APC (0.2%, *n* = 1), FECT (0.6%, *n* = 4) and KK (1.0%, *n* = 6). In contrast, the Scotch tape method detected 146 positives (23.3%), while qPCR identified 207 positives (33.1%). Among infected children, 58.1% were boys. Coinfections with other HINIs were common, including *A. lumbricoides* (16.7%), *S. stercoralis* (15.3%), *T. trichiura* (7.0%) and hookworm (2.3%). Despite the high prevalence of enterobiasis, 82.9% of infected children had received deworming within the six months preceding sample collection.

Caregiver KAP and environmental factors were significantly associated with enterobiasis status. Children whose caregivers had good knowledge of HINIs had lower odds of infection than those whose caregivers had poor knowledge (OR = 0.52, $p < .001$). Similarly, regular deworming (OR = 0.58, $p = .003$) and the absence of nail-biting behaviour (OR = 0.55, $p = .002$) were associated with reduced odds of enterobiasis.

The present study demonstrates that enterobiasis remains highly prevalent among PSC in Anuradhapura District despite the substantial decline in STH infections reported through the national deworming programme. The markedly higher detection rates achieved by the Scotch tape method and qPCR compared with conventional stool-based microscopy indicate that the true burden of *E. vermicularis* infection is considerably underestimated when surveillance relies solely on routine stool microscopy. The high proportion of infected children who had reportedly received deworming within the preceding six months suggests that current deworming strategies alone may be insufficient to interrupt transmission, probably because of rapid reinfection, suboptimal treatment coverage of household contacts and the absence of enterobiasis-specific surveillance (Centers for Disease Control and Prevention, 2024a; Shoup, 2001). The observed associations of caregiver knowledge, regular deworming and nail-biting behaviour with infection further highlight the importance of integrating health education and behavioural interventions with chemotherapy to reduce transmission. The frequent occurrence of coinfections with other HINIs also suggests that enterobiasis persists alongside other intestinal nematodes even in areas where STH prevalence has declined, emphasising the need for comprehensive surveillance rather than reliance on indicator parasites alone.

This study has several limitations. The use of a CRS incorporating all available diagnostic methods may have introduced incorporation bias when estimating diagnostic accuracy, although this approach was considered appropriate in the absence of a definitive gold standard for enterobiasis (Jayakody et al., 2026). In addition, only a single stool specimen and a single Scotch tape sample were collected from each participant. As repeated stool examinations and consecutive-day Scotch tape sampling are known to improve diagnostic

sensitivity, the true prevalence of enterobiasis and other intestinal nematode infections may have been underestimated (Cho & Kang, 1975).

Conclusions and Implications

Enterobiasis was highly prevalent among PSC in Anuradhapura, and routine stool-based surveillance substantially underestimated the burden of infection. The findings highlight the importance of appropriate diagnostics, including Scotch tape sampling, for the accurate detection of *E. vermicularis*. Molecular methods provide additional value for sensitive detection and for the assessment of coexisting HINIs. Despite recent deworming, the observed high prevalence indicates that enterobiasis remains an under-recognised public health concern, pointing to the need for better surveillance and hygiene-focused interventions for effective prevention and control. The protective associations observed with caregiver knowledge, regular deworming and reduced nail-biting behaviour highlight the potential value of integrating health education and behavioural interventions with existing HINI control programmes in Sri Lanka.

Keywords**:** *Enterobius vermicularis*, microscopic methods, prevalence, quantitative polymerase chain reaction, Sri Lanka

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Utility of Early White Blood Cell Parameters as a Predictor of Snakebite-Induced Acute Kidney Injury

Dilrangi T.[1,*], Mendis V.[1], Waiddyanatha S.[2], Chathuranga U.[2], Isbister G.K.[3] and Silva A.[2]
[1]*Department of Pathology, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka,* [2]*Department of Parasitology, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka,* [3]*Clinical Toxicology Research Group, University of Newcastle, NSW 2308, Australia*
*Corresponding author (email: tharakaadilrangi@gmail.com)

Introduction

Snakebite is a public health issue that mainly affects rural communities in tropical countries (Chippaux, 2017). Snake venom can induce both local and systemic effects in humans. The major systemic effects of snake envenoming are coagulopathy, haemorrhage, neurotoxicity, myotoxicity, microangiopathic haemolytic anaemia and shock (Mehta & Sashindran, 2002). Venom-induced consumption coagulopathy (VICC) is the most common haematological effect. In a minority of patients with VICC, features of thrombotic microangiopathy (TMA) may develop. TMA is characterised by microangiopathic haemolytic anaemia (MAHA), evidenced by increased schistocytes on peripheral blood smears, thrombocytopenia and acute kidney injury (AKI). Antivenom remains the sole specific intervention for systemic envenoming, yet its administration is frequently deferred for hours in initially asymptomatic patients until systemic signs emerge. Therefore, early identification of VICC and, more critically, of AKI is essential.

The full blood count is a simple, reliable and cost-effective test, particularly suitable for resource-limited settings such as Sri Lanka. This study aimed to explore the association of the white blood cell (WBC) count, neutrophil count, lymphocyte count and neutrophil-to-lymphocyte ratio (NLR) within the first 24 hours with AKI among snakebite patients in Anuradhapura, Sri Lanka.

Methodology

A cross-sectional study was conducted, recruiting all adult patients with confirmed snakebite admitted to the Teaching Hospital Anuradhapura from December 2024 to June 2026. Venepuncture was performed at 6 and 12 hours after the bite and daily thereafter until the patient was discharged from the hospital. Clinical data were recorded at 6, 12 and 24 hours and daily thereafter.

For the full blood count, approximately 2.0 mL of venous blood was collected into labelled ethylenediaminetetraacetic acid (EDTA) anticoagulant tubes, and the tubes were gently inverted 8–10 times to mix the blood. Samples were analysed within 2–6 hours of blood collection using a SYSMEX fully automated haematology analyser in the haematology laboratory of the Professorial Unit, Teaching Hospital Anuradhapura.

AKI was defined as an increase in serum creatinine of at least 0.3 mg/dL within 48 hours, a 1.5-fold increase in serum creatinine from baseline within the prior 7 days, or a urine output of less than 0.5 mL/kg/h for at least 6 h (Khwaja, 2012). Complete VICC was defined as an international normalised ratio (INR) of ≥ 3.0, and partial VICC as an INR of < 3 (Isbister et al., 2010).

Ethical approval for the study was granted by the Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka (ERC/2024/61, ERC/2025/14).

Results and Discussion

A total of 472 patients were recruited (median age, 40 years; interquartile range, 16–57 years; males, 64.6%). These included 262 (56%) *Hypnale hypnale* (HH) and 128 (27%) *Daboia russelii* (DR) bites; the remainder were other snakebites. Twenty-two patients (4.6%; DR, 13; HH, 9) developed AKI (stage 1, 10; stage 2, 3; stage 3, 9). Ten patients (2%; DR, 5; HH, 5) underwent haemodialysis. Sixteen patients developed complete VICC (3.3%; DR, 14; HH, 2) and 42 patients developed partial VICC (8.8%; DR, 37; HH, 5). The performance of the WBC count, neutrophil count, lymphocyte count and NLR in predicting AKI is presented in Table 1, while Figure 1 shows the receiver operating characteristic (ROC) curves for the four parameters tested.

Table 1

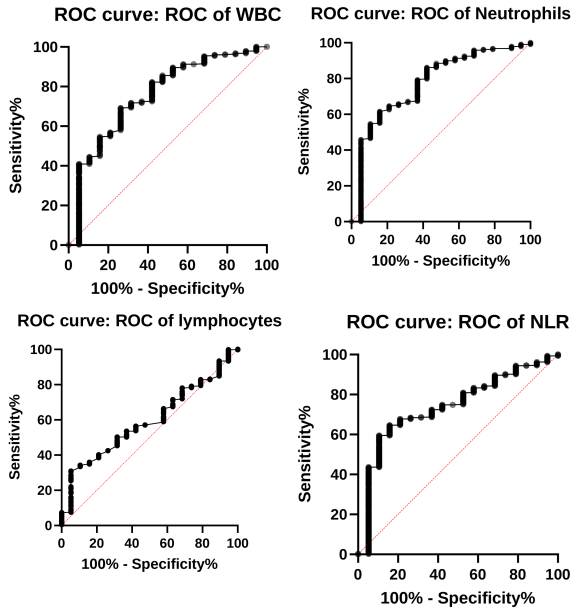
Performance of the White Blood Cell Count, Neutrophil Count, Lymphocyte Count and Neutrophil-to-Lymphocyte Ratio in Predicting Acute Kidney Injury

Parameter	WBC	Neutrophils	Lymphocytes	NLR
Area under the curve (95% CI)	0.7543 (0.6376–0.8709)	0.7743 (0.6628–0.8858)	0.5937 (0.4848–0.7025)	0.7406 (0.6365–0.8448)
Optimal cut-off from Youden index	$> 11.27 \times 10^3/\mu L$	$> 7.78 \times 10^3/\mu L$	$< 1.815 \times 10^3/\mu L$	> 5.017
Sensitivity, % (95% CI)	78.9 (59.7–95.3)	84.2 (66.9–98.2)	15.78 (5.6–38.3)	47.36 (30.5–61.4)
Specificity, % (95% CI)	55.81 (50.7–61.6)	55.58 (50.7–61.6)	89.31 (66.7–76.6)	79.09 (60.4–88.7)

Note. CI = confidence interval; NLR = neutrophil-to-lymphocyte ratio; WBC = white blood cell count.

Figure 1

Receiver Operating Characteristic Curves for the White Blood Cell Count, Neutrophils, Lymphocytes and Neutrophil-to-Lymphocyte Ratio



Note. (A, top left) White blood cell count; (B, top right) neutrophils; (C, bottom left) lymphocytes; (D, bottom right) neutrophil-to-lymphocyte ratio. Each panel plots sensitivity (%) against 100% − specificity (%); the dotted diagonal line indicates no discrimination.

In terms of sensitivity, specificity and area under the curve (AUC), the neutrophil count showed the highest performance as a predictor of AKI in snake envenoming, while the WBC count also showed acceptable performance. Clinically evident AKI usually develops after the first day. At present, snakebite patients in Sri Lanka are observed in hospital for 24 hours and discharged if clinically detectable envenoming does not develop during the period of observation. Accordingly, a patient with an abnormally high WBC count ($> 11.27 \times 10^3/\mu L$) within the first 24 hours could be kept under observation rather than being discharged from the hospital.

The NLR demonstrated good specificity in predicting AKI but had poor sensitivity. In a previous study, the NLR was significantly higher in snakebite patients who developed complications and required a longer hospital stay (Elbey et al., 2017).

Conclusions and Implications

The early neutrophil count (within the first 24 hours after snakebite) appears to be a useful, simple and cost-effective predictor of AKI, suitable for a resource-limited healthcare setting such as Sri Lanka. Further studies with larger sample sizes are recommended to validate the proposed cut-off values and to assess their applicability in the Sri Lankan population.

***Keywords*:** Acute kidney injury, snakebites, thrombotic microangiopathy, white blood cell count

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Methodological Lessons from Developing a Community-Based Intervention to Improve Healthcare-Seeking in Cutaneous Leishmaniasis

Gunasekara S.D.[1,2,*], Agampodi T.C.[2], Agampodi S.B.[2], Fernando M.S.[1], Weerakoon K.G.[3] and Wickramasinghe N.D.[2]

[1]*Department of Health Promotion, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Department of Community Medicine, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka,* [3]*Department of Parasitology, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka*

*Corresponding author (email: dinushika@as.rjt.ac.lk)

Introduction

Community-based interventions (CBIs) remain scarce for neglected tropical diseases (NTDs), particularly in low- and middle-income countries (LMICs) (Amazigo et al., 2012). Published studies have largely focused on intervention outcomes, with limited attention given to the systematic processes underpinning intervention conceptualisation, development and cultural adaptation (Das et al., 2014). Such methodological evidence is essential to improve the transparency and replicability of future interventions (World Health Organization, 2020). Cutaneous leishmaniasis (CL), an NTD and the most common form of leishmaniasis, causes chronic skin lesions, permanent scarring and a considerable psychosocial burden among affected individuals. In Sri Lanka, CL-related research has focused on epidemiology, parasite biology and vector characteristics, with no published studies on the development of CBIs aimed at improving healthcare-seeking (Amarasinghe & Wickramasinghe, 2020). This paper describes the methodological lessons learnt during the development of a CBI to improve healthcare-seeking for CL in rural Sri Lanka.

Methodology

The intervention was developed through a systematic, participatory, theory-informed and iterative process guided by the Intervention Mapping (IM) framework (Bartholomew & Parcel, 2016). A comprehensive mixed-methods needs assessment conducted in the CL-endemic Anuradhapura District combined qualitative approaches, including participant observation, ethnographic diary studies ($n = 28$), Participant Experience Reflection Journals ($n = 30$), follow-up interviews ($n = 25$), creative community workshops ($n = 15$) and interviews with healthcare providers ($n = 16$), with a district-wide cross-sectional community survey ($n = 1{,}555$). Findings were triangulated to identify the behavioural and contextual determinants of delayed healthcare-seeking, to formulate change objectives and to design contextually appropriate intervention strategies (Fernandez et al., 2019). Community engagement and involvement (CEI) was embedded throughout intervention conceptualisation, design and refinement. A qualitative feasibility assessment (ten interviews and a focus group discussion) was subsequently conducted to evaluate acceptability, practicality, adaptability, implementation and scalability, and its findings informed the final refinement of the intervention. Methodological lessons were generated through a reflective synthesis of the entire intervention development process.

Results and Discussion

The needs assessment revealed substantial delays in healthcare-seeking for CL in rural Sri Lanka, resulting from a complex interplay of individual, disease-related, sociocultural and structural determinants. Early symptom recognition of CL was frequently poor, with skin lesions often perceived as minor conditions that did not warrant prompt medical attention, while subsequent healthcare decisions were influenced by broader contextual realities. Building on this comprehensive understanding of the CL healthcare-seeking pathway and its underlying determinants, a CBI framework was systematically developed. The framework comprised four interdependent phases: (I) community entry and contextual analysis, (II) community sensitisation towards CL, (III) community-led actions and (IV) maintenance and sustainability.

The intervention development process generated important methodological lessons that can inform the design of context-specific CBIs for CL and other NTDs. The findings demonstrated that intervention development could begin with a comprehensive understanding of the local healthcare-seeking pathways in CL rather than with predefined intervention activities. The process showed that understanding how individuals recognise and interpret symptoms, make healthcare decisions and interact with their social and health system contexts is fundamental to identifying the behavioural and contextual determinants that the intervention should target. The systematic combination of qualitative and quantitative methods in data collection strengthened decision-making throughout intervention development. Qualitative approaches offered an in-depth understanding of the CL patient journey, including delays in healthcare-seeking behaviour, community perceptions, myths and misconceptions, and contextual realities, enabling the exploration of complex phenomena that could not be adequately captured through quantitative methods alone. A district-wide community awareness survey quantified knowledge gaps regarding CL and identified priority population groups across the study setting. Triangulating these findings informed the co-design of context-specific intervention strategies that reflected locally identified needs and available community resources. These strategies included the development and dissemination of culturally adapted information, education and communication (IEC) materials; participatory exhibitions and health camps in high-risk areas; capacity-building workshops for community members and healthcare providers; school- and youth-led street dramas; door-to-door awareness and lay surveillance of leishmaniasis cases; community leishmaniasis day activities; and locally appropriate communication through social media and existing community networks.

Another important methodological insight was that healthcare-seeking in CL should be conceptualised as a dynamic continuum rather than a single behavioural event (Kanbarkar & Chandrika, 2017). Healthcare decisions evolved through multiple interconnected stages, from symptom recognition and interpretation to treatment-seeking, with each stage influenced by individual, sociocultural, disease-related and structural factors. Consequently, interventions need to be designed to address the entire healthcare-seeking

pathway rather than focusing on isolated behaviours or single intervention activities. The findings further highlighted that CEI (Polidano et al., 2022) should not be considered a discrete intervention component but rather the foundation of intervention development. Meaningful engagement of community members, healthcare providers and other stakeholders throughout intervention conceptualisation, planning, design and refinement ensured that intervention priorities reflected local needs, strengthened cultural appropriateness, promoted stakeholder ownership and empowered communities. This participatory process also facilitated the identification of feasible implementation strategies.

Although the IM framework provided a systematic and theory-informed structure for intervention development, the study demonstrated that methodological flexibility is equally important. While behavioural theories guided the identification of potential intervention strategies, adapting these strategies to locally identified priorities, available resources and contextual realities was essential for developing a practical and contextually appropriate intervention. This iterative balance between theoretical rigour and contextual adaptation enabled the intervention to remain evidence-informed while responding to real-world implementation challenges. The intervention development process also reinforced that feasibility assessment (Bowen et al., 2009) should be viewed as an integral component of intervention development rather than as a separate evaluation phase. Stakeholder feedback enabled the refinement of intervention content, delivery mechanisms and implementation strategies before implementation, thereby improving the acceptability, practicality, adaptability and scalability of the intervention. Collectively, these methodological insights demonstrate that developing potentially effective CBIs requires a systematic, participatory and iterative process that combines mixed-methods evidence, behavioural theories, continuous community engagement, methodological flexibility and ongoing refinement.

Conclusions and Implications

Developing CBIs for NTDs requires a systematic approach that extends beyond intervention design to include comprehensive contextual understanding, theory-informed planning, continuous community engagement, methodological flexibility and iterative refinement. The methodological lessons presented in this paper help to address the limited evidence on intervention development by providing a transparent, replicable framework for designing contextually appropriate interventions. These insights offer practical guidance for researchers, programme planners and policymakers developing CBIs for CL and other NTDs, particularly in LMICs, where locally adapted and sustainable intervention strategies are essential.

Keywords**:** Community engagement, healthcare-seeking, intervention mapping, neglected tropical diseases, Sri Lanka

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Menstrual Health-Related Practices among Female Garment Factory Workers in Anuradhapura District, Sri Lanka

Weerasinghe D.W.G.K.[1,*], Senarathna L.[1] and Wickramasinghe N.D.[2]
[1]*Department of Health Promotion, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Department of Community Medicine, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Saliyapura, Sri Lanka*
*Corresponding author (email: gayathrikw99@gmail.com)

Introduction

Menstrual health is an essential component of women's physical, mental and social well-being and is increasingly recognised as a public health and human rights issue (Babbar et al., 2022; Hennegan et al., 2021). Despite this recognition, more than 500 million women and girls worldwide continue to lack adequate conditions to manage menstruation safely and with dignity (World Bank, 2018). Poor menstrual health practices have been associated with urinary and reproductive tract infections, iron deficiency, absenteeism, reduced productivity and poor quality of life (Das et al., 2015; Munro et al., 2023).

Women employed in labour-intensive industries such as the garment sector are particularly vulnerable because of demanding work schedules, inadequate workplace facilities, limited opportunities for self-care, financial constraints and persistent sociocultural stigma surrounding menstruation (Sommer et al., 2016). In Sri Lanka, menstrual health challenges, including period poverty and inadequate menstrual hygiene management, continue to affect many women, particularly those from economically disadvantaged communities (Hettiarachchi et al., 2023; UNFPA Sri Lanka, 2025).

Menstrual hygiene, dietary practices and pain management are key behavioural determinants of menstrual health. Appropriate menstrual hygiene practices reduce the risk of infections, while adequate dietary practices contribute to preventing iron deficiency. Similarly, appropriate pain management practices enable women to maintain their functional ability and productivity during menstruation (Das et al., 2015; Munro et al., 2023). Understanding existing menstrual health-related practices is essential for identifying behavioural gaps and informing workplace health promotion strategies. Therefore, this study aimed to assess menstrual hygiene, dietary and pain management practices among female workers in a selected mid-scale garment factory in Anuradhapura District, Sri Lanka.

Methodology

A descriptive cross-sectional study was conducted using baseline data collected before the implementation of a health promotion intervention among 75 female garment factory workers at Compass International (Pvt) Ltd., Anuradhapura District. Participants were selected using predefined eligibility criteria. Data were collected using a pre-tested, structured, self-administered questionnaire developed through a literature review and expert consultation. The questionnaire assessed sociodemographic characteristics, menstrual characteristics, menstrual hygiene practices both at home and in the workplace, dietary practices during menstruation, and pharmacological and non-pharmacological

pain management practices. Descriptive statistics were generated using SPSS version 22.0. Ethical approval was obtained from the Ethics Review Committee of the Faculty of Applied Sciences, Rajarata University of Sri Lanka, and informed consent was obtained from all participants.

Results and Discussion

A total of 75 female garment factory workers participated in the study. The mean age of the participants was 30.01 years (standard deviation [*SD*] = 9.47). Most participants were young adults aged 17–24 years (*n* = 30, 40.0%), had completed secondary education (*n* = 54, 72.0%), were married (*n* = 51, 68.0%) and reported a monthly income between Sri Lankan rupees (LKR) 25,000 and 49,999 (*n* = 57, 76.0%).

Menstrual hygiene practices are presented in Table 1. All participants reported using disposable sanitary pads as their menstrual absorbent both at home and in the workplace. However, adherence to recommended menstrual hygiene practices was generally better at home than in the workplace. Workplace practices were comparatively poorer with regard to timely absorbent changing, genital washing with soap, handwashing during absorbent changing and safe absorbent disposal. These findings suggest that although menstrual products were universally available, workplace conditions may have limited women's ability to maintain recommended menstrual hygiene practices.

Table 1

Menstrual Hygiene Practices among Participants (N = 75)

Practice	Home, *n* (%)	Workplace, *n* (%)
Used appropriate absorbent materials	75 (100.0)	75 (100.0)
Changed absorbents every 1–4 hours	51 (68.0)	40 (53.3)
Handwashing during every absorbent change	71 (94.7)	61 (81.3)
Used soap during every genital cleaning	56 (74.7)	31 (41.3)
Safe absorbent disposal practice†	53 (70.7)	26 (34.7)

Note. †Safe absorbent disposal included recommended disposal methods. At home, this comprised wrapping and binning or burning. In the workplace, wrapping and binning or taking used absorbents home for later disposal were considered safe.

Dietary and pain management practices were generally suboptimal among the participants. Regarding dietary practices, 38 participants (50.7%) reported considering dietary changes during menstruation. Non-pharmacological pain management mainly consisted of self-care strategies, with resting at home (*n* = 39, 52.0%) and drinking more water at the workplace (*n* = 37, 49.3%) being the most commonly reported practices. However, only 27 participants (36.0%) reported using pain medication during menstruation, and only 12 (16.0%) demonstrated appropriate awareness regarding pain medication use, indicating limited knowledge of evidence-based pharmacological pain management. These findings suggest that menstrual self-care practices and pain management were inadequate among female garment factory workers.

Although sanitary pad use was universal, recommended menstrual hygiene practices were less frequently followed in the workplace than at home, particularly regarding absorbent

changing, genital hygiene, handwashing and safe disposal. Only 50.7% of participants reported considering dietary changes during menstruation, while drinking more water at the workplace was reported by 49.3%. Pain management relied mainly on resting and other non-pharmacological measures, whereas awareness of appropriate pain medication use was limited. These findings are consistent with previous studies indicating that workplace environments and inadequate menstrual health literacy adversely influence menstrual self-care among working women (Das et al., 2015; Munro et al., 2023; Sommer et al., 2016).

Conclusions and Implications

The findings indicate that important gaps remain in menstrual hygiene, dietary practices and appropriate pain management, particularly within the workplace. They highlight the need for comprehensive workplace-based menstrual health promotion programmes that enhance menstrual health literacy, promote healthy self-care practices and create supportive workplace environments to improve menstrual health and well-being among female garment workers.

Keywords**:** Female garment factory workers, menstrual health, menstrual-related practices, workplace

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School-Based Health Promotion Intervention to Improve Adolescent Physical Activity in Anuradhapura District

Jayawardena H.S.C.[1,*], Gunathilake S.[2] and Senarathna L.[1]
[1]*Department of Health Promotion, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Department of Microbiology, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka*
*Corresponding author (email: sandunichathurnika98@gmail.com)

Introduction

Adolescent physical activity is crucial for healthy development and lifelong behaviours. There are many different ways to be physically active, such as walking, cycling, sports and other active forms of recreation. All forms of physical activity can provide health benefits when undertaken regularly, for a sufficient duration and at an appropriate intensity (World Health Organization, 2010). The World Health Organization (WHO) has developed age-specific physical activity recommendations, according to which children and adolescents should be physically active for 60 minutes per day. An insufficient level of physical activity to meet current global health recommendations is defined as physical inactivity, which is a silent global health threat. At present, 81% of adolescents worldwide do not engage in adequate physical activity (World Health Organization, 2022), a trend reflected in Sri Lanka, where the majority of adolescents (88.1%) fail to meet recommended physical activity levels (Family Health Bureau et al., 2024).

Physical inactivity often begins in adolescence and persists into adulthood, highlighting the need for early targeted interventions to reduce physical inactivity among adolescents. In Sri Lanka, existing programmes are policy-driven and top-down, with limited adolescent participation. Participatory health promotion interventions conducted to address various health issues have demonstrated effective results (Wickramasinghe et al., 2022). Therefore, a participatory health promotion intervention was implemented in this study. The participatory approach actively engages all adolescents as equal partners in identifying barriers and designing solutions. This study aimed to evaluate the effectiveness of a health promotion intervention in improving physical activity levels among adolescents in a school in Anuradhapura District.

Methodology

A quasi-experimental design with an intervention group and a control group was used to evaluate the effectiveness of the health promotion intervention. Two government mixed schools (Type 01C) in Anuradhapura District, approximately 12 km apart, were selected through convenience sampling based on their accessibility; the distance reduced inter-school interaction. The study targeted school-going adolescents of both genders aged 13 to 15 years in Grades 8 and 9. Students with permanent or temporary physical disabilities, chronic illness or medical conditions limiting physical activity were excluded. Using the PS Power and Sample Size Calculations software, a required sample size of 128 participants (64 per group) was determined. Ultimately, all eligible Grade 8 students at the intervention school (n = 67) and Grade 8 and 9 students at the control school (n = 63)

who provided informed consent and assent were recruited. Based on the average number of students per class, all Grade 8 students from Kalaththawa Maha Vidyalaya were selected, whereas both Grade 8 and Grade 9 students from Pothanegama Vidyalaya were included to ensure a more balanced and representative control group. Grade 8 and 9 students were selected because they are at a key developmental stage, are not burdened by major examination pressures and possess sufficient cognitive and social maturity to engage actively in participatory research. Although there is a one-year age difference, these adolescents are at a similar developmental stage, with no significant variation in physical or cognitive maturity.

The study procedure consisted of three phases. In the pre-intervention phase, data collection tools were developed. Baseline data were collected using a Sinhala-translated, pre-tested, self-administered questionnaire adapted from the WHO Global School-based Student Health Survey (World Health Organization & Centers for Disease Control and Prevention, 2017). The tool assessed sociodemographic information, physical activity patterns, knowledge and attitudes. Focus group discussion guides were designed to collect qualitative data from students in the intervention group after the intervention, in order to evaluate the acceptability of the intervention and the students' experiences under the developed themes.

During the intervention phase (a four-month period), a participatory health promotion intervention was co-designed and implemented with the intervention group, following successful engagement and facilitation by the researcher. The students at the intervention school were empowered to achieve a collective goal of improving physical activity levels. Participants identified and prioritised determinants of physical inactivity, such as poor time management, low motivation and low awareness. Students collectively implemented actions to address them, including playing during school intervals, walking with friends, reducing screen time, engaging in physical activities and playing peer-group games. Participants were facilitated to monitor their progress continuously and to identify their changes.

In the post-intervention phase, quantitative data were collected again from both groups using the same questionnaire, and qualitative data were gathered from the intervention group through two focus group discussions (eight students per group, approximately one hour each). Quantitative data were managed and analysed using IBM SPSS software. Independent-samples *t*-tests were used to compare continuous variables, reported as means and standard deviations (*SD*s). Proportions were calculated as descriptive statistics, and chi-square values were computed for categorical variables. Qualitative data were audio-recorded, transcribed and translated from Sinhala into English, and thematic analysis was used to organise key quotes into themes.

Results and Discussion

A total of 123 adolescents participated (intervention, $n = 62$; control, $n = 61$), with no statistically significant differences between the two groups in baseline sociodemographic characteristics, including mean age (13.6 vs. 13.7 years, $p = .239$) and gender distribution

(58.1% vs. 60.7% female, 41.9% vs. 37.7% male, p = .552). Knowledge related to physical activity was assessed in terms of the recommended duration and related diseases, and it improved significantly (p < .001; Table 1). A positive attitude towards engagement in physical activity was reported by 55 (88.7%) intervention and 51 (83.6%) control students before the intervention (p = .412) and by 59 (96.7%) and 51 (87.9%) students, respectively, after the intervention (p = .070), indicating a positive trend between groups.

Table 1

Knowledge Regarding Physical Activity

Knowledge component	Before the intervention			After the intervention		
	Intervention (n = 62), n (%)	Control (n = 61), n (%)	p	Intervention (n = 61), n (%)	Control (n = 58), n (%)	p
Students aware of the recommended physical activity duration	12 (19.4)	9 (14.8)	.498	52 (85.2)	11 (19.0)	< .001
Students who identified diseases associated with a lack of physical activity	45 (72.6)	46 (75.3)	.087	58 (95.0)	49 (84.5)	< .001

The intervention group increased its average daily physical activity from 17 minutes (SD = 21) at baseline to 21 minutes (SD = 22), while the control group increased from 16 minutes (SD = 21) to 21 minutes (SD = 22). Independent-samples t-tests indicated no statistically significant differences between the groups (p = .798 before, p = .907 after). The intervention group decreased its mean sedentary screen time from 302 minutes (SD = 145) at baseline to 266 minutes (SD = 134), while the control group increased from 225 minutes (SD = 172) to 238 minutes (SD = 175). At baseline, the intervention group reported significantly higher screen time than the control group (p = .008); after the intervention, this difference was no longer significant (p = .323). In the qualitative exploration, students expressed acceptance of the intervention, described their experiences and reported increased knowledge about physical activity, stress reduction and the importance of involving parents. Students reported understanding the importance of one hour of daily activity and the benefits of being active. They expressed pride in participating in cultural games, a willingness to spend more time being active and even sharing their knowledge with family members.

The intervention group demonstrated a significant increase in knowledge and a positive trend in attitudes towards physical activity compared with the control group. Expanding health literacy and fostering favourable attitudes are crucial initial steps, as evidence highlights that low health literacy is strongly linked to physical inactivity (Kolovelonis et al., 2024). Although the quantitative analysis did not show statistically significant behavioural changes within the short intervention period, the focus group discussions

revealed encouraging signs of progress. Students reported that they played more, managed their time better and even shared their health knowledge with their parents. The decrease in sedentary screen time in the intervention group also supports this positive direction. Previous studies show that short interventions often lead to rapid improvements in knowledge and intention, but that behaviour change takes much longer to be reflected in statistical data (Grauduszus et al., 2024). Nevertheless, the qualitative findings suggest that students were taking their first small steps towards changing their daily physical activity habits, laying the foundation for long-term improvements.

Conclusions and Implications

A significant increase in knowledge and a positive trend in attitudes were achieved among adolescents in the intervention school in Anuradhapura District. These shifts in health literacy and positive mindsets establish the necessary foundation for long-term behavioural change towards physical activity. This study was conducted over a short duration and was limited to a single school in Anuradhapura, which limits its generalisability. The findings demonstrate that empowering students through participatory interventions is practical, equitable and an alternative to traditional health programmes. Further participatory interventions should involve parents and teachers, in addition to students, to improve physical activity.

Keywords**:** Adolescents, physical activity, physical inactivity, school health

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Employee Retention Motives and Retention Intention: Examining the Moderating Role of Job Embeddedness in Sri Lanka's Apparel Sector

Ramesh A.R. and Manjula S.*
University of Jaffna, Sri Lanka
*Corresponding author (email: manjulasivarajah@gmail.com)

Introduction

Employee retention is a significant challenge for companies around the world, especially in labour-intensive sectors such as the apparel industry, where turnover affects operations, costs, and the development of knowledge and skills (Biron & Boon, 2013; Hom et al., 2017). It is therefore important to understand the variables that affect employee retention in order to improve retention strategies. Sri Lanka's apparel industry is a major export sector, generating around US$4.7–5.0 billion in 2024 and employing approximately 300,000 workers, which makes it one of the country's leading foreign exchange earners (Central Bank of Sri Lanka, 2024; Joint Apparel Association Forum Sri Lanka [JAAF], 2024). However, the industry faces a retention problem. Many apparel organisations experience high turnover owing to factors such as low job satisfaction, limited career development opportunities, demanding working conditions and attractive employment alternatives (De Silva & Morapitiya, 2023). This results in frequent employee departures, increased recruitment and training costs, disruptions to production and the loss of experienced workers, which in turn adversely affect productivity and performance. To maintain competitiveness in this labour-intensive sector, retaining talent is essential (Hom et al., 2017).

Previous studies have shown the significance of rewards, the working environment, career opportunities and work–life balance in shaping employees' attitudes and retention (Allen et al., 2010; Self et al., 2022; Wickramasinghe & Jayaweera, 2011). However, few studies have explored the impact of employee retention motives on retention intention, especially in the Sri Lankan apparel industry. Social exchange theory suggests that relationships between employees and employers are built on reciprocal exchanges, in which employees respond positively when they perceive that the organisation values and supports them (Blau, 1964). Drawing on social exchange theory, this study hypothesises that positive retention motives lead to reciprocal retention intentions. The moderating effect of job embeddedness in enhancing this reciprocal relationship is also examined. Hence, this research explores the influence of employee retention motives on retention intention, moderated by job embeddedness, in Sri Lankan apparel factories.

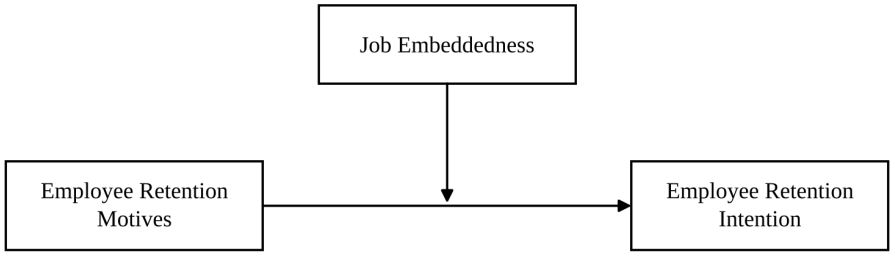
Methodology

This study adopted a quantitative cross-sectional survey design, with data collected through self-administered questionnaires from employees of selected apparel firms. The study examined employee retention motives as the independent variable, retention intention as the dependent variable and job embeddedness as the moderating variable (Figure 1). A total of 230 responses were obtained from a convenience sample of operational-level frontline workers, such as sewing machine operators and line workers.

Convenience sampling was adopted because of the difficulty of reaching large numbers of factory employees and constraints of time and permission; it was the most practical approach to gathering information from a large population in the apparel industry. The sample consisted primarily of employees aged between 25 and 39 years, the majority of whom had more than five years of work experience, ensuring relevant industry representation. The sample was predominantly female, reflecting the workforce composition of Sri Lanka's apparel industry, while male employees represented a smaller proportion of the respondents. This approach was suitable for analysing the relationships among the study variables; however, the use of convenience sampling and a cross-sectional design may limit the generalisability of the findings.

Figure 1

Conceptual Model



The questionnaire used standardised measurement scales to measure the dependent and independent variables, such as compensation and rewards, work environment, work–life balance, intention to stay and job embeddedness. The items were rated on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The scale items were drawn from the literature to ensure validity and reliability, and minor adaptations were made to align them with the context of the Sri Lankan apparel industry.

Results and Discussion

The correlation analysis (Table 1) shows that all variables are positively and significantly correlated at the .01 level. Retention motives have a strong positive relationship with retention intention (r = .72), indicating that better compensation, rewards, work environment and work–life balance are associated with a higher intention to stay. Similarly, job embeddedness shows a strong positive correlation with retention intention (r = .73), confirming that employees with stronger organisational connections are more likely to remain. Overall, the results provide initial support for the hypothesised relationships in the study.

Table 1

Correlation Analysis

Variables	Retention motives	Rewards	Work environment	Work–life balance	Retention intention	Job embeddedness
Retention motives	1					
Rewards	.71**	1				
Work environment	.65**	.69**	1			
Work–life balance	.60**	.58**	.62**	1		
Retention intention	.72**	.69**	.74**	.71**	1	
Job embeddedness	.64**	.61**	.63**	.65**	.73**	1

Note. **$p < .01$ (two-tailed).

Source: SPSS output

The regression model has high explanatory power (Table 2). In Model 1, 46% of the variance in retention intention is explained. When the interaction (job embeddedness) is added to the original model, Model 2 explains 55% of the variance (an additional 9%, $\Delta R^2 = .09$). This suggests a substantial effect of job embeddedness.

Table 2

Model Summary

Model	*R*	R^2	Adjusted R^2	ΔR^2	Std. error of the estimate
1	.68	.46	.45		0.52
2	.74	.55	.54	.04	0.48

Source: SPSS output

Accordingly, the analysis of variance (ANOVA) shows that the regression model as a whole is significant, $F(3, 226) = 92.47$, $p < .001$. This suggests that the variables included in the regression model account for a significant proportion of the variance in employee retention intention.

According to the coefficient results, the direct effect of retention motives on retention intention is positive and significant ($\beta = .61$, $p < .001$), showing that better employee support leads to higher retention. There is also a direct effect of job embeddedness ($\beta = .28$, $p < .001$). Importantly, the interaction is also significant ($\beta = .22$, $p = .002$), suggesting that job embeddedness strengthens the effect of retention motives on retention intention.

Conclusions and Implications

The study finds that retention motives play a significant role in influencing employee retention in the Sri Lankan apparel industry. Moreover, it emphasises the role of job embeddedness: the interaction between retention motives and job embeddedness increased the explained variance in retention intention from 46% to 55%, with the moderating effect (job embeddedness) explaining an additional 9% of the variance. This

indicates that employees with higher job embeddedness are more likely to translate motives into stronger intentions to remain with the organisation. The results lend support to social exchange theory in predicting retention in labour-intensive industries.

In terms of theoretical implications, this research builds on social exchange theory by adding job embeddedness as a moderating variable, and it shows that employee retention depends not only on organisational rewards and support but also on employees' level of embeddedness and integration in the organisation. In practical terms, apparel industry managers should focus on strengthening both motivational factors (including job rewards, compensation and working conditions) and embeddedness factors (including relationships, career opportunities and organisational identification) to boost employee retention. Future research could use longitudinal data and samples from various industries to enhance generalisability and to explore the longitudinal relationship between retention motives, job embeddedness and employee retention.

Keywords**:** Apparel industry, employee retention motives, job embeddedness, retention intention, social exchange theory

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Exploring Motivational Factors in English Language Learning Among Certificate in English (Extension) Programme Students at Rajarata University of Sri Lanka

Nandarathna B.G.D.S.*, Wehella D.A., Nizam A.A.M. and Pathirana H.P.K.
Department of English Language Teaching, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: darshikasrihani@gmail.com)

Introduction

English is an obligatory subject across all tiers of education in Sri Lanka, encompassing competencies in reading, writing, speaking, and listening. Its significance has markedly increased, not only as a vital instrument for global communication but also as a comprehensive indicator of linguistic proficiency that extends beyond mere examination performance. Students learn English for academic, professional, personal, and travel reasons, with motivation playing a crucial role in language acquisition. At Sri Lankan universities, English instructions vary by program; some offer it only for the students of internal degree programmes, while others give access to external students through specialized courses. Despite extensive instructions, students' proficiency levels vary significantly, mainly due to motivational factors. In *"The importance of motivation in second language acquisition.",* Anjomshoa and Sadighi (2015) says how motivation influences second-language learning. They describe motivation as a key factor in learners' effort, persistence, engagement, and willingness to continue despite difficulties. According to Oletić and Ilić (2014), motivation in language learning comprises two primary forms: intrinsic and extrinsic. Intrinsic motivation arises from internal factors, such as personal interest and the inherent enjoyment of learning. External rewards, such as grades, praise, or future benefits, drive extrinsic motivation. Simbolon, Nina, and Ramadhani (2019) emphasized that both types influence behavior and student development, with extrinsic motivation fostering competitiveness and intrinsic motivation encouraging genuine engagement. While previous research highlights intrinsic and extrinsic motivators, their specific influence on students in external English courses remains underexplored. Accordingly, based on the research question, "How do motivational factors affect English learning among students in the Advanced Certificate in English (Extension) Programme - 2026 at Rajarata University of Sri Lanka?", the researchers aim to examine the specific motivational factors influencing English language acquisition among students enrolled in the program.

Methodology

This study investigated the factors that influence motivation in English language learning among 250 students enrolled in the Advanced Certificate in English (Extension) Programme - 2026 at Rajarata University of Sri Lanka. Researchers used a 27-item Likert scale questionnaire, which took approximately 15 minutes for participants to complete during lectures. The questionnaire covered three main areas: motivation (intrinsic and extrinsic), the learning process, and the benefits of learning English. It also included items related to personal information. The Likert scale ranged from 1 (Strongly disagree) to 5 (Strongly agree). Data collected from the questionnaires were analyzed using the

Statistical Package for the Social Sciences (SPSS), with descriptive statistics used to present the frequencies and percentages of participants' responses.

Results and Discussion

Findings of the study are very significant when designing curriculum for students. Alizadeh (2016) says that motivation has a very important role in learning English as a foreign or second language successfully. So, it is very important to identify the motivational factors of learning English at first. Brophy (2004) emphasizes that teachers can foster students' motivation by connecting learning activities to meaningful classroom goals. After identifying the motivational factors, the teachers can foster students' motivation in the classroom.

The questionnaire's internal consistency was assessed using Cronbach's alpha. The Motivation Factors in Learning English subscale, comprising 13 items, had an alpha of .622. The Learning Process in Learning English subscale included 6 items and had an alpha of .647, while the Benefits of Learning English subscale consisted of 8 items and had an alpha of .626. The Learning Process subscale showed the highest alpha, although the three values were similar. Overall, the coefficients indicate modest internal consistency; their adequacy is interpreted in light of the study's context and the criteria adopted.

According to the results interpreted through mean rank interpretation, the mean scores for motivational factors in learning English ranged from 2.22 to 4.45, indicating varying levels of agreement among students. The strongest motivation was the aspiration to speak English fluently (MFLE11, M = 4.45, SD = 0.77), followed by excitement about continuing the English-learning journey (MFLE1, M = 4.34, SD = 0.717), curiosity about learning (MFLE4, M = 4.13, SD = 0.739), and the belief that English supports deeper understanding by connecting new and existing knowledge (MFLE13, M = 4.08, SD = 0.77). Students also generally agreed that English helps them express themselves confidently (MFLE9, M = 3.98, SD = 0.70), that learning English is a priority (MFLE3, M = 3.80, SD = 0.808), and that they enjoy participating in lessons (MFLE2, M = 3.74, SD = 0.817) and feel comfortable answering questions (MFLE10, M = 3.71, SD = 0.80). Embarrassment when speaking in front of peers received a moderately high mean (MFLE12, M = 3.67, SD = 1.04), while preference for studying in their native language (MFLE6, M = 3.13, SD = 1.10) and studying English solely to pass exams (MFLE5, M = 2.92, SD = 1.01) were closer to neutral. Students reported some tension when speaking during lectures (MFLE8, M = 2.72, SD = 0.98), while the lowest mean was for having little enthusiasm for English lectures (MFLE7, M = 2.22, SD = 0.99), suggesting that most respondents did not lack enthusiasm. Overall, the results indicate strong motivation, particularly toward fluency and continued learning, alongside some speaking-related anxiety and embarrassment. Accordingly, students are highly motivated by intrinsic factors, with moderate challenges noted.

The mean scores for students' perceptions of the English-learning process ranged from 3.40 to 4.29, indicating general agreement with the statements. The highest mean was for

the view that learning English helps connect new information with existing knowledge and supports deeper understanding (LPLE18, M = 4.29, SD = 0.722), followed by agreement that English lectures cover a lot of ground (LPLE15, M = 4.20, SD = 0.698). Students also agreed that they feel embarrassed speaking English in front of their peers (LPLE17, M = 4.15, SD = 0.721) and when speaking with peers (LPLE19, M = 3.83, SD = 0.806). They reported difficulty independently summarizing key points in English subject material (LPLE14, M = 3.67, SD = 0.774) and found English somewhat challenging to learn (LPLE16, M = 3.40, SD = 0.888). Overall, students recognized the learning benefits of English while also reporting challenges, particularly around speaking and summarizing material.

The mean scores for the perceived benefits of learning English ranged from 2.78 to 4.23, indicating varying levels of agreement. The highest mean was for the belief that English contributes to overall personal development (BLE27, M = 4.23, SD = 0.735), followed by having a genuine interest in learning English (BLE24, M = 4.11, SD = 0.736) and believing that English supports effective communication (BLE21, M = 4.07, SD = 0.755). Students also agreed that multilingual individuals possess significant knowledge (BLE20, M = 3.94, SD = 0.910), that they would like to have many English-speaking friends (BLE23, M = 3.85, SD = 0.825), and that they can think critically and analyze English content (BLE22, M = 3.63, SD = 0.787). Procrastination on English homework received a more moderate mean (BLE25, M = 3.32, SD = 1.003), while the lowest mean was for refraining from asking friends or lecturers for assignments after missing lectures (BLE26, M = 2.78, SD = 1.206). Overall, students viewed English as beneficial to their communication, personal development, and interest in learning, although some reported procrastination and varied follow-up behavior after missing lectures.

In addition, independent sample t-test between genders was done to show the gender differences in motivation, learning, and perceived benefits. Accordingly, some significant differences were found: females scored higher in motivation (M = 3.66, SD = .501) than males (M = 3.59, SD = .302; t(248) = -1.412, p = .007); males scored higher in learning (M = 3.95, SD = .377) than females (M = 3.87, SD = .623; t(248) = 1.144, p = .001); and females again scored slightly higher in perceived benefits (M = 3.77, SD = .603) than males (M = 3.73, SD = .393; t(248) = -0.538, p = .005). Intrinsic motivation, like curiosity and the value of English, motivated 54% of students, while extrinsic motivation was less influential (28.8%). Barriers included classroom tension (41.6%) and embarrassment (23.2%). Many students enjoyed discussions (51.2%) and saw English as a link to prior knowledge (56.8%). The study recommends creating supportive, interactive environments to reduce anxiety and increase motivation, noting the need for further research on age and gender differences.

Conclusions and Implications

This study aimed to identify key challenges and evaluate the effectiveness of English language learning among students of the Advanced Certificate in English (Extension) programme - 2026, with a focus on intrinsic and extrinsic motivation factors. Analyzing data revealed that intrinsic motivation plays a more significant role in influencing English

learning. Despite diverse learning approaches, students shared common goals and recognized personal benefits from English courses, emphasizing the importance of motivation for academic success. The researchers recommend further investigations to deepen understanding in this area, emphasizing the need for ongoing research to enhance English proficiency, which is vital for global business and international communication.

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Algorithms as Cultural Gatekeepers: Social Media Recommendations and Aesthetic Diversity in Sri Lankan Youth Cinema

Ranathunga R.M.N.A.*
Department of Performing Arts, Sri Palee Campus, University of Colombo, Sri Lanka
*Corresponding author (email: anuradharanathunga2@gmail.com)

Introduction

The rapid evolution of digital technology and the subsequent proliferation of social media platforms have fundamentally restructured the landscape of global cinema consumption and spectator psychology. Historically, film selection and the cultivation of cinematic appreciation were governed by organic, subjective and institutional factors. Traditional spectatorship relied on physical cinema attendance, localised word-of-mouth recommendations, film journalism, printed critical reviews and deeply personal aesthetic preferences. However, the contemporary digital era has ushered in a paradigm shift, transforming the spectator from an active, autonomous seeker of art into a passive consumer navigated by algorithmic ecosystems.

In the contemporary Sri Lankan context, this digital transition has reshaped the cultural and leisure habits of young people. As smartphones and high-speed internet become ubiquitous, the traditional gatekeepers of cinema, such as professional film critics, national film societies and mainstream media reviews, have been largely superseded by proprietary digital recommendation engines. Platforms such as YouTube, TikTok and Facebook function as cognitive curators that continuously monitor, analyse and predict user behaviour.

The core problem addressed by this research is the subtle yet profound erosion of aesthetic diversity and independent cinematic choice among Sri Lankan youth due to the pervasive gatekeeping influence of social media recommendation engines. While digital platforms democratise access to information, their underlying algorithms prioritise high-engagement content, creating an ideological and aesthetic echo chamber that marginalises non-mainstream film traditions. In Sri Lanka, young audiences (aged 18–30 years) increasingly consume cinema through fragmented digital artefacts such as short movie clips, algorithmic reels, user-generated TikTok reviews and Facebook video essays. This algorithmic feedback loop continuously feeds viewers content aligned with their historical data, thereby severely limiting their exposure to diverse cinematic genres, independent films, world cinema traditions and avant-garde art.

The academic justification for this study lies in addressing a critical gap in contemporary Sri Lankan media studies: while extensive research exists on general social media usage, there is a distinct lack of empirical, qualitative scholarship analysing how algorithmic gatekeeping actively reshapes taste culture, critical thinking capacities and the preservation of aesthetic diversity among local youth. Therefore, the study has four objectives. The first is to investigate the specific mechanisms through which short-form cinematic content (YouTube clips, TikTok trends and Facebook Reels) influences the movie selection patterns of Sri Lankan youth. The second is to analyse the extent to which

algorithmic recommendation engines compromise or diminish the autonomy of young viewers in making independent cinematic choices. The third is to evaluate critically the impact of algorithmic culture on the preservation of aesthetic diversity and on the willingness of young audiences to engage with complex, diverse world cinema traditions. The fourth is to formulate a new conceptual framework for media and cinema literacy within Sri Lankan academic discourse, addressing the specific challenges posed by algorithmic dependency.

Methodology

To capture the nuanced, subjective and psychological dimensions of this phenomenon, the study adopts an entirely qualitative research methodology. Primary data collection relies on focus group discussions (FGDs) with young Sri Lankan cinema enthusiasts and casual viewers aged 18 to 30 years, selected from among university undergraduates and young corporate professionals. The FGDs explore daily social media consumption habits relating to film content, the psychological triggers that prompt the viewing of specific films on the basis of viral recommendations, and self-awareness regarding algorithmic manipulation and the resulting restriction of exposure to diverse cinema. In parallel, the study conducts a qualitative content analysis of viral Sri Lankan social media materials, including YouTube summary videos, TikTok film reviews and Facebook Reels. The analysis of narrative structures, editing styles and emotional hooks decodes how algorithms construct viral trends that homogenise film choices.

Results and Discussion

The anticipated findings indicate that cinematic choices among youth are largely synthetic, engineered by predictive modelling rather than by authentic agency. The structural tendency of the algorithm to promote high-engagement content results in standardised consumption patterns. Culturally significant, aesthetically demanding and politically radical films (such as Marxist cinema, neorealist works or independent Sri Lankan productions) are systematically marginalised, directly threatening aesthetic diversity. Furthermore, the continuous consumption of fragmented, fast-paced micro-content alters cognitive capacity, creating resistance towards long-form storytelling and complex narrative structures. In contrast to traditional critical engagement, the algorithm acts as an automated extension of the culture industry that optimises commercial engagement over artistic value, reinforcing an echo chamber that isolates young viewers from diverse cinematic traditions.

Conclusions and Implications

The rise of algorithms as cultural gatekeepers poses a significant threat to the preservation of aesthetic diversity, pluralism and intellectual vitality in Sri Lanka's cinematic landscape. When public taste is outsourced to commercial algorithms, the democratic potential of cinema as a tool for social reflection is severely compromised. This study emphasises the urgent need for "algorithmic literacy". It provides a foundational text to assist educators, cultural policymakers and film institutions in Sri Lanka in developing

strategies that encourage young spectators to dismantle digital echo chambers, reclaim critical autonomy and safeguard aesthetic diversity within contemporary film culture.

***Keywords*:** Aesthetic diversity, algorithmic culture, algorithmic literacy, recommendation engines, Sri Lankan youth

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AI-Assisted ESL Pedagogy in Sri Lankan Higher Education: Opportunities, Challenges, and Sustainability

Kuruppuarachchi M.T.K.*
Department of English Language Teaching, University of Peradeniya, Sri Lanka
*Corresponding author (email: mkuruppuarachchi@gmail.com)

Introduction

The rapid advancement of digital technologies has significantly transformed educational practices across the globe, particularly in the field of English as a second language (ESL) education. Among these technological innovations, artificial intelligence (AI) has emerged as a powerful educational tool that enhances teaching and learning experiences through personalised instruction, automated feedback, adaptive learning systems and interactive digital platforms. AI-powered applications such as content generation platforms, grammar correction software and speech recognition tools are increasingly being integrated into language learning environments to support communication skills, learner autonomy and flexible access to educational resources. In contemporary higher education, sustainable learning has become a central concern as institutions seek innovative methods to provide inclusive and future-oriented education.

Recognising the need for quality education, the United Nations (UN) established Education for Sustainable Development (ESD) and sustainable education as education targets for 2030. Under Sustainable Development Goal (SDG) 4, Quality Education, the ESD target is set as follows: "By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development" (United Nations Department of Economic and Social Affairs, 2015). Thus, ESD refers to "learning to clarify one's own values; learning to envision more positive and sustainable futures; learning to think systemically; learning to respond through applied learning; and learning to explore the dialectic between tradition and innovation" (UNESCO, 2010).

These educational approaches promote continuous learning, critical thinking, adaptability and lifelong skill development while ensuring the efficient use of educational resources. Within ESL education, AI technologies have the potential to support sustainable practices by reducing dependency on traditional teaching materials and enabling self-directed, collaborative and technology-enhanced language learning.

In developing countries, including Sri Lanka, the integration of AI into university education remains an emerging area of research. Although digital learning technologies have gained greater attention since the COVID-19 pandemic, many higher education institutions continue to face challenges related to infrastructure, digital literacy, technological accessibility and teacher preparedness. ESL learners in Sri Lankan universities are increasingly exposed to AI-based tools for academic writing, grammar correction, pronunciation practice and language communication, which further

complicates this scenario. Despite these developments, only limited research has explored how university students and teachers perceive the opportunities and challenges associated with AI-assisted ESL learning in the Sri Lankan higher education context.

Thus, this study aimed to explore the experiences, perceptions and attitudes of university ESL teachers and students towards the integration of AI technologies into tertiary-level ESL pedagogy. Additionally, the research examined the educational benefits, ethical concerns, technological limitations and sustainability-related implications of AI-supported ESL instruction. The study was guided by three objectives: to identify the opportunities that AI technologies provide for sustainable ESL learning; to examine the challenges and limitations associated with integrating AI tools into ESL education; and to provide recommendations for the effective and sustainable use of AI in ESL teaching and learning in higher education contexts.

Methodology

This study adopted a qualitative research design to obtain an in-depth understanding of participants' experiences and perceptions regarding the use of AI tools in ESL education. A purposive sampling technique was employed to select participants with prior exposure to AI-assisted learning technologies. The participants consisted of twenty undergraduate ESL students and four university teachers attached to a state university in Sri Lanka. The students were in their third academic year and were following the ELA1000 course.

Data were collected through semi-structured interviews with the university teachers and focus group discussions with the students. The semi-structured interviews with teachers provided detailed insights into pedagogical practices, challenges and professional attitudes towards AI integration in sustainable education-based ESL instruction. The focus group discussions with students examined learner experiences, opinions and concerns related to AI-based learning tools. The qualitative data were analysed using thematic analysis: recurring themes, patterns and participant perspectives were identified and categorised to explore the opportunities and challenges associated with AI-supported sustainable learning practices in ESL education.

Ethical considerations were maintained throughout the study. Participants were provided with informed consent forms covering participation, confidentiality and anonymity prior to data collection, and the data collected were stored in accordance with university recommendations.

Results and Discussion

The study revealed that AI tools positively influenced ESL learning by improving learner engagement, motivation and independent learning. Students perceived AI technologies as accessible and supportive tools for grammar correction, vocabulary development, pronunciation practice and academic writing. They valued AI for its ability to provide personalised and learner-centred instruction.

This finding supports the view that "there are numerous advantages to using instructional technology in teacher education with regard to its cost-effectiveness, online discussion

tools, virtual field trips and constructivist-orientated practices to support learning" (Cheng & Myles, 2003; Howard & McGrath, 1995; McAlister & Curtis, 2001). Teachers mentioned that digital learning platforms helped to reduce reliance on printed materials, supported remote learning opportunities and provided flexible educational access for diverse learners. In ESL education, AI technologies can create interactive and engaging learning environments that foster communication skills, creativity and critical thinking. Shor and Freire (1987) note that "action, critical reflection, curiosity, demanding inquiry, uneasiness, and uncertainty – all these virtues are indispensable to the cognitive subject, to the person who learns." Both teachers and students noted that AI tools have the capacity to accommodate these diverse curiosities, enquiries and engagements of students, because AI tools never become tired or impatient as people do and, with their ever-evolving capacities and databases, can respond to these diverse requests.

It was also observed that AI applications enhanced ESL learners' confidence through immediate, non-judgemental feedback and repeated practice opportunities, which reduced learner anxiety when using a second or foreign language. MacIntyre (1998, as cited in Zheng, 2008) defined language anxiety as "the worry and negative emotional reaction aroused when learning or using a second language". In this regard, Wu (2024, as cited in Jeon, 2025) notes that AI-supported learning can markedly "enhance motivation, reduce anxiety, and increase willingness to communicate and learner engagement". This was evident in the students' responses during the focus group discussions, as they increasingly relied on AI despite being aware of certain inconsistencies and limitations.

The findings further indicated that university teachers recognised the potential of AI tools to support flexible and sustainable learning environments with access to a vast hub of resources. These benefits include increased student participation, creative engagement and skill building related to digital learning materials, with Canva, Gemini and ChatGPT being notably prominent in this regard.

However, the study also identified several challenges in AI integration. Teachers reported concerns about overreliance on AI-generated content, reduced critical thinking, plagiarism and limited authentic communication. Students also tended to trust AI and thereby lose their authenticity while disowning their creative process. Technological issues, including poor internet access, a lack of devices and insufficient institutional support, were also significant barriers in the Sri Lankan higher education context. The study highlighted the need to balance AI-assisted learning with human interaction. While AI provided valuable support, participants emphasised that teachers remained essential for guiding communication, providing emotional support and fostering language development.

Conclusions and Implications

By exploring the experiences of students and teachers, the research enhanced the understanding of the role of AI in supporting sustainable ESL education. It provides timely implications for educators, curriculum developers and policymakers regarding the effective and ethical use of AI in ESL contexts. The findings contribute to discussions on

digital education, learner autonomy and technology in language learning. Overall, the study shows that although AI offers significant benefits, successful integration depends on balanced pedagogy, accessibility and responsible use.

***Keywords*:** Artificial intelligence, education for sustainable development, English as a second language, higher education, sustainable learning

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Impact of Artificial Intelligence-Based Mobile Applications on Second Language Writing Development: A Study Among BAMS Students Learning English as a Second Language

Gunarathne D.T.[1,*] and Dissanayake S.A.R.R.P.[2]
[1]*English Language Teaching Department, University of Peradeniya, Sri Lanka,* [2]*Gampaha Wickramarachchi University of Indigenous Medicine, Sri Lanka*
*Corresponding author (email: dinukag@sci.pdn.ac.lk)

Introduction

In the contemporary educational landscape, proficiency in English serves as a crucial bridge to professional advancement, academic publication and international collaboration. Students and professionals who master English can share ideas across cultures, participate in high-level summits and navigate digital networks. This linguistic competence is therefore no longer merely an impressive asset; it is an essential catalyst for personal growth and collective innovation on the world stage.

Despite possessing a basic knowledge of grammar, many Sri Lankan undergraduates experience notable difficulties in developing their English writing skills during their university education (Mohamed Aaqil et al., 2022). These challenges commonly manifest as grammatical inaccuracies, such as errors in irregular morphemes, alongside structural issues with vocabulary and paragraph organisation (Kulathunga, 2025; Navaz, 2017). Additionally, first-language interference significantly affects their academic performance, as students often subconsciously rely on the syntax and structures of their native languages when writing in English (Sanmuganathan, 2013).

Researchers have increasingly demonstrated that mobile-assisted language learning (MALL) plays a vital, positive role in enhancing the writing skills of second language (L2) learners. By using handheld devices, students gain flexible, immediate access to digital tools that support the core stages of the writing process, including drafting and revising. Studies indicate that integrating specialised mobile software helps L2 learners reduce structural errors and improve overall text organisation, making them more independent and confident writers over time (Mihaylova et al., 2022).

Within the domain of indigenous medicine, specifically the Bachelor of Ayurveda Medicine and Surgery (BAMS) degree programme offered by institutions such as the Gampaha Wickramarachchi University of Indigenous Medicine, the development of English writing proficiency is a critical component of undergraduate success. Undergraduates in this discipline are increasingly expected to demonstrate advanced skills in academic writing, research publication and clinical documentation in order to communicate indigenous medical knowledge globally.

Despite the growing interest in MALL, existing research focuses predominantly on the general utility of artificial intelligence (AI) in strengthening standard English as a Second Language (ESL) academic writing skills. Furthermore, investigations in these areas have highlighted the ability of ChatGPT to enhance the drafting efficiency, vocabulary and syntactic precision of general medical undergraduates. However, a distinct research gap

remains, as the effectiveness of AI-driven applications in specialised, traditional and indigenous medical frameworks has not yet been satisfactorily investigated (Wang et al., 2024). Undergraduates in disciplines such as BAMS face a unique dual linguistic burden, as they must blend classical medical concepts with global academic English standards, a nuance overlooked by generalised AI research. Consequently, there is a critical lack of empirical evidence on how conversational AI models can be deployed to minimise communicative anxiety and to form a specialised written proficiency framework tailored to indigenous medicine students.

This study investigated the effectiveness of the ChatGPT mobile application as an AI-driven intervention designed to bridge the gap between theoretical language knowledge and the practical, communicative use of written language among BAMS undergraduates. The specific objectives were to quantitatively evaluate the effectiveness of a two-month ChatGPT mobile application intervention on BAMS undergraduates' second language writing proficiency; to investigate undergraduates' perceptions of and attitudes towards the use of AI tools as a low-anxiety, constructive environment for enhancing writing fluency and structural text organisation; and to identify pedagogical implications that can inform a specialised written proficiency framework for indigenous medicine students.

Methodology

This study employed a quantitative quasi-experimental design with a supplementary attitudinal survey to evaluate the impact of the AI-driven intervention over a specified period. This design allowed the generation of more comprehensive findings that included not only measurable outcomes but also participants' perceptions of the effectiveness of the intervention (Olsen et al., 2004).

The target population consisted of undergraduates enrolled in the BAMS degree programme. The final sample comprised 80 BAMS students who were selected using a systematic sampling approach and identified as possessing B1-level English writing proficiency on the basis of an initial diagnostic assessment.

The selected participants took part in a structured two-month intervention consisting of ten targeted demonstration sessions on using the ChatGPT mobile application as a personalised writing assistant. The sessions covered formulating and structuring academic topics, developing coherent essays, refining academic drafts and using AI to obtain immediate feedback on syntax and style. A standardised matrix of prompt templates was provided to ensure consistent feedback scaffolding and to minimise variation in AI-generated responses across participants.

The study was conducted after obtaining ethical approval from the Dean of the Faculty. The purpose and procedures of the study were explained to the participants, and written informed consent was obtained. All data collected were anonymous and confidential and were used only for research purposes; participation was voluntary. The participants were also reminded not to provide any private or personal data in the ChatGPT application.

To triangulate the research findings, data were collected using pre- and post-tests based on predetermined rubrics to assess writing proficiency in Ayurveda discourse, together with a post-intervention Likert-scale perception questionnaire to examine participants' attitudes towards the intervention. Quantitative data were analysed using a paired-samples *t* test to determine the statistical significance of improvements in writing proficiency following the two-month ChatGPT intervention.

Results and Discussion

The analysis of the pre- and post-test data demonstrated a statistically significant improvement in the undergraduates' written proficiency scores following the AI-driven mobile application intervention. The paired-samples *t* test revealed that the mean post-test score ($M = 5.9$, $SD = 0.48$) was significantly higher than the baseline pre-test score ($M = 5.3$, $SD = 0.68$), $t(79) = 14.32$, $p < .01$, indicating that the observed progress was highly significant and unlikely to have occurred by chance. Furthermore, the writing evaluation showed significant improvement in three areas: broader academic vocabulary, greater grammatical accuracy, and stronger paragraph organisation and logical coherence.

The descriptive statistics derived from the Likert-scale questionnaire strongly supported the quantitative findings, revealing highly positive learner perceptions of the integration of AI tools. Specifically, 86% of the participants agreed that the AI-based practice provided a low-anxiety, constructive environment. This non-threatening digital workspace enhanced their writing fluency, the structural organisation of complex medical texts, and the acquisition and use of vocabulary.

The combination of immediate, private feedback and individualised scaffolding through the mobile application successfully lowered the affective filter, allowing students to experiment with language and correct errors in real time without the anxiety often present in traditional classrooms (Ebadijalal & Yousofi, 2021).

Conclusions and Implications

The findings of this study suggest that AI-driven mobile applications offer a highly viable, personalised learning strategy for improving the English writing skills of ESL learners in specialised indigenous medical contexts. By providing an accessible, low-anxiety medium for continuous practice, the ChatGPT application successfully translated theoretical grammar knowledge into functional communicative competence (Hayashi & Sato, 2024).

The pedagogical implications of this research are twofold. First, it demonstrates that mobile-assisted AI tools can complement traditional ESL curricula, offering teachers a scalable method of providing individualised feedback to large student cohorts (Guo et al., 2025). Second, this study provides empirical baselines that can inform future curriculum design and specialised writing frameworks for indigenous medicine. Such a framework will help ensure that future medical professionals possess the communicative tools needed to document clinical findings and publish valuable research on a global stage.

One limitation of this study is its focus on ESL learners in a specialised medical context in an indigenous setting. The results may therefore not be applicable to students in other disciplines, cultural groups or educational environments. The results are preliminary, and further research with larger and more varied samples is required to validate the general applicability of AI-driven mobile applications for enhancing English writing skills.

***Keywords*:** Artificial intelligence, Bachelor of Ayurveda Medicine and Surgery students, ChatGPT, mobile-assisted language learning, writing proficiency

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Digital Diplomacy and Soft Power Projection: A Comparative Study of Sri Lanka and Singapore

Jayarathna I.*
Department of International Studies, University of Kelaniya, Sri Lanka
*Corresponding author (email: isini.jayarathna123@gmail.com)

Introduction

In the 21st century, digital diplomacy has emerged as a crucial component of modern international relations, facilitating states' engagement, connection and communication with foreign audiences through advanced digital tools. Grounded in Nye's concept of soft power, digital diplomacy has gained relevance in statecraft as a means of amplifying national branding and foreign policy outreach compared with traditional diplomatic practices. However, Bjola (2015) argues that, despite the possibilities that digital diplomacy offers for the maintenance of international relations, analytical information remains limited on how digital diplomacy works, its degree of success and the limitations entangled with it. This highlights a gap in the existing literature regarding a reliable conceptual framework for evaluating the efficiency of social media for public diplomacy purposes (Bjola & Jiang, 2015).

Furthermore, despite the growing importance of digital diplomacy in shaping global narratives, there is a lack of comparative research examining how countries with differing levels of development and digital capacity employ digital diplomacy for soft power projection. This gap limits the understanding of how digital tools can be adapted and optimised across varying contexts within the Global South. Therefore, this study comparatively examines the similarities, differences and effectiveness of the digital diplomacy strategies of Sri Lanka and Singapore to understand how digital diplomacy contributes to soft power projection in different national contexts. By comparing these two small states, the study helps to clarify how differences in institutional capacity, digital infrastructure and strategic coordination influence the effectiveness of digital diplomacy for soft power projection, while identifying opportunities and challenges relevant to strengthening Sri Lanka's digital diplomatic framework.

Methodology

This study adopted a pragmatic philosophical framework and a qualitative research approach, which allowed the exploration of the diverse perceptions of individuals in Sri Lanka interpreting digital diplomacy as a tool of soft power projection. Given the scope of the study, both primary and secondary data were gathered to evaluate the tactics, challenges and opportunities in the two different settings and to present a comprehensive, comparative analysis of the dynamics of digital diplomacy. Information about Singapore's digital diplomacy tools and their implications was gathered from secondary sources such as journals, books, government websites and government reports. Nye's concept of soft power served as the theoretical framework for examining how digital diplomacy contributes to a state's ability to communicate with, engage and influence foreign audiences.

In line with the context of the study, data on Sri Lankan digital diplomacy tactics and on the digital diplomacy tools used within the administration of Sri Lanka were gathered from a sample of 30 Sri Lankan government officials from the Ministry of Foreign Affairs. The participants were selected through purposive sampling, as they possessed relevant institutional knowledge and professional experience concerning Sri Lanka's foreign policy and digital diplomacy practices. The interviews were conducted using a semi-structured interview guide and focused on institutional practices, digital platforms, strategic objectives, challenges and opportunities related to digital diplomacy. Drawing on these two sources, the study employed content analysis and comparative analysis for both the primary and the secondary data, which enhanced the depth and breadth of the analysis.

Results and Discussion

The findings demonstrate a substantial difference between the digital diplomacy frameworks of Singapore and Sri Lanka. Analysis of the 30 interviews with Sri Lankan Ministry of Foreign Affairs officials, together with documentary evidence, identified institutionalisation, digital infrastructure, public engagement, institutional coordination and international collaboration as key dimensions shaping digital diplomacy (Table 1).

Table 1

Comparison of Digital Diplomacy Practices in Singapore and Sri Lanka

Dimension	Singapore	Sri Lanka
Policy framework	Institutionalised national strategy	Emerging policy structure
Digital infrastructure	Advanced ICT and AI integration	Developing technological capacity
Public diplomacy	Strategic digital campaigns	Social media-based engagement
Institutional coordination	Centralised governance	Fragmented coordination
Digital initiatives	Highly integrated digitalised diplomatic tools	Experimenting with initiatives that are in the developmental stage
Regional and international collaborations	Strong region-centric digital diplomatic engagements and international collaborations	Minimal regional or international collaborations
Soft power projection	Strong global digital reputation	Growing but underutilised potential

Note. AI = artificial intelligence; ICT = information and communication technology.

Singapore demonstrates a highly institutionalised model supported by national initiatives, including Smart Nation 1.0, Smart Nation 2.0 and national artificial intelligence strategies, which facilitate the integration of digital technologies into governance and diplomatic engagement. In contrast, Sri Lanka demonstrates an emerging model in which social media and official digital platforms are increasingly used for public engagement and information dissemination, but without a comprehensive national digital diplomacy strategy. Differences in technological capacity further influence implementation, with Singapore benefiting from advanced digital infrastructure, artificial intelligence integration and digital governance, while Sri Lanka faces infrastructural and digital

literacy constraints. These findings correspond with previous research identifying institutional and technological challenges in Sri Lankan digital diplomacy (Ariyawardana, 2021; Jayatilaka, 2020; Madusha, 2024).

Public diplomacy also distinguishes the two countries. Singapore employs coordinated digital campaigns to promote its economic and cultural interests and to engage international audiences, whereas Sri Lanka relies more heavily on social media and on initiatives such as the Contact Sri Lanka Portal, including for tourism promotion and crisis communication. Singapore also demonstrates stronger institutional coordination and regional engagement through the Association of Southeast Asian Nations (ASEAN) and international digital governance initiatives, while Sri Lanka's practices remain comparatively fragmented and less integrated. From a soft power perspective, the findings indicate that digital diplomacy contributes more effectively to Singapore's international visibility and reputation because of the coherence between its digital policies, technological capacity, institutional coordination and diplomatic engagement. Sri Lanka's increasing adoption of digital tools demonstrates an emerging potential for digital soft power, but this potential remains constrained by limited strategic integration and institutional capacity.

Conclusions and Implications

The study concludes that effective digital diplomacy for soft power projection depends on institutional coordination, strategic policy integration, technological capacity and sustained international engagement, rather than on digital platforms alone. The comparison with Singapore demonstrates how a coherent national digital framework can strengthen digital diplomacy and public diplomacy. In Sri Lanka, the absence of a clear national-level digital diplomacy policy framework emerged as a key factor contributing to fragmented and inconsistent practices. Therefore, the study proposes a national digital diplomacy strategy led by the Ministry of Foreign Affairs that defines foreign policy objectives, establishes standardised digital communication guidelines, ensures policy continuity across political transitions and aligns digital diplomacy with broader foreign policy priorities. Strengthening institutional coordination, digital capacity, strategic audience engagement, and regional and international cooperation alongside such a framework could enable Sri Lanka to move from predominantly informational digital communication towards a more coordinated approach to digital diplomacy and soft power projection.

Keywords**:** Digital diplomacy, foreign policy, Singapore, soft power, Sri Lanka

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"English as the Icing on the Cake": Exploring the Role of English in the Professional Lives of a Selected Group of Lawyers

Wickramasinghe W.M.C.A.*
Department of English Language Teaching, Wayamba University of Sri Lanka
*Corresponding author (email: ashanthi@wyb.ac.lk)

Introduction

According to Ratwatte (2011), English has been both a resource and a problem in the Sri Lankan context. Many scholars argue that it has long been identified as a marker of class and privilege and as a tool that guaranteed different kinds of social, cultural and economic privilege (Kandiah, 1989, 2010; Parakrama, 1995, 2010; as cited in Rambukwella, 2018). Thus, the presence and dominance of English in Sri Lanka involve a combination of complex associations. Bourdieu's (1991) concept of linguistic capital is useful in understanding this context: certain languages are valued more highly than others in different linguistic markets, and they can be converted into "cultural", "economic" and "symbolic capital". In Sri Lanka, it is assumed that English has more linguistic capital than Sinhala or Tamil and that it plays a vital role in shaping careers.

Considering the dearth of research on the relationship between the English language and legal professionals in the Sri Lankan context, this study aims to explore the dynamic roles played by the English language in the professional lives of a selected group of Sri Lankan lawyers whose first language is Sinhala. The study does not seek to generalise the findings to the wider Sri Lankan legal community, as the sample is limited to five participants. Rather, it aims to contribute to areas in which further research is necessary and to provide insights into the complex relationship between the English language and the lives of the selected participants.

Methodology

This study employs narrative inquiry as its methodological approach to discover the role played by English in the lives of the selected sample of lawyers, since "the narrative inquiry research approach, with its ability to focus on critical life events while, at the same time, exploring holistic views, holds valuable potential for researchers in a broad range of learning areas" (Webster & Mertova, 2007, p. 1). The sample of five lawyers was selected through purposive sampling: two lawyers who claimed to be fluent in English and three lawyers who claimed to be weak in English were selected. Three participants (Kasun, Akalanka and Gamini) work in Sinhala-based legal forums only and claim that they are not fluent in English, whereas two participants (Indika and Jagath) work in both Sinhala- and English-based legal forums and claim that they are fluent in English; in both groups, fluency in English is self-assessed. In addition, only lawyers with more than 10 years of experience were selected, in the expectation that their narratives would be shaped by their years of experience.

Data were collected through life history interviews and autobiographies. Life history interviews were used as a research tool since "in the life history is revealed as in no other way the inner life of the person, his moral struggles, his successes and failures in securing

his destiny in a world too often at variance with his hopes and ideals" (Burgess, 1930/1966, as cited in Taylor et al., 2016, p. 103). The interviews were conducted first. Almost all the stories were narrated without any linear structure, and the participants talked about their childhood as well as their present professional experiences with the English language. The longest interview lasted almost 60 minutes, while the shortest lasted about 15 minutes. Each session was audio-recorded, transcribed and translated, and complementary follow-up sessions were conducted. The written accounts were gathered later to give the participants ample time to write amid their busy schedules. The data were analysed using thematic analysis, by analysing the content and "finding common thematic elements across research participants and the events they report" (Riessman, 2005, p. 2).

Results and Discussion

According to the participants' views, English is associated with professional mobility, identity development and recognition. This aspect of professional mobility is further validated by Kasun, who argues that a lawyer's duty is not only to perform in courts: "A lawyer must excel in everything. He should be able to perform confidently in any forum or position. For that, English is essential. If a client comes and tells you to secure him bail from the Appeal Courts, you can't refuse and tell him to find another lawyer ('gentleman')."

Kasun reiterates that a lawyer without English would have to pass on a case to a colleague fluent in English, which is an indispensable requirement for a lawyer to function in the Court of Appeal. By passing on a case to another lawyer, a lawyer without competence in English loses not only the stipulated fee but also their reputation. Kasun understands the void in a lawyer's career in the absence of a good knowledge of English. On the other hand, according to the participants (especially the lawyers who claim that they are not fluent in English), English as one isolated factor is not synonymous with the law itself. If the law is like a cake, English is merely the icing on that cake; the cake can be enjoyed with or without the icing. However, it also appears that a glass ceiling is created. As Gamini says, "People like the designs/decorations associated with English. English is like the icing on the cake, and everyone likes it. Even the people who are watching like this. Within the profession, status and recognition have their highs and lows. What I want to say is that English is necessary, whereas the lack of it is never a major problem. If the goal can be achieved, it is what matters. However, there are limitations."

Furthermore, one can appear competent and confident without English. There are certain legal spaces where Sinhala carries more symbolic value. For instance, the lower forums, such as the District and Magistrate Courts, function in Sinhala. In addition, some judges prefer and are comfortable with the use of Sinhala owing to their lack of fluency in English, and a lawyer does not want to antagonise such a judge or make them uncomfortable through the use of English. In Kasun's words, "Even some judges are not fluent in English. Knowing that nature, we do not want to mess up the situation by using English. And it is just another language. There is nothing miraculous about it." Thus, persuading the judge through the application is what counts. In this sense, English is only

another language, and it is not necessary to give it undue importance. However, this remark should also be considered in light of the subject position of Kasun, who is limited to Sinhala-based legal forums and cannot move beyond the glass ceiling. He understands that he cannot grasp the '*kaduwa*' (sword, a metaphor for English) firmly, and thus a degree of spite as well as resignation to his fate is clearly evident.

Additionally, the results reveal that, particularly for the less fluent participants, professional status and recognition may not depend only on a lawyer's fluency in English. There are many other factors, such as one's contacts, the number and type of one's clients, and one's performance and skills. Indika, who is a competent user of English, describes other vital skills that need to be accumulated in the Sinhala-medium legal context in this manner: "Our job does not solely depend on English. Our knowledge of the law and our presentation skills are more important. If you know the law, you can control anything which comes after that." This quotation highlights that the ideological stances occupied by the participants also determine the role played by English in their professional lives. Kasun, Akalanka and Gamini perceive a void in their careers and a sense of 'failure' in the absence of a desirable competence in English. Nevertheless, having adapted to the system and being able to 'progress' in their careers has also led them to feel that English is one among several factors in their professional lives. Hence, all five participants, while acknowledging the supremacy of English, also emphasise that English is not the sole factor in their professional lives, for various reasons and from the different subject positions they occupy. Nevertheless, the notion that without English one is somehow 'lesser' or 'deprived' feeds, like a self-fulfilling prophecy, into the narrative of English as mandatory for professional and career development.

Conclusions and Implications

The study reveals the dual and contradictory roles played by the English language in the professional lives of the selected group of lawyers. It shows that English is a key factor in the renegotiation and formulation of a lawyer's legal identity and career mobility. Nevertheless, the findings also show that, for the lawyers in the sample who are less fluent in English, English is required and useful in specific situations only. This disrupts the common perception of English as a key factor in determining a lawyer's 'successful' professional life. The study argues that the relationship between English and the selected lawyers is complex, fluid and context-dependent. English is not viewed as an exclusively mandatory requirement but rather as an added advantage operating alongside a wider matrix of socio-cultural and ideological realities, such as personal and career-related objectives and goals, ideological stances and subject positions, and the types of legal forums and legal fields in which the lawyers are engaged. The study highlights the need for future research exploring the broader socio-cultural and ideological realms that shape and determine the relationship between the English language and the Sri Lankan legal system.

Keywords**:** English, lawyers, narrative inquiry, professional lives

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Sustainability Deferred: An Interpretative Phenomenological Analysis of Savings and Financial Survival Under Economic Uncertainty in Pakistan

Ajmal M.M.[1,*], Salman S.[1] and Ali T.[2]
[1]*National University of Computer and Emerging Sciences,* [2]*University of the Punjab*
*Corresponding author (email: mobeen.ajmal123@gmail.com)

Introduction

Economic uncertainty becomes qualitatively different when it stops behaving like an event and starts returning as part of ordinary financial life. Rising prices, weaker purchasing power, changing household claims and uncertainty around income can leave a salary intact while altering what that salary can sustain. Household-finance research shows that uncertainty changes saving and spending, while resilience research draws attention to the capacity to absorb shocks and adapt (Bufe et al., 2022; Coibion et al., 2024). The unresolved issue is what happens to financial meaning when the cues do not settle.

Research has established that scarcity can make immediate demands more salient and that perceived losses are not independent of reference points. Financial decisions are also shaped by family relationships and social context, and financial strain is associated with workplace outcomes (Hosany & Hamilton, 2023; Mullainathan & Shafir, 2013; Rosso et al., 2024). Yet this literature tells us less about the interpretive work through which recurring financial cues are turned into a workable course of action. What does planning become when the future cannot be held still? What becomes of security when a buffer is repeatedly drawn back into ordinary life?

We examine this problem through eight idiographic accounts from Pakistan. Pakistan is used here as an empirical setting in which prolonged instability makes the broader process visible, not as a claim of regional exceptionalism. We ask how salaried employees make sense of prolonged uncertainty and what security, saving, planning and the future come to mean; how recurring cues are interpreted in relation to household responsibilities; how financial adaptation is experienced; and how uncertainty enters working life. Our theoretical focus is sensemaking under chronic threat. Scarcity and prospect theory are retained as background sensitivities, not as rival explanatory frameworks. The argument is that recurring cues may do more than trigger new decisions: they can change what planning is for.

Methodology

We used Interpretative Phenomenological Analysis (IPA) because the phenomenon concerns lived meaning rather than the prevalence of financial practices. IPA brings phenomenological attention to experience together with hermeneutic interpretation and an idiographic commitment to the case (Smith et al., 2022). The final corpus comprised eight employed participants ($N = 8$), anonymised as P01–P08, after three cases from the original corpus were excluded. Semi-structured interviews addressed saving, financial pressure, income and employment uncertainty, household responsibilities, financial decisions, work and family life, beliefs and change over time. Participation was voluntary;

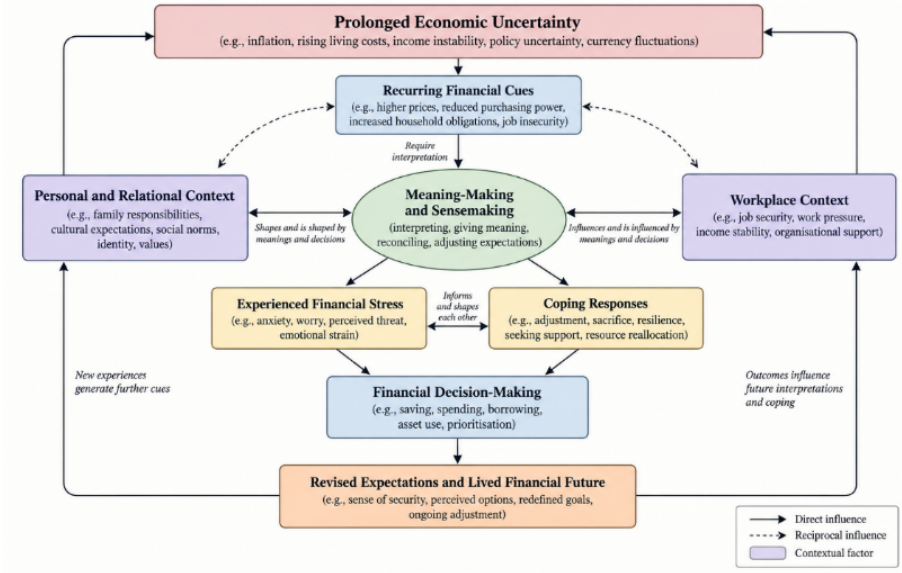
confidentiality and pseudonymisation were maintained, and participants could decline questions or stop participating.

Each case was read and re-read as a whole before descriptive, linguistic and conceptual exploratory noting. Observations were developed into experiential statements, clustered into Personal Experiential Themes (PETs), and then brought across cases to develop Group Experiential Themes (GETs). Convergence and divergence were retained, as were guarded disclosure and the negative case that most clearly tested the interpretation. The analytic trail runs from transcript to experiential statement, PET and GET. Theory entered only after this primary IPA structure had been established; it was used to interrogate the findings, not to decide in advance what a participant's account meant.

Meaning-making remains the interpretive stance, but sensemaking under chronic threat is the paper's single theoretical conversation. As the economic scenario changes, new cues are generated, and this flux of recurring financial cues requires the decision maker to make sense of the change, to understand what remains possible and to assess what remains within their control. Figure 1 depicts the iterative conceptual model. The framework is interpretive rather than causal; after the idiographic analysis, the sensitising perspective helps to ground the findings in theory.

Figure 1

Interpretive Architecture of Financial Survival Under Prolonged Economic Uncertainty



Note. Interpretive architecture; arrows indicate iterative interpretive relations rather than fixed causal pathways.

We examine how individuals make sense of financial insecurity when what was initially experienced as a temporary disruption becomes an enduring condition. The study addresses three research questions. The first asks how recurring financial cues alter

salaried employees' lived understanding of financial security and resource allocation under sustained macroeconomic pressure. The second asks in what ways individuals re-interpret the function of planning and relational commitments when long-term economic forecasting fails. The third asks how formal employment is re-signified as part of a household's broader defensive architecture against chronic threats.

To answer these idiographic phenomenological questions, we focused on understanding the decision maker's sensemaking perspective and interpreting their expressed reality. The lived experiences were examined through double hermeneutic interpretation while maintaining the idiographic commitment to each interviewee's voice, which was made possible by adopting IPA (Smith et al., 2022). The IPA design enabled us to examine the participants' meaning-making around financial cues and then to use the sensitising perspectives to interpret issues that remained relevant in their changing circumstances.

Results and Discussion

Four group experiential themes emerged: security became room to manoeuvre; when planning cannot hold, planning changes its job; the future became relational and biographical; and employment became part of the financial meaning system.

First, security became room to manoeuvre. Security was experienced less as a quantity of money than as retained capacity. P01 described saving as something he could rely on "during difficult times" for "security and stability"; P06 called her salary a "security net" for herself and her son. Across cases, savings, employment continuity, assets, skills and additional earning capacity mattered because they preserved options. The distinction extends resilience research by adding a temporal question: can a buffer remain a buffer when demands keep returning (Bufe et al., 2022)?

This also separates employment security from lived adequacy. Regular employment did not remove concerns about purchasing power, rising costs or future capacity. Netemeyer et al. (2018) distinguish present financial circumstances from perceived future security; our findings show how that distinction is lived. Security was felt when enough room remained to respond to the next demand without immediately giving up independence. The relevant object was capacity under pressure, not the balance-sheet figure alone.

Second, when planning cannot hold, planning changes its job. The clearest theoretical movement concerns planning. Participants did not simply stop planning as uncertainty intensified; they recalculated, postponed, reduced and protected. P07 deferred home ownership while saying "No compromise" on her daughters' education. P08, after describing years of saving and preparation, said "no planning is working", yet described asset use, cheaper transport and a lower standard of living. In context, the phrase signals a mismatch between the pace of change and the absorptive capacity of an earlier plan. Planning becomes a way of keeping a workable course rather than forecasting an entire future. Sensemaking under chronic threat is therefore less about restoring a settled baseline than about repeatedly recalibrating what can still be protected.

Third, the future became relational and biographical. The future was carried by people and identities: children's education, a future self, independence, career progression and family dignity. P04 explicitly linked investment to "my future self", while P08 protected children's education despite cutting other expenditure. P02 had little room for saving but still said, "future behtar he hoga." These accounts qualify a strong reading of scarcity as mere present focus. Immediate demands were powerful, yet future-oriented commitments could become more protected when they carried biographical meaning. Financial decisions were therefore not only resource allocations; they were decisions about which parts of a life should remain possible.

Faith belonged to this interpretive process without becoming a separate explanatory variable. Participants placed trust in Allah alongside budgeting, work, saving, cost reduction and continued effort. The data support neither pure surrender nor pure control. Rather, they point to a way of living with uncertainty in which action is directed towards what can be influenced, while outcomes that cannot be guaranteed are held through faith.

Fourth, employment became part of the financial meaning system. Workplace research has established links between financial stress and employee well-being, commitment, performance and work–family outcomes (Rosso et al., 2024). Our findings shift the starting point. Employment did not merely receive the consequences of financial stress; it also became a resource through which financial security was pursued. Ayesha said, "I can't afford to not be good at my work." Nadia used teaching, training and project work to extend financial capacity, while Sana understood career progression and doctoral study as routes towards greater security. Work thus becomes part of the household's protective architecture.

That architecture is not uniformly agentic. P04 described temporary drops in motivation, P05 reported an effect on concentration while keeping his account guarded, and P08 described delayed tasks and mental exhaustion. These differences matter. They preclude a simple stress-to-performance pathway and support a more processual reading: under chronic threat, the meaning of work changes because continued competence, employability and progression can become financially consequential. The contribution is not a new causal model; it is a sharper account of how recurring economic cues can reorganise the practical and symbolic role of work.

Conclusions and Implications

The study suggests a shift in how financial survival should be theorised. When uncertainty is episodic, planning can be oriented towards restoring or anticipating a future that is assumed to be reasonably stable. When uncertainty becomes recurrent, the task changes: people repeatedly make sense of what has changed and protect a workable continuity rather than a fully specified future. Our theoretical contribution is to extend the sensemaking conversation towards this chronic condition. Sensemaking here is not only the interpretation of disruption; it is the ongoing maintenance of viability under repeated, unresolved cues.

The practical implication is modest but consequential. Financial well-being initiatives should look beyond nominal employment security and the presence of savings to the capacity that those resources actually leave available. Organisations can matter because benefits, progression and employment conditions may form part of household protection, while restrictions on additional work may narrow the options available to employees. Financial support should also recognise that people protect valued commitments, so the meaning of an expense matters for how support is likely to be used. These are implications drawn from the accounts, not causal prescriptions.

The contribution is bounded by the small idiographic corpus, the retrospective accounts and the variation in household and employment circumstances. Some financial experiences were deliberately withheld and were not inferred. Future research should follow sensemaking over time, especially the point at which planning moves between prediction, adaptation and prioritisation, and should examine whether this chronic form of financial sensemaking travels across employment forms and national settings. The broader question is whether prolonged uncertainty changes not only what people decide, but also the kind of future they understand themselves to be planning for.

***Keywords*:** Financial security, financial survival, prolonged economic uncertainty, sensemaking, workplace financial stress

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Preparing Humanities and Social Sciences Graduates for the AI Era: A Critical Review

Silva H.D.* and Weerawansa S.R.S.D.K.
Department of Economics, University of Colombo, Sri Lanka
*Corresponding author (email: dilushahr@gmail.com)

Introduction

The Fourth and Fifth Industrial Revolutions are reshaping labour markets and the purpose of higher education through the expansion of artificial intelligence (AI). Science, technology, engineering and mathematics (STEM) disciplines have attracted substantial policy and scholarly attention regarding AI readiness. By contrast, humanities and social sciences (HSS) graduates remain comparatively under-represented in this discussion, despite accounting for the majority of graduate enrolments in many developing-country universities, including those in Sri Lanka. This can be considered a critical gap, given that the human-centred competencies cultivated by HSS education, such as critical thinking, ethical reasoning and intercultural communication, are widely projected to become the most valued attributes in AI-driven economies (World Economic Forum, 2023).

The existing literature draws heavily on developed-country contexts and STEM-oriented evidence, and it lacks theoretical and empirical evidence and discussion on preparing HSS graduates in developing countries. Therefore, this review critically examines the global and developing-country literature published between 2020 and 2026 to investigate how universities are preparing HSS graduates for AI-driven economies, and it proposes an integrated framework to guide future research, policy and practice. The study has five research objectives: (i) to examine how AI is transforming higher education globally; (ii) to identify the competencies required by HSS graduates for AI-driven economies; (iii) to evaluate institutional responses to AI adoption; (iv) to identify barriers to inclusive AI preparedness in developing countries; and (v) to propose future directions for inclusive AI readiness.

Methodology

This study adopts a critical review methodology to synthesise and evaluate the literature addressing AI readiness among HSS graduates. Systematic searches were conducted across Scopus, Web of Science, ScienceDirect, Emerald, Springer, Taylor & Francis, Wiley, IEEE Xplore and Google Scholar using combinations of keywords including "Artificial Intelligence", "Higher Education", "Humanities", "Social Sciences", "Graduate Employability" and "Developing Countries". The search was restricted to peer-reviewed publications from 2020 to 2026, the period of most rapid AI evolution, and was supplemented by seminal earlier theoretical works.

The synthesis was guided by five research questions (RQs) aligned with the five research objectives: (i) how is AI transforming higher education globally; (ii) what competencies are required by HSS graduates; (iii) what institutional responses to AI exist; (iv) what are the barriers to inclusive AI preparedness in developing countries; and (v) what are the future directions for inclusive AI readiness? Five theoretical perspectives were used in

this study: Human Capital Theory (Arthur, 2026; Becker, 1964), the Technology Acceptance Model (Davis, 1989; Xue et al., 2026), Employability Theory (Tomlinson, 2017), Digital Competence Frameworks (Vuorikari et al., 2022) and Social Inclusion Theory (Devisakti et al., 2024). These theories served as an analytical lens to critically evaluate the retrieved literature and to develop an integrative conceptual framework.

Results and Discussion

With regard to RQ (i), on how AI is transforming higher education globally, the synthesis shows that AI can improve teaching through personalised learning and intelligent tutoring. However, its benefits are mainly available in well-resourced institutions, which raises concerns about educational inequality (Selwyn, 2022). Generative AI also challenges academic integrity, particularly in HSS disciplines that depend on written assessments, and this creates room for redesigning assessments around higher-order thinking (Cotton et al., 2024). In the labour market, AI may replace routine cognitive tasks in entry-level HSS jobs (Frey & Osborne, 2017), but human–AI collaboration is likely to be more important than complete human replacement (Wilson & Daugherty, 2018). Overall, AI should therefore be viewed as a tool that complements human capabilities rather than one that replaces human workers.

Concerning RQ (ii), on the competencies required by HSS graduates for AI-driven economies, Vuorikari et al. (2022) show that existing digital competence frameworks provide a systematic basis for digital literacy. At the same time, these areas remain empirically under-examined among HSS graduates in developing-country contexts. In terms of Human Capital Theory, AI-related competencies establish a graduate capital that develops individual productivity and labour-market value in AI-driven economies (Arthur, 2026). Furthermore, Tomlinson's (2017) Employability Theory indicates that graduate employability depends on structural and institutional factors. This highlights that employability is not merely an individual, skill-related factor, as it is linked with competency development in an institutional environment.

RQ (iii) asks what institutional responses to AI exist. Studies applying the Technology Acceptance Model show that institutional adoption of AI-related teaching tools depends on staff and students' perceptions of their usefulness and ease of use (Davis, 1989; Xue et al., 2026). Evidence from South Asian higher education indicates that acceptance of AI tools depends on both technology acceptance and socio-cultural factors. This suggests that institutional responses in developing countries such as Sri Lanka cannot be assumed to be the same as those in developed countries (Awal & Haque, 2025). However, institutional strategies for embedding AI literacy within HSS curricula are not systematically discussed in the published literature.

With respect to RQ (iv), on the barriers to inclusive AI preparedness in developing countries, infrastructure deficits, policy delays, gender disparities and low digital literacy among academic staff are commonly reported across the Sri Lankan and South Asian literature. This highlights the consequences of ad hoc and unevaluated AI literacy interventions for HSS graduates. From the perspective of Social Inclusion Theory,

disparities in access and usage reflect the digital divide, which is evident among the majority of under-resourced students in developing countries (Devisakti et al., 2024). The ethical and governance dimensions of AI (Floridi et al., 2021) and the foundational construct of AI literacy (Long & Magerko, 2020) are identified as areas in which HSS graduates can be well developed and can make a better contribution. However, institutional support for developing these competencies is lacking, and empirical findings indicate that approximately 2.9 billion people remain offline globally (UNESCO, 2023). This highlights the scale of the digital divide that constrains inclusive AI readiness.

In response to RQ (v), on the future directions for inclusive AI readiness, the review proposes the Inclusive AI Readiness Framework for Higher Education, which comprises seven dimensions: AI Literacy, Digital Competence, Human-Centred Skills, Ethical Awareness, Learning Adaptability, Inclusive Educational Support and Employability Readiness. The first five dimensions represent the key skills and competencies required by students, consistent with the Human Capital, Digital Competence and Employability perspectives discussed under RQ (ii). However, these five competencies alone are not sufficient for success without inclusive educational support and employability readiness. Inclusive Educational Support provides the institutional support needed to develop these competencies, as emphasised by the technology acceptance and social inclusion perspectives discussed under RQ (iii) and RQ (iv). Employability Readiness is the outcome expected from the framework.

Taken together, these seven dimensions show how the implications were derived from the evidence. The competency gaps identified under RQ (ii) and RQ (v), namely insufficient AI literacy, digital competence and ethical awareness among HSS graduates, indicate that universities are the primary actors responsible for embedding these dimensions within curricula. The institutional and infrastructural barriers identified under RQ (iii) and RQ (iv), including uneven technology access, policy delays and the digital divide, indicate that policymakers are best placed to accelerate accreditation, resource curriculum reform and set governance standards for AI-related education. The structural dimension of employability discussed under RQ (ii), together with Tomlinson's (2017) Employability Theory, shows that graduate outcomes depend on institutional as well as individual factors. This indicates that employers are responsible for translating these competencies into labour-market value through their hiring practices.

Conclusions and Implications

This review demonstrates that no single theoretical framework addresses the inclusion-related challenges faced by HSS graduates in AI-driven economies. Integrating these theoretical perspectives provides the most comprehensive explanation of the opportunities, competency gaps, institutional responses, barriers and future directions for inclusive AI readiness identified in this review. The proposed Inclusive AI Readiness Framework for Higher Education offers an integrative model that bridges economic, behavioural, ethical and inclusion-orientated perspectives.

Building on this evidence, the findings have clear implications for three groups of stakeholders. Universities should embed AI literacy, digital competence and ethics across HSS curricula and redesign assessment to emphasise creativity and critical judgement, in line with the competency gaps identified under RQ (ii) and RQ (v). Policymakers should develop AI-related education strategies, including accelerated accreditation processes and updated curricula targeting HSS graduates, to address the institutional and infrastructural barriers identified under RQ (iii) and RQ (iv). Employers should adopt competency-based hiring practices that recognise human-centred graduate attributes, reflecting the structural dimension of employability established under RQ (ii). Future research should prioritise longitudinal and quasi-experimental designs that validate discipline-specific AI literacy instruments, as well as comparative studies across South Asian higher education systems. HSS graduates should be understood as essential assets because of their human-centred competencies, which should be adequately developed, credentialed and supported. This will enable a fair path for all in an inclusive AI era.

Keywords**:** Artificial intelligence in higher education, developing countries, graduate employability, human–AI collaboration, inclusive education

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Communication Strategies for HIV/AIDS Awareness Programmes in Sri Lanka: A Narrative Review (2015–2024)

Perera S.T.* and Jayasinghe R.A.N.M.
Department of Humanities, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: shanaka@ssh.rjt.ac.lk)

Introduction

Although important progress has been made in prevention, treatment and care, human immunodeficiency virus (HIV) infection and acquired immune deficiency syndrome (AIDS) remain important global public health challenges. Stigma, misinformation and lack of access to health services continue to shape prevention practices, testing behaviour and treatment-seeking decisions. HIV/AIDS remains a major health, social and economic challenge for many societies (UNAIDS, 2023). Awareness and communication help to prevent and control HIV/AIDS. Communication provides people and communities with the right information and helps them to understand health risks and make informed decisions. This is especially so in the prevention of HIV/AIDS, where fear, stigma and discrimination can prevent people from seeking information, testing and health care services (Aggleton, 2000). Effective communication strategies can help to increase awareness, promote preventive behaviour, encourage voluntary testing and reduce negative attitudes towards people living with HIV.

Sri Lanka has a low HIV burden relative to many neighbouring countries in the region. However, recent national reports show that new HIV infections are still being reported, especially among young people and key populations (National STD/AIDS Control Programme [NSACP], 2024). There is therefore a need to improve HIV/AIDS awareness programmes by utilising appropriate communication strategies. In Sri Lanka, the NSACP has used traditional approaches, such as seminars, school-based sessions, community outreach, and television and radio campaigns, as well as digital approaches, such as social media campaigns, webinars and online counselling. Previous studies have focused on knowledge, awareness and public attitudes towards HIV/AIDS in Sri Lanka, but little attention has been paid to the communication strategies used in awareness programmes. Much of the research is concerned primarily with levels of awareness rather than with how communication methods can be used to change behaviour, reduce stigma and promote public health. Therefore, the present study investigates the communication strategies adopted by HIV/AIDS awareness programmes in Sri Lanka from 2015 to 2024, with special emphasis on traditional and digital methods, communication challenges and the role of the NSACP.

Methodology

The present study adopted a qualitative narrative review approach to examine the communication strategies used in HIV/AIDS awareness programmes in Sri Lanka from 2015 to 2024. Secondary data were obtained from a range of credible sources, such as journal articles, research papers, books, policy documents, reports and publications from

the Ministry of Health, the NSACP, the World Health Organization (WHO) and the Joint United Nations Programme on HIV/AIDS (UNAIDS), which were retrieved through Google Scholar, PubMed, ResearchGate and official health websites. From this literature, seven key secondary sources were purposively selected for in-depth analysis (Table 1). These sources were manually coded through a systematic process of reading and re-reading the texts, identifying recurring ideas and assigning initial codes. The codes were then grouped into main themes and further refined into sub-themes to capture patterns related to HIV/AIDS communication strategies. The thematic analysis was based on themes such as communication channels, awareness strategies, stigma reduction and digital communication trends, and the findings were elaborated on the basis of the identified themes and sub-themes. The study was informed by the Health Belief Model and Behaviour Change Communication theory, which provided a framework for understanding how communication strategies influence HIV/AIDS awareness, prevention behaviours, testing uptake and stigma reduction.

Table 1

Summary of Key Literature Review

Author(s)	Year	Focus	Key contribution to the study
Aggleton	2000	HIV/AIDS stigma	Shows that stigma and discrimination can prevent people from seeking HIV information, testing and care.
Rosenstock	1974	Health Belief Model	Explains how perceived risk, severity, benefits and barriers influence preventive health behaviour.
Storey & Figueroa	2012	Behaviour Change Communication	Highlights the importance of participation, attitude change and culturally appropriate communication.
World Health Organization	2017	Health communication	Supports the use of mixed communication channels to reach different audiences effectively.
World Health Organization	2021	Digital health	Shows the growing role of digital technologies in health communication and awareness.
UNAIDS	2023	Global HIV/AIDS update	Emphasises the continuing importance of awareness, stigma reduction and community participation.
NSACP	2024	HIV/AIDS in Sri Lanka	Provides national evidence on HIV trends, awareness activities and prevention communication in Sri Lanka.

Results and Discussion

The results show that HIV/AIDS awareness programmes in Sri Lanka during 2015–2024 were implemented using both traditional and digital communication strategies. Traditional methods, such as seminars, workshops, counselling, school-based sessions,

community outreach, television, radio and printed materials, continued to be important. These served as useful methods, as they facilitated direct communication, trust-building and wider access, especially in communities with poor digital facilities (NSACP, 2024). Digital communication gained importance after 2020, especially following the COVID-19 pandemic. Digital methods reached broader audiences, especially young people, through social media campaigns, webinars, online counselling, digital posters and videos. These methods helped organisations to disseminate information quickly and to present health messages in a more attractive way (World Health Organization, 2021). However, digital communication alone is not sufficient: limited internet access, low digital literacy, language barriers and rural disparities can reduce its effectiveness. Therefore, a hybrid approach that combines traditional and digital communication methods is more appropriate for Sri Lanka (World Health Organization, 2017).

The results also suggest that HIV/AIDS communication should do more than simply disseminate information. Awareness programmes should aim at behaviour change, testing, prevention and stigma reduction. This is supported by the Health Belief Model, which states that people are more likely to take preventive action when they understand their risk, the seriousness of the disease, the benefits of prevention and the barriers to action (Rosenstock, 1974). The findings also concur with Behaviour Change Communication theory, which stresses the role of participation, attitude change and culturally appropriate messages (Storey & Figueroa, 2012).

Stigma, discrimination, misinformation and cultural sensitivity were identified as some of the major barriers to effective HIV/AIDS communication. Fear and negative social attitudes can stop people from talking openly about HIV/AIDS, getting tested or seeking treatment (Aggleton, 2000). Future communication strategies therefore need to be accurate, respectful, non-judgemental and inclusive. The NSACP has played a vital role in HIV/AIDS awareness and prevention communication in Sri Lanka through national campaigns, counselling services, community programmes and digital awareness activities (NSACP, 2024). However, future programmes should give more attention to youth engagement, stigma reduction, community participation and audience-specific messages for key populations, school communities, healthcare workers and the general public.

Conclusions and Implications

This narrative review reveals that communication remains an important part of HIV/AIDS awareness and prevention in Sri Lanka. During 2015–2024, traditional methods (seminars, counselling, television, radio and community outreach) supported awareness raising and outreach to different communities. Digital strategies, such as social media advertising, webinars, videos and online counselling, increased the reach of awareness programmes, especially among young people. The review suggests that Sri Lanka would benefit from an integrated communication approach in which both traditional and digital approaches are used for improved coverage, inclusiveness and effectiveness.

Future HIV/AIDS awareness programmes should focus on stigma reduction, disinformation control, youth involvement, community participation, internet literacy and

the development of culturally suitable messages. The findings have practical implications for policymakers, health professionals, communication experts and organisations working in the area of HIV/AIDS prevention. Awareness programmes should not only impart knowledge but also bring about behavioural change, build trust and reduce negative attitudes towards people living with HIV. Although this study is limited to secondary data and does not include interviews or surveys, it provides a useful overview of HIV/AIDS communication strategies in Sri Lanka and suggests directions for future public health communication.

***Keywords*:** Awareness, communication, human immunodeficiency virus, prevention, Sri Lanka

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Exploring the Implementation of Inclusive Education Policies: A Case Study of a Disabled Girl

Sanjeewanie R.B.A.*
Professional Development Centre for Teachers, Anuradhapura, Sri Lanka
*Corresponding author (email: amilakeerthirathna78@gmail.com)

Introduction

Inclusive education is a strategy that aims to give all students, including those with disabilities, equal learning opportunities in regular classroom settings. As ensured by the Universal Declaration of Human Rights, all learners should have equal rights without any discrimination. The United Nations Educational, Scientific and Cultural Organization (UNESCO) also conceptualises inclusive education for all (UNESCO, 2017), and the Salamanca Statement is a policy statement introduced by UNESCO (1994) to ensure that children with special educational needs are educated in mainstream schools with their peers wherever possible. However, as emphasised by Sethunga et al. (2014), several barriers, such as inadequate teacher preparation, limited professional development opportunities, lack of resources and insufficient institutional support, hinder the effective implementation of inclusive education in Sri Lanka. Furthermore, Sustainable Development Goal (SDG) 4 focuses on quality education, while SDG 5 emphasises gender equality (United Nations, 2015).

In this context, the current qualitative case study focuses on a female student with a physical disability in an inclusive school. Although she has all four limbs, they are not functionally active, which significantly affects her participation in learning activities. The study explores her lived educational experiences and challenges, and the extent to which inclusive education policies are implemented in practice. This research is particularly important for understanding early childhood inclusive education, developmental challenges and the effectiveness of support systems at the preschool level, as the child is aged 3–5 years and has a congenital condition resulting in severe mobility impairment.

The main objective of this study is to understand the nature of the educational experiences of a girl with a disability, as the implementation of inclusive education policy at the preschool level is important. The study is based on four research objectives: first, to explore the social and educational experiences of a girl with a disability in a rural preschool; second, to understand how classroom and school activities incorporate inclusive education policies; third, to understand the difficulties in putting inclusive education plans into practice; and fourth, to describe how inclusive education is facilitated by educators, school administrators and family support. Accordingly, four research questions were considered: What social and academic experiences does a girl with a disability have at a remote school? How are inclusive education policies incorporated into regular school operations? What obstacles and difficulties arise when implementing inclusive education policies? How do the activities of stakeholders affect how well inclusive education policies are implemented?

Methodology

The research adopted an interpretivist paradigm, an inductive approach and a mono-qualitative case study design, focusing on a preschool-aged girl who is unable to use gross motor skills, mobility and fine motor control. As noted by Yin (2018), case studies provide in-depth investigations of classroom interactions, instructional techniques and stakeholder viewpoints in real-life circumstances. It is particularly important to focus on a girl with a disability because research shows that gender and disability interact to create additional obstacles to school participation (United Nations Children's Fund [UNICEF], 2017).

This study is based on a qualitative research approach, as it aims to provide a comprehensive understanding of how inclusive education policies are implemented in a real-life educational setting. The case study technique was chosen because it enables a thorough and contextualised investigation of the experiences, behaviours and interactions surrounding a single child with limited experience of a mainstream preschool setting. A purposive sampling technique was used because the chosen child was directly related to the study's goals. Data were collected using qualitative methods, namely classroom observations and interviews with a purposive sample of preschool teachers, the head teacher and the parents. Thirty randomly chosen lessons taught by 10 preschool teachers were observed. Both the father and the mother of the child were interviewed using an unstructured interview format. The data were analysed using thematic analysis following Braun and Clarke (2006).

Results and Discussion

Four themes were identified through thematic analysis of the data: disability-related factors, learning–teaching process-related factors, institutional factors and government policy-related factors.

The data showed that the degree of instructional adaptation had a significant impact on the child's involvement in academic activities. When one-on-one assistance was given, the student was able to participate meaningfully in holding things, creating objects and using visual aids during teacher-guided activities. Owing to her lack of separate fingers and inability to move her arms, the student is unable to colour, paste, cut and perform other tasks. The loss of both fine and gross touch deprives her of equal rights and access to an engaging teaching and learning process. Limited adaptation occasionally resulted in passive engagement. The girl has adapted to gross and fine touch using her arm, fist, face and disabled arms while engaged in classroom activities.

The results indicated that, although inclusive education policies were officially recognised at the school level, teachers' understanding of how these policies should be implemented differed. Inclusive practices were often interpreted broadly rather than translated into systematic classroom strategies. Preschool teacher preparation programmes lack in-depth content on classroom management, particularly on strategies for addressing the difficulties of inclusion. There was no ongoing monitoring, measurement or expert physiotherapy.

The findings suggest that inadequate professional training not only affects teachers' competence but also influences their attitudes towards inclusion, sometimes leading to anxiety, resistance or reliance on traditional teaching methods that do not support learner diversity. The 10 preschool teachers in the sample had not been equipped with sufficient knowledge, attitudes and skills related to inclusive education. A lack of specialised teaching materials, assistive and technological devices, classroom access and support staff emerged as a major challenge.

Educators and school officials promoted inclusion by allowing enrolment and fostering favourable attitudes towards diversity. Participation by peers and family was essential for strengthening social and academic skills. However, the institution lacks the equipment necessary to guarantee equal participation in education.

Conclusions and Implications

Four themes concerning inclusive education at the preschool level in the North Central Province were identified through data analysis. Inadequately trained professionals and inadequate infrastructure made inclusive education ineffective. The classroom setting was not designed to ensure equal educational rights for all students, which falls short of SDG 4. Children with disabilities face participation barriers in preschool settings, and a poor self-concept can create negative mindsets.

Preschool administrations should actively support inclusive education by providing sufficient resources and infrastructure for an inclusive learning environment. The effective implementation of inclusive education policy at the preschool level depends on strengthening teacher education programmes and on ongoing professional development. Teachers, special educators and support personnel should be encouraged to work together; through peer mentoring, team teaching and professional learning communities, teachers can exchange experiences, solve problems and implement successful inclusive practices. When combined with inclusive teaching methods, early intervention programmes can greatly enhance the academic performance and social engagement of children with impairments. Awareness programmes for teachers, parents and the wider school community should be conducted to promote positive attitudes towards disability and inclusion. It is also suggested that a resource hub be created to distribute resources when needed.

Keywords**:** Disability, early childhood education, inclusive education, preschool, teacher preparation

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Consecutive Interpreting and Inclusive Communication: Perspectives from Professional Interpreters in Sri Lanka

Subangan P.*
Department of Translation Studies, University of Jaffna, Sri Lanka
*Corresponding author (email: subapavi1993@gmail.com)

Introduction

In increasingly diverse and multilingual societies, interpreters play a vital role in promoting linguistic inclusion, intercultural understanding and equitable access to information. Among the various modes of interpreting, consecutive interpreting requires interpreters to listen to a segment of speech, process the message and accurately reproduce it in the target language after the speaker pauses. In multilingual societies, effective interpreting contributes to social inclusion by ensuring that language differences do not prevent individuals from participating in legal, educational, professional and public life. In Sri Lanka, where Sinhala and Tamil are the official languages and English serves as a link language, consecutive interpreters facilitate communication in courts, conferences, business meetings, government institutions and public events. Despite their significant contribution to multilingual communication, interpreters frequently encounter linguistic, cognitive, cultural and professional challenges that may affect interpreting quality.

Previous studies have explored areas such as simultaneous interpreting and interpreting for individuals with special needs, and they have examined cognitive demands in interpreting (Gile, 2009), interpreter competencies (Pöchhacker, 2016) and translation strategies applicable to interpreting contexts (Baker, 2018). However, limited research has specifically examined the experiences of professional consecutive interpreters in the Sri Lankan context. This study addresses this gap by investigating the challenges encountered by professional consecutive interpreters, the strategies they employ to overcome these difficulties and the skills required for effective interpreting in multilingual settings. The study was guided by three research questions: what challenges professional consecutive interpreters encounter in facilitating inclusive communication in Sri Lanka; how they overcome these challenges to ensure effective multilingual communication; and how they contribute to linguistic inclusion and intercultural understanding in Sri Lanka.

Methodology

This study adopted a qualitative research design to explore the experiences and perceptions of professional consecutive interpreters in Sri Lanka. A qualitative approach was considered appropriate because the study aimed to explore interpreters' lived experiences and perceptions in depth. Ten professional consecutive interpreters with approximately five to six years of experience participated in the study. All participants worked with Sinhala, Tamil and English language combinations; two were court interpreters and eight were freelance or on-site interpreters who provided interpreting services at meetings, conferences, workshops and public events.

Data were collected through semi-structured interviews that focused on the challenges encountered during interpreting assignments, the coping strategies employed to address

these challenges and the professional skills required for effective interpreting. Semi-structured interviews were selected because they give participants the flexibility to discuss their professional experiences and insights while allowing the researcher to address specific research objectives. Thematic analysis was employed to identify recurring patterns and themes within the interview data (Braun & Clarke, 2006).

Results and Discussion

The findings revealed four major categories of challenges: linguistic, cognitive, cultural and professional. The linguistic challenges, dialect variation and audience comprehension, cultural challenges and the coping strategies adopted by interpreters are discussed in turn.

With regard to linguistic challenges, most participants reported difficulties related to technical terminology, language-specific nuances and the absence of direct equivalents between Sinhala, Tamil and English. Participant 1 explained that interpreters are not always familiar with every cultural expression or nuanced term in the source language and therefore seek clarification from speakers and review scripts before events to understand unfamiliar terminology. Similarly, Participant 2 noted that speakers often deviate from prepared scripts, requiring interpreters to remain highly attentive to unexpected vocabulary and concepts. Participants also highlighted challenges in translating technical terms, explaining that certain English words, such as 'coding', 'system' and 'CPU', are often retained in English because suitable Tamil or Sinhala equivalents may sound unnatural or fail to convey the intended meaning accurately. These findings suggest that terminology management and preparation are essential components of effective consecutive interpreting. They are consistent with Baker (2018), who argues that translators and interpreters frequently employ borrowing when direct lexical equivalents are unavailable in the target language. Furthermore, Newmark (1988) emphasises that technical and culture-bound terms often require alternative translation procedures to maintain communicative effectiveness. Failure to address terminology challenges may hinder effective communication and reduce accessibility for linguistically diverse audiences.

Several participants identified dialect variation as a significant challenge affecting audience comprehension in consecutive interpreting. They noted that speakers and audiences may use different regional varieties of Sinhala or Tamil, which often contain unfamiliar vocabulary, pronunciation patterns and expressions. Participant 6 explained that "sometimes the speaker uses regional Tamil or Sinhala expressions that are not familiar to the audience. In such situations, we have to explain the meaning using more commonly understood terms." Similarly, another participant stated that even when both the speaker and the audience communicate in the same language, dialectal differences can lead to misunderstandings and require interpreters to adapt their language to the audience's linguistic background. These findings suggest that interpreters must possess a broad understanding of dialectal variation and demonstrate linguistic flexibility to ensure accurate message transfer and audience comprehension. This challenge highlights the

important role of interpreters in promoting inclusive communication by bridging not only language barriers but also dialectal differences within the same language community.

Turning to cultural challenges, participants frequently discussed difficulties associated with culture-specific terms and concepts during consecutive interpreting. Participant 5 explained that interpreting between Tamil or Sinhala and English becomes particularly challenging when cultural concepts need to be conveyed to foreign audiences who are unfamiliar with local traditions and practices. The participant cited examples such as *Perahera*, *Kiribath*, *Thiruvizha* and *Pongal*, noting that these terms often require descriptive explanations because direct English equivalents do not exist. These findings indicate that interpreters must possess not only linguistic competence but also extensive cultural knowledge to facilitate effective cross-cultural communication. According to Newmark (1988), culture-specific items frequently require descriptive or functional equivalents when direct translation is not possible. Similarly, Nida and Taber (1982) argue that achieving an equivalent response from the target audience may necessitate adaptation and explanation rather than literal translation. Cultural competence therefore emerges as a crucial skill for professional interpreters working in multilingual and multicultural contexts. By effectively interpreting culture-specific concepts, interpreters contribute to intercultural understanding and the preservation of cultural diversity in multilingual communication settings.

As coping strategies, participants reported employing various techniques to overcome the challenges encountered during consecutive interpreting. Participant 8 explained that preparation is essential and noted that understanding the topic and researching relevant terminology before an assignment helps to improve interpreting accuracy. Participant 9 emphasised the importance of note-taking, stating that it assists in retaining information and reduces the memory burden during lengthy speeches. In addition, participants reported using techniques such as borrowing, paraphrasing, modulation, omission, addition and descriptive equivalence when faced with linguistic or cultural difficulties. Participant 10 stated that when a specific word cannot be recalled, the concept is explained descriptively to ensure audience comprehension. These findings demonstrate the adaptive techniques employed by interpreters to maintain communicative effectiveness. Many of these strategies correspond to translation procedures identified by Baker (2018) and Newmark (1988), including borrowing, paraphrasing and descriptive equivalence. The findings suggest that successful interpreters rely on both thorough preparation before assignments and effective problem-solving during interpretation to ensure accurate and meaningful communication. These strategies enable interpreters to facilitate accurate and inclusive communication among speakers from diverse linguistic and cultural backgrounds.

Conclusions and Implications

This study found that professional consecutive interpreters in Sri Lanka encounter a range of linguistic, cognitive, cultural and professional challenges in their daily practice. To overcome these difficulties, interpreters employ various strategies, including note-taking,

terminology preparation, borrowing, paraphrasing and descriptive equivalence. The findings highlight the crucial role of interpreters in facilitating inclusive communication and intercultural understanding within Sri Lanka's multilingual society. A limitation of this study is the relatively small sample of ten interpreters, which may not represent the experiences of all consecutive interpreters in Sri Lanka.

The study underscores the need for enhanced interpreter training, greater professional recognition and improved working conditions to support effective interpreting practice. By addressing these challenges, stakeholders can strengthen linguistic inclusion and promote equitable access to information, contributing to a more inclusive, culturally diverse and sustainable future in which individuals can participate equitably regardless of their linguistic background.

Keywords**:** Consecutive interpreting, inclusive communication, linguistic inclusion, multilingual communication, Sri Lanka

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The Rhythm of Regional Realities: Pitch and Plurality in the Uragasmanhandiya Dialect

Rev. Uparathana G., Kumari K.P.P.S., Rev. Chandrasiri O., Dissanayake W., Abeyrathne A., Millagahathenna H., Dayananda N., Rev. Anuruddhasiri K., Wanninayake W.M.R.S.K., Wakista M. and Mathammana D.
Department of Languages, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: aravindiabeyrathne@gmail.com)

Introduction

Sinhala, the language of Sri Lanka, has been continuously shaped by historical, cultural and social processes, absorbing influences from Pali, Sanskrit and Tamil. Within this composition, regional dialects reflect localised identity through distinct syntactic, morphological, phonological and lexical variation.

While the socio-cultural variation and grammatical structure of Sinhala have been widely studied (e.g. Lankamulla's work on the Kandyan Sinhala of Sabaragamuwa), its phonological dimension, particularly pitch and tone variation across regional dialects, remains underexplored. This gap is increasingly urgent as the media, urbanisation and educational homogenisation reshape speech practices among younger generations. This study therefore examines how pitch in the Uragasmanhandiya dialect (Galle District) differs from standardised Sinhala pronunciation, which factors drive that variation and how speakers' social positioning shapes their divergence from standard forms.

Methodology

This study adopts a mixed-methods approach, combining primary data from native Sinhala speakers in Uragasmanhandiya with a secondary corpus of journal articles, books and digital publications for theoretical framing. Pronunciation patterns are analysed against speakers' gender, age, education, employment and caste.

High and low pitch ranges (Hz) were measured using the Praat phonetic analysis software and compared against standardised Sinhala pronunciation to assess convergence or divergence. Fieldwork covered the southern, northern and eastern regions of Uragasmanhandiya within the Karandeniya Zonal area, and mean, median, maximum and minimum values were calculated for pitch and pronunciation duration.

Results and Discussion

Pitch varies markedly by age. Children (5–10 years) show volatile pitch averaging 200–230 Hz; youth (11–28 years) shift downwards to 150–170 Hz as they adopt standardised speech through formal education; working-age adults (29–59 years) rise sharply to 250–350 Hz, reflecting their role as the region's economic core; and the elderly (60 years and above) settle into a lower, less stable average of 150–220 Hz.

Socio-economic profile is a major determinant of pitch: higher education corresponds to lower, more standardised pitch, while minimal education corresponds to pitches exceeding 250 Hz. Occupation reinforces this pattern, as workers in the cinnamon industry show higher pitch than those in trade, office work or the beauty industry. The area's predominantly Halagama and Wahumpura caste communities, tied to the cinnamon

industry and local religious life, maintain a distinctively higher natural pitch, reflecting a unique blend of academic, professional, caste-based and religious influences on speech.

Conclusions and Implications

This research challenges the assumption that the Uragasmanhandiya dialect is inherently high-pitched, showing instead that its defining marker is rhythmic vocal elongation, closely tied to the region's caste, occupational and religious composition. The study recommends three directions: further research into understudied prosodic features across variables such as age and sex; systematic documentation of regional dialects to prevent linguistic erasure; and the integration of regional variation into school curricula to support inclusive pedagogy.

***Keywords*:** Dialects, linguistics, phonology, pitch, Sinhala

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Shifting Roles of Religious Populism in Sri Lanka: A Comparative Study of the Mahinda Rajapaksa Era and the Anura Kumara Dissanayake Government

Pathiraja K.A.D.M.M.K.*
Department of International Studies, Faculty of Social Sciences, University of Kelaniya, Sri Lanka
*Corresponding author (email: malrupathi2001@gmail.com)

Introduction

Politics and religion have long been interconnected, with religion continuing to influence political identity, legitimacy and public discourse in modern democracies. Populism can be understood as a political approach that constructs politics around the opposition between the "people" and "the elites" (Mudde, 2004), while political style, performance and communication also shape how populist appeals are constructed (Moffitt, 2016). Religious populism extends such political appeals through the use of religious symbols, narratives, institutions and moral claims to construct political identity, legitimacy and boundaries of belonging. Religion can also function as a cultural and civilisational marker in political competition (Roy, 2016). Although existing research has largely examined religious populism in Western contexts, comparatively less attention has been given to Asian societies, where religion is closely connected with nationalism and state identity. Sri Lanka provides an important case owing to the historical and political significance of Buddhism.

This study therefore compares the Mahinda Rajapaksa era (2005–2015) and the post-2024 National People's Power (NPP) government period to examine how the role of religious populism changes across political contexts. Previous studies on Sri Lanka have extensively examined Buddhism, nationalism, ethnic conflict, state formation and political legitimacy, including the political influence of Buddhist institutions and nationalist movements (DeVotta, 2007; Schonthal, 2016; Tambiah, 1992). However, limited attention has been given to religious populism as a changing and context-dependent political strategy. This study addresses this gap by examining how religious populism shifts according to political priorities, crisis conditions, electoral incentives and legitimacy needs. Based on the existing literature and refined through the analysis, the study develops a four-dimensional framework focusing on religious symbolic mobilisation, religious institutional influence, the changing salience of religious populism and political legitimacy construction.

Methodology

This study adopts an interpretivist philosophy and a qualitative comparative design to examine the changing role of religious populism between the two political periods. A deductive approach was initially guided by the four-dimensional framework developed from the existing literature and was subsequently refined through the analysis of the selected data. Approximately 20 secondary materials, including political speeches, campaign materials, party documents, media reports, social media content and public political statements, were purposively selected from the Rajapaksa period (2005–2015) and the post-2024 NPP government period, based on their relevance to religious

symbolism, institutional involvement, strategic religious narratives and political legitimacy. The data were analysed using thematic analysis (Braun & Clarke, 2006), with systematic coding organised around the four dimensions to identify similarities, differences and shifts between the two political periods. This approach enables an interpretation of how religious meanings and political strategies are constructed and transformed across changing political contexts.

Results and Discussion

The findings are presented according to the four dimensions of the framework. With regard to religious symbolic mobilisation, the findings demonstrate a significant difference in the intensity and function of religious symbolism between the two political periods. During the Rajapaksa era, Buddhist rituals, temple visits, *jayapiritha* ceremonies, Buddhist visual symbols and Sinhala-Buddhist identity narratives were consistently incorporated into political communication. These practices contributed to portraying the political leadership as a protector of Buddhism and the nation (DeVotta, 2007; Tambiah, 1992). In contrast, Anura Kumara Dissanayake's (AKD's) electoral campaign relied more heavily on anti-corruption, economic recovery and systemic change, while religious symbolism played a comparatively limited role. This suggests a movement from identity-centred electoral appeals towards issue-centred political communication. However, the post-election period showed greater engagement with Buddhist institutions and religiously significant state activities, indicating that religious symbolism was not removed but repositioned within governance and legitimacy.

Regarding religious institutional influence, the findings reveal differences in the political role of religious institutions. During the Rajapaksa era, organisations such as the *Jathika Hela Urumaya*, together with sections of the Buddhist clergy, contributed to political mobilisation and reinforced Sinhala-Buddhist political legitimacy (DeVotta, 2007; Schonthal, 2016). Buddhist institutions and monastic networks were therefore closely connected with political communication and national identity. In contrast, AKD's electoral success was achieved without comparable direct monastic endorsement. Following the election, however, engagement with the Maha Sangha and state-supported Buddhist activities became more visible. This indicates that Buddhist institutions continued to have political relevance, but that their function shifted from direct electoral mobilisation towards governance and legitimacy. The finding demonstrates that the political influence of religious institutions can vary according to political context and leadership needs.

As for the changing salience of religious populism, the findings show that it changed according to the dominant political context and public concerns. During the Rajapaksa era, the civil war and national security concerns increased the political salience of Sinhala-Buddhist identity, while the defeat of the Liberation Tigers of Tamil Eelam (LTTE) was presented through narratives of national protection and restoration (Rajapaksa, 2009). In contrast, the NPP emerged in the context of the post-2022 economic crisis, when corruption, economic hardship and institutional reform became more prominent public

concerns (Reuters, 2024). Consequently, anti-elite and reform-oriented narratives were more electorally salient than religious identity. This suggests that religious populism is strategically recalibrated according to changing crisis conditions, public priorities and competing political narratives. The findings are also consistent with broader populism research, which highlights the importance of political context and issue salience in shaping the effectiveness of political appeals.

Finally, political legitimacy was constructed through different combinations of political, moral and religious resources during the two periods. Under Rajapaksa, electoral legitimacy was reinforced through Sinhala-Buddhist identity, wartime leadership, religious rituals and the portrayal of political authority as protecting the nation and Buddhism. In contrast, AKD's electoral legitimacy was primarily associated with anti-corruption, economic recovery, accountability and systemic political change following the economic crisis. Nevertheless, religious engagement became more visible after he assumed office, through interactions with Buddhist institutions and participation in religiously significant state activities. Thus, the findings indicate that religious populism did not simply disappear under the NPP government. Rather, its timing and function changed from a more continuous element of electoral and political mobilisation under Rajapaksa to a more selective resource associated with post-electoral governance and legitimacy.

Conclusions and Implications

The study concludes that religious populism in Sri Lanka is a flexible and context-dependent political resource rather than a fixed political strategy. During the Rajapaksa era, religious symbols, rituals, Buddhist identity narratives and religious institutions were strongly integrated into electoral mobilisation, political communication and legitimacy construction, particularly in the context of the civil war and national security concerns. In contrast, the rise of the NPP occurred within a post-2022 context dominated by economic hardship, corruption and demands for systemic change, making religious identity less salient during electoral mobilisation. However, religious engagement became more visible following the assumption of office. The findings therefore suggest not a simple decline of religious populism but a shift in its salience, timing and political function. Religious populism may not be necessary for electoral success when alternative narratives, such as anti-corruption and economic reform, become more salient. Nevertheless, religious institutions and narratives continue to provide resources for political and governance legitimacy in Sri Lanka.

This study contributes to the understanding of religious populism in a non-Western context by demonstrating how religion can be recalibrated according to changing political and social conditions. The findings have implications for inclusive governance, social cohesion and the management of religious diversity, particularly in societies where religion is closely connected with national identity. Political leaders should engage with religious institutions in ways that promote inclusion and social harmony while avoiding a politicisation of religious identity that deepens social divisions. Maintaining an

appropriate and balanced relationship between the state and religious institutions is therefore important for democratic governance. The study is limited to publicly available secondary data and two selected political periods. Future research could examine public perceptions, minority religious experiences and the role of digital media in shaping religious populism in Sri Lanka.

***Keywords*:** Buddhism and politics, political legitimacy, religious populism, salience theory, symbolic politics

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Monetising the Intangible Cost of Cutaneous Leishmaniasis: Patients' Perceptions from Anuradhapura District, Sri Lanka

Lalani J.M.G.[1,2,*], Agampodi T.A.[1], Prasanna R.P.I.R.[2], Agampodi S.B.[1] and Wickramasinghe N.D.[1]
[1]*Department of Community Medicine, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Department of Economics, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka, Mihintale, Sri Lanka*
*Corresponding author (email: lalani.mihin@yahoo.co.uk)

Introduction

Cutaneous leishmaniasis (CL) is an endemic neglected tropical disease in Sri Lanka, with limited evidence on its economic burden. The economic burden of a disease is classified into direct, indirect and intangible costs (IC) (Jo, 2014), of which IC remains the least clearly defined and most inconsistently measured component. Health-related IC has no universally accepted definition. IC refers to the non-market burden of illness, including pain, suffering, anxiety and other consequences that cannot be directly valued through market transactions (Rice, 1967). It also includes the overall loss of well-being associated with disease, diagnosis, treatment, recovery and rehabilitation (Carney et al., 2018).

The valuation of IC, especially its monetary valuation, has long been debated in health economics, and there is little consensus on its conceptualisation or measurement. IC is widely acknowledged to be difficult to quantify (Gervès et al., 2013) and to assign a monetary value to (Soler & Borzykowski, 2021), because it lacks an observable market value (Mével et al., 2016), is inherently subjective and emotionally influenced (Tharkar et al., 2010), has no universally accepted measurement approach (Wai et al., 2019) and is difficult to validate (Amoakoh & Aikins, 2013). These methodological limitations also hinder the ability of future researchers to build upon previous experience and to develop more robust approaches for assessing IC (Pérez-Núñez et al., 2012). The assessment of IC is further complicated by its multidimensional nature, including physical, psychological, emotional and social consequences that vary across individuals, diseases and cultural contexts.

Although the challenges associated with monetising IC are well recognised across the health economics and global health literature, published data on patients' perceptions of assigning a monetary value to the IC associated with CL are scarce at both the local and global levels. Understanding these perceptions is important for informing future approaches to estimating the full economic burden of CL and for incorporating patient-valued outcomes into economic evaluations. Hence, this study aimed to explore patients' perceptions of monetising the IC associated with CL in rural Sri Lanka.

Methodology

A qualitative study was conducted among patients with CL attending the three dermatology clinics in the Anuradhapura District, Sri Lanka, with thirty participants recruited using purposive sampling. Participants were accommodated between March and May 2026. Data were collected through in-depth interviews using a semi-structured interview guide developed on the basis of the findings of the previous scoping review on

the concept of IC. The interview guide included open-ended questions exploring patients' perspectives on the main causes of the difficulties they experienced in the CL patient journey, on their perceptions of assigning monetary values to the most significant difficulties, and on feasible approaches for monetising these ICs, namely assigning a monetary value, willingness to pay (WTP) and comparison with daily costs. The interview data were analysed using thematic analysis.

Results and Discussion

The mean age of participants was 44.1 years (*SD* = 14.7), with ages ranging from 18 to 81 years. Regarding age composition, 13.3% of respondents were aged 18–29 years (*SD* = 4.8), 76.7% (*SD* = 8.1) were aged 30–59 years, and 10.0% (*SD* = 6.4) were aged ≥ 60 years. The most frequently reported difficulties were related to disease management rather than to the disease itself. Treatment-related issues were the most common (*n* = 20, 66.7%), particularly pain from injections (*n* = 15, 50%), followed by challenges associated with clinic travel (*n* = 4, 13.3%). Psychological and emotional difficulties were reported by over one-third of participants (*n* = 11, 36.6%) and included fear, sadness, shyness, inconvenience and psychological distress related to both disease signs and treatment. In contrast, relatively few participants reported difficulties directly attributable to nodules (*n* = 1, 3.3%) or wounds (*n* = 5, 16.7%).

The in-depth interviews on monetising IC revealed that most participants (*n* = 28, 93.3%) had difficulty assigning monetary values to pain and fear, for varied reasons. Many participants indicated that they were unfamiliar with the idea of assigning a monetary value to such experiences and had never previously attempted to monetise them. Some participants felt that the severity of pain was too great to be adequately expressed in monetary terms, while a few considered pain and fear to be temporary or highly subjective experiences that were difficult to value financially. Participants also emphasised the irreversible impact of the disease, which they felt could not be meaningfully represented by a monetary amount. In addition, some participants referred to cultural and religious beliefs that encourage the acceptance of pain and the practice of letting go of suffering, which further limited their willingness or ability to conceptualise these experiences in monetary terms. Some participants were unable to recognise IC in the context of monetisation and hence interpreted it as direct or indirect costs, such as medication expenditure or productivity losses.

Thirteen participants (43.3%) reported difficulty in identifying an appropriate method for assigning a monetary value to disease-related difficulties. While direct valuation and comparison with daily costs were not successfully interpreted, assigning a monetary value to time lost because of the disease or its management was the most frequently proposed method (*n* = 8, 26.7%). Three participants (10.0%) suggested using WTP to avoid or alleviate disease-related difficulties. However, perceptions of WTP varied: some participants were able to state a monetary amount they would be willing to pay, whereas others considered pain and suffering to be experiences that could not be eliminated or adequately compensated through monetary payment. Overall, the findings suggest that

participants generally recognised the burden of pain and fear but experienced conceptual and practical difficulties in translating these subjective experiences into monetary values. This suggests that conventional valuation methods, particularly the WTP approach, may have limited applicability in this setting, despite their frequent use in high-income settings.

Conclusions and Implications

This study provides novel insights into the IC experienced by patients with CL in rural Sri Lanka and their perceptions of assigning monetary values to these non-market burdens. The findings demonstrate that the burden of CL extends beyond its clinical manifestations and direct economic costs, encompassing significant physical, psychological and social consequences that are often overlooked in conventional cost-of-illness assessments.

Participants reported that the greatest IC was associated not only with the disease itself but also with its management. These findings highlight that healthcare delivery itself can substantially influence patients' well-being; IC should therefore be considered when assessing the total burden of CL. Participants' perception that pain and suffering cannot be alleviated through monetary payment suggests that conventional valuation methods, particularly the WTP approach, may have limited applicability in this setting, despite their widespread use in high-income countries.

The findings highlight the challenges patients face in assigning monetary values to the subjective experiences associated with CL, including treatment-related pain, time spent attending clinic visits, difficulties in accessing services and psychosocial consequences. Although patients recognise these experiences as important aspects of their illness, translating them into monetary values remains difficult. Future research should develop and validate culturally appropriate methods for measuring and valuing IC, potentially combining qualitative approaches with preference-based valuation techniques. Incorporating these hidden burdens into economic evaluations will enable more comprehensive assessments of disease impact and support the development of patient-centred policies and interventions for CL and other neglected tropical diseases.

Keywords**:** Cutaneous leishmaniasis, intangible cost, monetisation, Sri Lanka

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Strengthening Legal Protection for Tourists in Sri Lanka: Towards a Dedicated Tourist Harassment Offence and Fast-Track Tribunal

Kithmini M.N.[1,*] and Samarathunga W.H.M.S.[2]
[1]*Faculty of Law, University of Colombo, Colombo, Sri Lanka,* [2]*Department of Tourism and Hospitality Management, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka*
*Corresponding author (email: narendrakithmini@gmail.com)

Introduction

"All persons are equal before the law and are entitled to the equal protection of the law." The principle of equality before the law constitutes a cornerstone of the Sri Lankan legal framework, and Sri Lanka is a state that relies heavily on tourism revenue. Sri Lanka therefore has an obligation to formulate the legal frameworks necessary to ensure the safety and protection of tourists. Although Sri Lanka has enacted the Tourism Act No. 38 of 2005 and various other legislation relating to the tourism industry, these legal frameworks focus primarily on the regulation and administration of the tourism sector rather than specifically addressing the protection of tourists and their access to justice.

Tourist harassment has become a common problem in the Sri Lankan context, and research has noted that more than 30% of tourists who visited Sri Lanka were harassed for various reasons (Rathnayake & Wijesundara, 2015). While the existing academic literature widely acknowledges that safety strongly influences destination choice (Dhananjaya et al., 2025), previous studies have largely overlooked the structural and systemic failure of Sri Lanka's current statutory framework to address the temporal vulnerability of foreign travellers (United Nations World Tourism Organization [UNWTO], 2021). Current legal scholarship does not address how the fragmented, non-specific nature of the Penal Code actively disenfranchises short-term visitors who cannot remain in the country for protracted trials. However, certain countries, such as Thailand, have taken significant measures to promote judicial inclusivity and ensure greater protection for tourists, with the broader objective of fostering the development of the tourism industry. This study fills this gap by examining the legal framework underlying this systemic exclusion.

The main aim of this study is to formulate a dedicated, constitutionally sound legal framework that criminalises tourist harassment and establishes a fast-track judicial mechanism to protect short-term foreign travellers in Sri Lanka.

Methodology

Since law is a theoretical subject and tourism is a practical application, this study adopts a mixed-methods approach. It combines a library-based doctrinal analysis of legal frameworks and academic literature with an empirical qualitative content analysis of online traveller reports and domestic media reports to map the prevalence and patterns of harassment.

The legislation examined in the library-based doctrinal analysis includes the Constitution of Sri Lanka, the Tourism Act No. 38 of 2005, the Consumer Affairs Authority Act No. 9 of 2003, the Sale of Goods Ordinance No. 11 of 1896, and the Penal Code No. 2 of 1883.

Online databases were used to examine the relevant provisions for the protection of tourists under international law, including conventions, soft law instruments, and guidelines issued by the UNWTO. To gain an understanding of the patterns of harassment targeting tourists, relevant journal articles reporting previous research were reviewed.

Results and Discussion

As highlighted in previous studies, the harassment of tourists in Sri Lanka is largely a micro-level issue, carried out primarily by private individuals rather than institutions. Researchers have identified various types of harassment faced by tourists (Arachchi, 2020), mainly (1) persistent vendors (exorbitant charging), (2) sexual harassment (soliciting an unwanted sexual relationship), (3) the provision of unsatisfactory service (selling of substandard items), (4) physical harassment (misappropriation), (5) theft or robbery, (6) pestering, threatening, or assault, (7) cheating, and (8) begging.

This research therefore used these types as criteria for data collection. The empirical analysis was based on tourist reports published on the Sri Lanka forum of the Tripadvisor website from 1 January 2026 to 28 June 2026. There were 20 tourist reports; among the incidents identified, 6 reports related to persistent vendors, 2 involved theft, 2 involved fraud, and 1 related to sexual harassment (Tripadvisor LLC, 2026), demonstrating that Sri Lanka does not currently provide a highly satisfactory level of security for tourists. Specifically, according to these reports, victims were generally not motivated to take legal action in response to a single incident of harassment. Instead, many of them chose to inform other tourists about the incident as a precautionary measure.

These empirical patterns highlight critical weaknesses in the current legal regime. First, statutory protection is severely restricted: Section 28 of the Tourism Act protects privacy only within ministerially declared “tourism development areas”. It is the only tourist-specific statutory framework in Sri Lanka relating to the safety of tourists, and even so, its implementation procedure is not tourist-friendly. Second, the lack of a consolidated statutory definition leaves micro-level harassment scattered across disjointed, hard-to-enforce laws. Third, the absolute lack of punitive powers within the Tourist Police Unit, coupled with long judicial backlogs, means that the legal system effectively rewards offenders by running out the clock on the victim’s visa.

In contrast, the Kingdom of Thailand has taken significant steps towards addressing these issues, demonstrating a relatively positive approach to the protection of tourists. Thailand has explicitly recognised the provision of safety and facilities for tourists as a primary objective of the Tourism Authority of Thailand under section 8 (3) of the Tourism Authority of Thailand Act, B.E.2522 (1979), whereas the Sri Lankan Act does not. In 2022, Thailand introduced a specialised judicial mechanism for tourists. As part of this initiative, the Court of Justice designated Tourist Case Sections in four courts (Pattaya Provincial Court, Phuket Provincial Court, Phathum Wan District Court, and Dusit

District Court, Bangkok) to facilitate the efficient and accessible resolution of cases involving tourists (Royal Thai Embassy Copenhagen, 2022). Since Sri Lanka also has a provincial high court system with a strong first-instance judiciary, and tourism is an item on the Concurrent List under the 13th Amendment to the Constitution, Sri Lanka has the capability to adopt such a mechanism in a suitable manner.

Conclusions and Implications

To resolve these weaknesses, Sri Lanka must formalise a distinct, consolidated criminal offence of "tourist harassment" and establish a specialised fast-track Tourist Judicial Division, modelled on Thailand's Tourist Courts. A separate offence is necessary to capture legally the broad spectrum of tourist exploitation not covered by the general criminal law, while a fast-track tribunal is essential to bypass lengthy standard procedures, allowing testimonies to be recorded and cases settled before the tourist leaves the country. This separate legal classification is constitutionally justified under Article 12 of the Sri Lankan Constitution: because foreign tourists lack political sovereignty, face language barriers, and have only a temporary physical presence, they constitute a vulnerable group entitled to reasonable classification and special protective measures.

Transitioning from a fragmented legal approach to a consolidated, expedited judicial framework will directly eliminate the structural loopholes that permit tourist exploitation. Implementing these reforms will not only restore international travellers' confidence and protect human rights but will also secure the long-term economic sustainability of Sri Lanka's tourism industry in alignment with global sustainability goals.

Keywords**:** Sri Lanka, tourism law, tourist court, tourist harassment, tourist protection

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Shaping the Context for Social Engagement: How a Business School Mentoring Programme Cited Dominant Discourses to Enable Critical Performativity

Racz M.*
The Graduate School, British University Vietnam, Vietnam and Bayes Business School, City St George's, University of London
*Corresponding author (email: marton.r@buv.edu.vn)

Introduction

Studies of critical performativity (Spicer et al., 2009, 2016) have proposed that the boundary between managers and critical management scholars is more likely to be successfully transgressed through smaller and affectively more relatable acts of critique than through grandiose imaginaries of revolutionary change. This position belongs to the so-called third wave of critical management studies, which rejects non-performativity (Fournier & Grey, 2000) in favour of experimental, situated interventions aimed at public benefit (Racz & Parker, 2020). Yet such interventions frequently falter (Fleming & Banerjee, 2016), in part because academics, middle managers or consultants lack the illocutionary authority – the socially recognised capacity to make things happen through speech (Austin, 1962; Butler, 2010) – that hierarchy, ritual or formal position would confer, and in part because the context in which they act is unreceptive (Parker et al., 2020).

The existing literature has largely treated this organisational context as given: a background condition against which critical interventions succeed or fail. Far less attention has been paid to whether, and how, the context itself can be reshaped so that critique becomes possible. This is the gap that the study addresses.

Butler's (1997, 2010) reading of performativity through Derrida's (1988) notion of citationality offers a lens for this question. For Butler, a performative does not work because of the intention or standing of the speaker; it works because it cites a prior chain of authoritative utterances, drawing on the sedimented force accumulated in conventions that precede and exceed the speaker. Authority, in other words, is not held but invoked. An academic who speaks in the name of employability, responsible management or an institution's own strategic commitments borrows a force they do not personally command, and every citation slightly displaces the convention it invokes. It is in this gap between the cited norm and its enactment that the possibility of reworking resides.

Against this background, the objective of the study is to examine how the context for a critically performative intervention can be actively assembled, rather than simply inherited, through the strategic citation of dominant discourses. In doing so, the study moves the question of context from a background condition of critical performativity to one of its objects, and offers practical guidance to academics seeking to create space for socially engaged education within business schools.

Methodology

The study adopts a qualitative, single embedded case study design (Yin, 2018), which is suited to examining a contemporary phenomenon in its real-life context, where the boundary between phenomenon and context is itself under investigation. The case is the Schools Engagement Programme (SEP), run at a leading United Kingdom (UK) business school in London. Through a 15-credit elective module, final-year undergraduates learn the interpersonal skills required to be effective mentors (active listening, giving and receiving feedback, and self-awareness) and then practise them across eight to ten mentoring sessions with 16- to 18-year-old pupils from socio-economically deprived areas of London or with first-year university students at risk of dropping out. Built on service learning principles (Bringle & Hatcher, 1996), the programme takes students beyond discussing 'real-world examples' in the classroom and into communities in their own city that many of them did not know existed. Over ten years of operation, SEP has involved more than 300 undergraduate mentors and nearly 500 mentees (Compton et al., 2024).

The case was selected because it is revelatory (Yin, 2018) of an intervention that had to build its own legitimacy. It is also information-rich in its own right: SEP was recognised as a United Nations Principles for Responsible Management Education (PRME) Champion project, one of a small number at the time, and both its aims and its funding model were without close parallel in UK business schools.

The data comprise SEP's theory of change (Anderson, 2005), Steering Committee minutes and interviews with its members, a survey of and follow-up interviews with module alumni, partner school feedback, and students' reflective assignments. The data were analysed thematically (Braun & Clarke, 2006). Interviews with programme participants and programme documents were read for the discourses through which SEP was justified to its stakeholders; four recurrent discourses were identified and then examined against the literature on each, to establish how SEP's use of them departed from their dominant meanings.

The author's position as a facilitator of the project granted access to the institutional context and strategic challenges that an external observer could not reconstruct. It also carries an evident risk of downplaying tensions and limitations. Reflexivity is therefore treated as a methodological commitment rather than a caveat, with interpretations triangulated against documentary evidence and tested in dialogue with colleagues outside the programme.

Results and Discussion

The analysis indicates that the context for SEP was not inherited but assembled – incrementally, opportunistically and only partly by design – through the strategic citation of four dominant discourses, which were combined and quietly mis-cited to open space for alternative forms of learning.

The first discourse was responsible management education. The post-2008 rise of responsibility in business schools offered legitimacy through PRME. It anchored SEP to a recognised global agenda and supplied external validation that secured renewed funding. Yet PRME is also a framework whose critical content remains up for grabs (Louw, 2015), and citing it allowed SEP to expand what 'responsibility' can mean.

The second discourse was that of caring capitalism and social value. Caring capitalism (Barman, 2016) brought with it the demand for evidence of social value. SEP met this demand by constructing an evaluation framework that spoke the language of theory of change and social return on investment while shifting the substance towards narrative, relational and small-scale accounts of transformation – using funders' idiom as discursive shelter for a programme grounded in affect, presence and care.

The third discourse concerned science, technology, engineering and mathematics (STEM) education. The importance attributed to STEM education secured the original grant on the premise that business students are competent in school mathematics and that STEM attainment drives social mobility. When the programme shifted after two years towards life coaching and raising aspiration, the credibility already accrued allowed SEP to leave this framing behind: STEM had been an entry point, not a straitjacket.

The fourth discourse, employability, was the most ideologically loaded of the four. The employability agenda in higher education risked reducing SEP to a curricular tick-box, yet ignoring it would have rendered the programme unintelligible to key stakeholders. Working against the critique of responsibilisation (Chertkovskaya et al., 2013), SEP positioned relational and affective capacities as career-relevant and as central to the formation of graduates who understand structural inequality in access to work and education.

Each discourse on its own could have narrowed the space for creative pedagogy. However, they articulated into a coherent theory of change and were cited simultaneously to different audiences: transferable skills for the university, responsible management for the business school, and practical experience and a sense of contribution for students. Assembled in this way, they instead opened up the space for creative pedagogy. Compared with accounts of failed critical performativity (Fleming & Banerjee, 2016), the case suggests that a lack of personal illocutionary authority can be compensated for not by acquiring authority but by borrowing it from several conventions at once. From the perspective of a more radical critique, SEP would seem to have failed to challenge any of the discourses it engaged; the findings suggest instead that it worked within them, using their language, legitimacy and leverage to open space for alternatives.

Conclusions and Implications

The study concludes that the context for critical performativity is not a fixed terrain on which interventions succeed or fail but a citational fabric that actors can rework incrementally, experimentally and reflexively. As its outcomes show, SEP failed neither the university students nor the school pupils involved. The case provides an instance of

agonistic critique in which dominant discourses are (re)appropriated to build alliances between the stakeholders of a business school and to further social good.

Theoretically, the study contributes to the critical performativity literature a more mobile conception of context, recasting it from a background condition into an object of intervention, and shows how citationality can explain the success, and not only the failure, of situated interventions. Practically, it suggests that academics seeking to establish socially engaged programmes in business schools can map the discourses that carry authority in their institution, address each stakeholder in its own idiom, design evaluation frameworks that satisfy funders while preserving relational substance, and treat initial framings as entry points to be revised once credibility has accrued.

The findings rest on a single case studied by an insider, and the analysis remains exploratory. Further work will formalise the thematic analysis and test the argument against comparable programmes in other institutions and national contexts.

***Keywords*:** Critical management studies, critical performativity, responsible management education, service learning, social engagement

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Diffusion-Guided Semantic Embedding Model for Topic Modelling Using SEDiff-Gen Framework

Reddy Ch.N.*, Gandla D., Sunkara S., Jakku M. and Sankepally S.R.
Department of Computer Science and Engineering (Data Science), Sreyas Institute of Engineering and Technology, Telangana, India
*Corresponding author (email: narsireddy.ch@sreyas.ac.in)

Introduction

The rapid growth of digital text across news media, academic publications, social networks and organisational information systems has significantly increased the need for automated techniques to organise, analyse and extract meaningful information from large collections of unstructured text. Topic modelling plays a crucial role in this process by identifying latent thematic patterns without requiring manual annotation. Traditional topic modelling techniques, such as Latent Dirichlet Allocation (LDA), rely primarily on word-frequency statistics and co-occurrence patterns to identify topics. Although these methods have been widely used in text analysis, they often fail to capture the deeper contextual semantics and sentence-level relationships present in modern textual data, resulting in less coherent topic representations.

Recent advances in transformer-based language models have enabled the use of contextual embeddings that capture semantic similarity more effectively than traditional bag-of-words representations. Sentence-BERT (SBERT) generates high-quality sentence embeddings by placing semantically similar sentences close together in the embedding space, making it suitable for clustering-based topic discovery. In addition, diffusion-based generative models have demonstrated strong performance in learning complex data distributions and generating high-quality synthetic data. Extending diffusion modelling to semantic embedding spaces enables the learning of topic-specific latent representations and the generation of semantically meaningful embedding samples, providing opportunities for topic exploration, dataset expansion and semantic diversity analysis.

Despite these advances, existing approaches still face limitations in capturing contextual semantic relationships and generating topic-aware semantic representations. Traditional methods such as LDA rely on statistical word distributions, while many semantic embedding approaches focus primarily on topic discovery without supporting topic-aware sample enrichment. These limitations highlight the need for a unified framework that improves both topic coherence and semantic representation.

To address these limitations, this research proposes SEDiff-Gen, a diffusion-guided semantic embedding framework for topic modelling and topic-aware sample enrichment. The proposed framework integrates SBERT for semantic embedding generation, Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN) for density-based topic discovery, and a diffusion-based denoising network for learning topic-specific embedding distributions. The primary objective of this research is to improve semantic topic coherence, enhance clustering quality and generate topic-aware semantic representations while preserving contextual relationships between documents.

The effectiveness of the proposed framework is evaluated using the British Broadcasting Corporation (BBC) News Dataset and compared with conventional topic modelling approaches.

The remainder of this paper first reviews the literature related to topic modelling, semantic embeddings and diffusion models, then describes the BBC News Dataset used for experimentation and the proposed SEDiff-Gen methodology, presents the experimental results and comparative analysis, and finally states the conclusions and directions for future work.

Probabilistic diffusion models have emerged as effective generative models owing to their ability to generate high-quality synthetic data through an iterative denoising process (Fan et al., 2024). Recent studies have demonstrated their effectiveness in magnetic resonance imaging (MRI) applications, including image reconstruction, image generation, anomaly detection and modality translation. Compared with generative adversarial networks (GANs), diffusion models provide greater training stability and improved sample quality, and their discrete-time and continuous-time formulations further demonstrate their suitability for generating realistic synthetic data.

A comprehensive survey of diffusion models in computer vision (Croitoru et al., 2023) explains the forward noise-addition and reverse denoising processes and categorises diffusion approaches into denoising diffusion probabilistic models, score-based models and stochastic differential equation-based variants. The study reports that diffusion models generally achieve more stable training and produce more diverse samples than variational autoencoders (VAEs) and GANs, although they require greater computational resources and longer sampling times. These findings provide a strong theoretical foundation for diffusion-based generative learning.

LDA remains one of the most widely used probabilistic topic modelling techniques and has been successfully applied in software engineering, healthcare, politics and social media analysis (Jelodar et al., 2019). However, LDA relies primarily on word-frequency statistics and bag-of-words representations, which limits its ability to capture contextual semantics and meaningful relationships between documents. These limitations have encouraged the development of semantic embedding-based and neural topic modelling approaches.

Recent research has integrated neural embedding representations with diffusion-based learning for topic modelling. The Diffusion-Enhanced Topic Modelling (DeTiME) framework combines encoder–decoder language model embeddings with diffusion learning to improve topic coherence, clustering quality and semantic representation (Xu et al., 2023). In contrast, the proposed SEDiff-Gen framework uses SBERT for semantic embedding generation, HDBSCAN for density-based topic discovery and diffusion-based denoising for topic-specific embedding learning. SEDiff-Gen further employs nearest-neighbour retrieval to map the resulting semantic embeddings to documents in the original corpus rather than directly generating free-form text. These differences define the proposed pipeline and distinguish it from the existing DeTiME framework.

Studies on information diffusion in social media analyse user interaction patterns, coordinated influence behaviour and information propagation across different communities (Iamnitchi et al., 2023). Although these studies do not directly address topic modelling, they highlight the importance of semantically aware analytical frameworks for identifying latent thematic structures and meaningful topic patterns in large-scale textual data.

Although previous studies have improved topic modelling using probabilistic methods, semantic embeddings and diffusion models, limitations remain in capturing contextual semantics and supporting topic-aware sample enrichment. Therefore, a unified framework integrating semantic embeddings, density-based clustering and diffusion-guided learning is needed to improve topic coherence and clustering quality. The proposed SEDiff-Gen framework addresses this gap by combining SBERT, HDBSCAN and diffusion-based denoising within a unified topic modelling architecture.

Methodology

The proposed framework is evaluated using the BBC News Text Dataset, a publicly available collection of 2,225 news articles published by the BBC. The dataset is organised into five categories: Business (510 articles), Sport (511), Politics (417), Technology (401) and Entertainment (386). Each document contains a news headline, the article text and its corresponding topic label, making the dataset suitable for topic modelling, semantic clustering and embedding-based analysis, as illustrated in Figures 1 and 2. Before model training, the dataset was pre-processed using lower-casing, stop-word removal, punctuation removal and text segmentation while preserving meaningful lexical information. The balanced distribution of topic categories and the diversity of writing styles make the dataset appropriate for evaluating topic coherence, semantic clustering and topic-aware sample enrichment using the proposed SEDiff-Gen framework.

Figure 1

Category Distribution of the Dataset

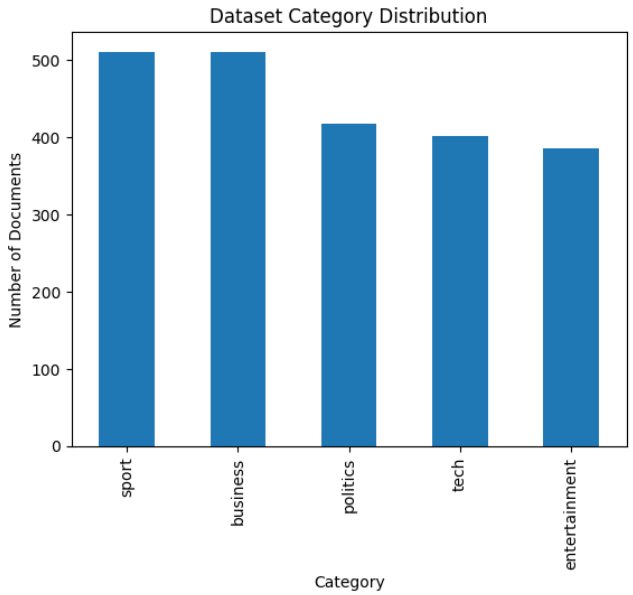
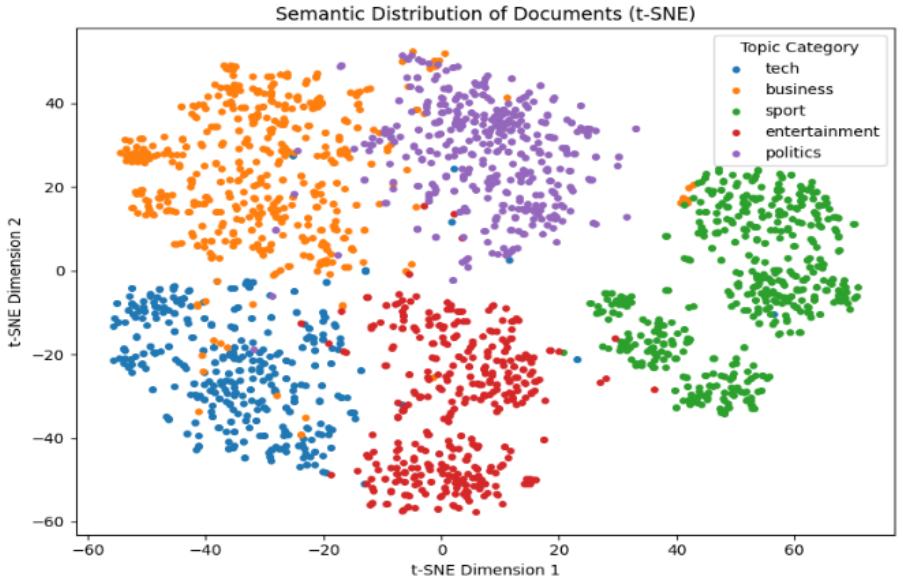


Figure 2

Semantic Distribution of Documents

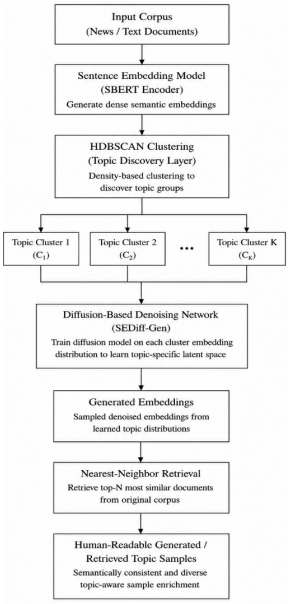


The proposed SEDiff-Gen framework integrates semantic representation learning, topic discovery, diffusion-guided embedding generation and text reconstruction into a unified pipeline, as shown in Figure 3. The input text corpus is first converted into dense semantic

embeddings using SBERT. These embeddings are clustered using HDBSCAN to identify semantically similar topic groups. Each topic cluster is then processed by a diffusion-based denoising network that learns the latent distribution of topic-specific embeddings and generates semantically enriched embedding samples. Finally, a nearest-neighbour retrieval mechanism reconstructs readable text by matching the generated embeddings with the most similar documents in the original dataset, preserving semantic consistency throughout the framework.

Figure 3

System Architecture of the SEDiff-Gen Framework



In the first stage, sentence-level semantic embedding, each document is encoded into a dense semantic vector using SBERT. Unlike traditional bag-of-words methods, SBERT captures contextual meaning by placing semantically similar sentences close together in the embedding space. These embeddings serve as the input for topic discovery and diffusion-based learning.

In the second stage, topic discovery, the semantic embeddings are clustered using the HDBSCAN density-based clustering algorithm. HDBSCAN identifies clusters of varying densities, detects irregular topic structures and labels unrelated documents as noise instead of forcing them into predefined clusters. The resulting clusters represent semantically coherent topic regions for subsequent processing.

In the third stage, diffusion-based denoising in the embedding space, each topic cluster is used to train a diffusion-based denoising model. During the forward process, noise is gradually added to the embeddings, while the reverse process learns to reconstruct the original embedding distribution. Instead of generating raw text, the framework produces

synthetic semantic embeddings that preserve topic-specific semantic relationships and improve embedding quality.

The proposed framework can be represented mathematically as follows. Let $X = \{x_1, x_2, \ldots, x_N\}$ denote the input document collection. Each document x_i is transformed into a semantic embedding using SBERT:

$$z_i = \text{SBERT}(x_i)$$

where z_i represents the semantic embedding of document x_i. The resulting embedding set is then partitioned into topic clusters using HDBSCAN:

$$C = \text{HDBSCAN}(\{z_i\}_{i=1}^{N})$$

where $C = \{C_1, C_2, \ldots, C_K\}$ represents the discovered topic clusters. For each topic cluster C_k, the diffusion-based denoising model learns the corresponding topic-specific embedding distribution. The diffusion stage can be represented generally as:

$$\hat{z}_i = D_\theta(z_i, C_k)$$

where D_θ denotes the trained denoising model and $\hat{z}_i$ represents the resulting denoised semantic embedding. The generated embedding is subsequently matched with the embeddings in the original corpus, and the retrieved document is determined using cosine similarity:

$$x^* = \underset{x_i \in X}{\text{argmax}} \frac{\hat{z} \cdot z_i}{\| \hat{z} \|_2 \| z_i \|_2}$$

where x^* is the retrieved text corresponding to the generated semantic embedding $\hat{z}$.

The complete procedure is summarised in Algorithm 1 (SEDiff-Gen Framework), which takes the document corpus X as input. The algorithm first preprocesses the input documents, generates semantic embeddings using SBERT, applies HDBSCAN to the generated embeddings and obtains the discovered topic clusters. For each topic cluster, it then selects the embeddings belonging to the cluster, trains the diffusion-based denoising model and generates denoised semantic embeddings. Next, it compares each generated embedding with the original corpus embeddings and retrieves the nearest document using semantic similarity. Finally, it returns the discovered topics and retrieved samples, so that the output consists of the topic clusters and topic-aware semantic samples.

For text reconstruction, the generated semantic embeddings are converted into readable text using a nearest-neighbour retrieval mechanism. Each generated embedding is matched with the closest embedding in the original dataset, and the corresponding document is returned as the reconstructed text sample. This retrieval-based approach preserves semantic consistency while avoiding the limitations of direct text generation.

The proposed framework is evaluated in terms of topic coherence, cluster quality and classification performance, and its performance is compared with conventional approaches, including LDA, SBERT + K-Means and term frequency–inverse document frequency (TF-IDF) + K-Means. The comparative analysis demonstrates the effectiveness

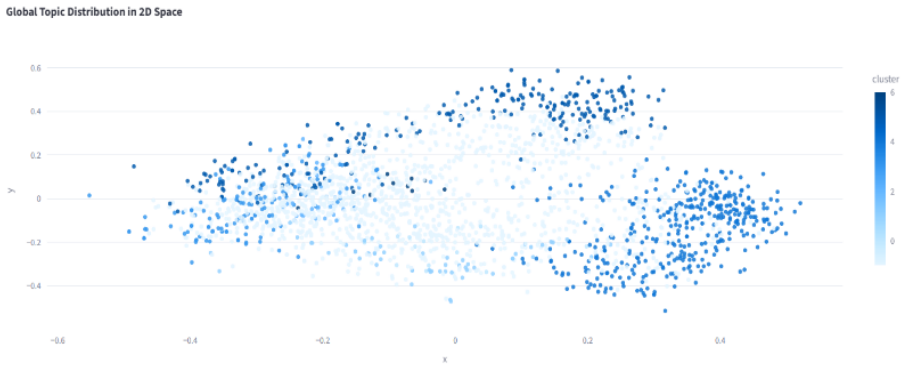
of the proposed SEDiff-Gen framework in generating coherent topic structures, improved clustering quality and topic-aware semantic sample enrichment.

Results and Discussion

The proposed SEDiff-Gen framework was evaluated on the BBC News Dataset containing 2,225 text documents. The experimental results demonstrate the effectiveness of the framework in semantic topic modelling and topic-aware sample enrichment, as illustrated in Figure 4. The model identified seven semantically coherent topic clusters, achieving an average topic coherence score of 0.67 and a cluster quality score of 0.6766. These results indicate that the generated topic clusters are well separated and semantically meaningful within the embedding space. The obtained silhouette score of 0.099 is consistent with the characteristics of high-dimensional semantic embedding spaces reported in previous studies.

Figure 4

Global Topic Distribution



In terms of classification performance, the proposed framework achieved an overall classification accuracy of 88.1% (0.881), a weighted precision of 0.8620, a weighted recall of 0.8810 and a weighted F1-score of 0.8615. These results demonstrate strong agreement between the discovered topic clusters and the corresponding ground-truth topic labels, confirming the effectiveness of the proposed semantic embedding framework.

The diffusion-based denoising network exhibited a steady reduction in both training and validation loss during training, indicating stable model convergence (Figure 5). The consistently lower validation loss suggests good generalisation capability with no significant evidence of overfitting.

Figure 5

Training vs Validation Loss



The proposed framework was compared with SBERT + K-Means, TF-IDF + K-Means and LDA. As shown in Table 1 and Figure 6, SBERT + HDBSCAN achieved the highest topic coherence (0.6609) and cluster quality (0.6766), outperforming all baseline methods. These results demonstrate the effectiveness of the proposed SEDiff-Gen framework for semantic topic modelling and topic-aware sample enrichment.

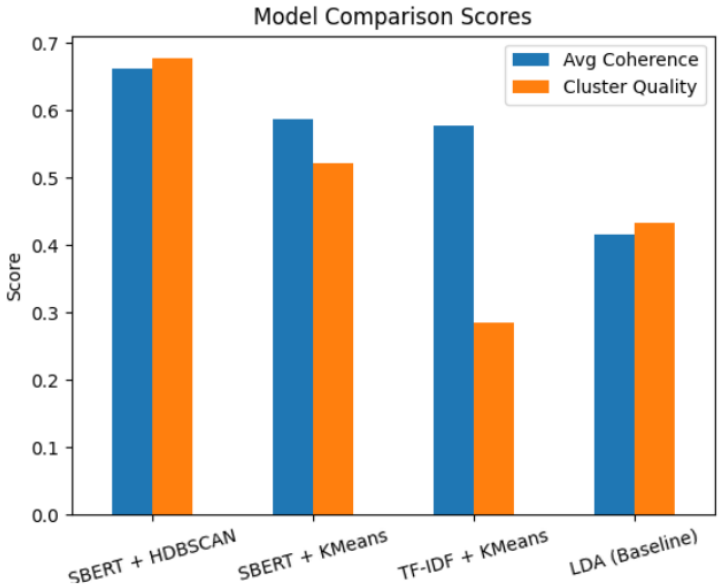
Table 1

Model Performance

Model	Clusters	Avg. Coherence	Cluster Quality
SBERT + HDBSCAN	7	0.6609	0.6766
SBERT + K-Means	7	0.5904	0.5232
TF-IDF + K-Means	7	0.5797	0.2860
LDA (baseline)	7	0.4180	0.4387

Figure 6

Comparison of Topic Coherence and Cluster Quality Across Models



Conclusions and Implications

The proposed SEDiff-Gen framework integrates SBERT, HDBSCAN and diffusion-based denoising to improve topic modelling and topic-aware sample enrichment. Experimental results on the BBC News Dataset, on which the framework achieved an overall classification accuracy of 88.1% and a keyword matching accuracy of 92.5%, demonstrate improved topic coherence, clustering quality and semantic representation compared with conventional LDA-based and other unsupervised clustering approaches. Overall, the framework provides an effective solution for semantic topic discovery, topic exploration, corpus expansion, document organisation and embedding-based semantic content analysis, demonstrating the potential of combining semantic embeddings with diffusion-guided learning for modern topic modelling applications.

Future work will focus on extending the proposed SEDiff-Gen framework to multilingual and large-scale real-world text datasets to evaluate its scalability and robustness across diverse domains. The framework can be further enhanced by integrating transformer-based large language models to improve semantic text reconstruction and topic-aware content generation. Future research will also explore optimising the diffusion-based denoising process to reduce computational complexity and improve inference efficiency while maintaining high topic coherence and clustering quality.

***Keywords*:** Density-based clustering, diffusion models, semantic embeddings, Sentence-BERT, topic modelling

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Development and Characterisation of Starch-Based Biopolymer Films Derived from Ambul and Cavendish Banana Corms

Jayasekara G.O.G.P.P.B.[1], Kulathunga K.A.R.R.[1], Liyanawalage T.S.[1], Polkotuwa P.W.C.L.K.[1], Weerasinghe W.D.C.[1,*] and Yasassri M.A.H.[2]

[1]*Department of Materials Technology, Faculty of Technology, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Faculty of Materials Science and Technology, TU Bergakademie Freiberg, Freiberg, Germany*

*Corresponding author (email: dcweeras@tec.rjt.ac.lk)

Introduction

The accumulation of non-biodegradable synthetic plastics has created a severe pollution crisis because these materials resist degradation, driving a shift towards biopolymers (non-toxic, biodegradable substances derived from renewable sources). Currently, biopolymers represent only 0.5% of the 400 million tons of plastic produced annually, with capacity expected to rise from 2.18 to 7.43 million tons between 2023 and 2028 (Edo et al., 2025; European Bioplastics, n.d.). Starch, which comprises amylose and amylopectin, is a promising biodegradable packaging material because it is abundant, low-cost and biocompatible (Zhang et al., 2008). Sri Lanka is a major hub of banana cultivation, with approximately 60,000 ha dedicated to cultivars including Cavendish, Ambul and Anamalu (Athukorala et al., 2020). Banana cultivation generates significant waste, about three tons of pseudo-stems and corms per ton of fruit, yet these corms are typically discarded after harvest (Zhang et al., 2008). Although extraction methods have been optimised for other starch sources used in starch-based films, such as corn starch and potato starch (Pooja et al., 2024), banana corm starch remains largely unexplored as a biopolymer film matrix. This study addresses that gap by isolating starch from discarded Ambul and Cavendish banana corms to develop a sustainable packaging material.

Methodology

Banana corms of the Ambul (*Musa* spp. (Ambul)) and Cavendish (*Musa acuminata*) varieties were obtained from CIC Agri Businesses in Pelwehera, Dambulla, and from banana farms in Habarana. Ambul banana ribs were sourced from farms in Habarana and Mihintale, Sri Lanka. Analytical-grade sodium bisulfite ($NaHSO_3$) was used to inhibit enzymatic browning, glycerol served as the plasticising agent, and sodium hydroxide (NaOH) was employed for fibre extraction. Distilled water (DW) was also used in this study.

For starch extraction, banana corms were peeled, washed, cubed, treated with $NaHSO_3$, blended, filtered, sieved, sedimented and dried at 40 ± 5 °C. For fibre extraction, Ambul banana ribs (50 g) were digested in 400 mL of 2.5 wt.% NaOH, rinsed and dried at 50 ± 5 °C. Films were solvent-cast from gelatinised starch with DW and glycerol, optionally reinforced with fibre, and then oven-dried. All formulations used are presented in Table 1.

Table 1

Formulations for Film Preparation

Sample No.	Sample Name (Percentage by Weight)	DW (g)	Gly (g)	Starch (g)	Fib. (g)
A 1	95% ACS, 5% Gly	150	0.075	1.425	0.000
A 2	90% ACS, 10% Gly	150	0.150	1.350	0.000
A 3	85% ACS, 15% Gly	150	0.225	1.275	0.000
A 4	90% ACS, 5% ABRF, 5% Gly	150	0.075	1.350	0.075
A 5	88% ACS, 7% ABRF, 5% Gly	150	0.075	1.320	0.105
C 1	95% CCS, 5% Gly	150	0.075	1.425	0.000
C 2	90% CCS, 10% Gly	150	0.150	1.350	0.000
C 3	85% CCS, 15% Gly	150	0.225	1.275	0.000
C 4	90% CCS, 5% ABRF, 5% Gly	150	0.075	1.350	0.075
C 5	88% CCS, 7% ABRF, 5% Gly	150	0.075	1.320	0.105

Note. ACS = Ambul corm starch; CCS = Cavendish corm starch; Gly = glycerol; ABRF = Ambul banana rib fibre; DW = distilled water; Fib. = fibre.

The films were characterised for thickness, water vapour transmission rate (WVTR), water vapour permeability (WVP) and colour. Film thickness was measured at five randomly selected points using a micrometre screw gauge; two replicates were evaluated for each formulation, and the average thickness was calculated.

To determine WVTR and WVP, film samples were sealed over 50 mL beakers containing dehydrated silica gel to maintain a relative humidity (RH) of 0% inside the cup and then placed in a desiccator with a saturated KNO_3 solution to maintain an external RH above 75%. Weight changes were recorded hourly for 8 hours, and WVTR was calculated using Equation (1), where M_f is the cup mass at time t, M_i is the initial mass, and A is the exposed film area.

$$\text{WVTR} = \frac{(M_f - M_i) \times 240}{A \times t} \qquad (1)$$

Equation (2) was used to determine WVP, where S is the saturated vapour pressure of water at 30 °C, R_1 and R_2 are the RH inside the desiccator and the cup, respectively, and ε is the film thickness.

$$\text{WVP} = \frac{\text{WVTR} \times \varepsilon}{S} \times (R_1 - R_2) \qquad (2)$$

Film colour was analysed using a colorimeter (PCE-CSM 4, PCE Instruments, Southampton, UK), recording the International Commission on Illumination (CIE) coordinates L^* (lightness), a^* (red–green) and b^* (yellow–blue) for each sample to evaluate its visual characteristics. These parameters were processed using a Nix Colour converter to obtain the corresponding red–green–blue (RGB) values.

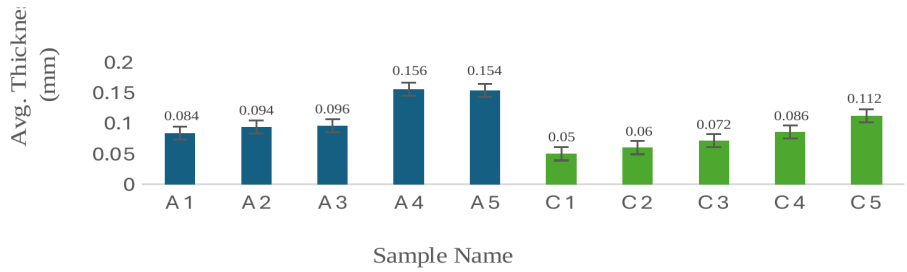
Results and Discussion

The thickness of the starch-matrix films depends mainly on the percentages of glycerol and fibre reinforcement. The thickness of both types of film increased slightly when the glycerol content rose from 5% to 15%. This occurs because glycerol can penetrate the

starch structure and weaken intermolecular interactions, thereby enlarging the volume of the matrix through the plasticisation effect (Agustin et al., 2024). Reinforcement with insoluble banana rib fibre particles significantly increased film thickness and produced films nearly twice as thick as those made of pure starch. The average thicknesses of the Ambul and Cavendish banana corm starch films are presented in Figure 1.

Figure 1

Average Thickness of Ambul and Cavendish Corm Starch Films



Glycerol concentration and fibre reinforcement significantly influenced WVTR and WVP, as shown in Table 2. Increasing glycerol from 5% to 15% raised WVP from 0.5941 ± 0.0219 to 1.1162 ± 0.0502 × 10^{-5} g·m/m²·day·Pa in Ambul films and from 0.8410 ± 0.0185 to 1.19 ± 0.0402 × 10^{-5} g·m/m²·day·Pa in Cavendish films. This trend occurs because glycerol acts as a plasticiser that increases free volume and chain mobility, thereby promoting moisture absorption (Agustin et al., 2024). Fibre incorporation further increased permeability, with the 7% fibre formulations yielding the highest WVP values of 1.5854 ± 0.0718 × 10^{-5} g·m/m²·day·Pa for Ambul and 1.79 ± 0.0559 × 10^{-5} g·m/m²·day·Pa for Cavendish films. This is attributed to the hydrophilicity of cellulose and hemicellulose and to structural discontinuities in the polymer matrix that allow water molecules to pass more easily (Müller et al., 2009).

Table 2

WVTR and WVP of the Films

Sample No.	WVTR (g/m²·day)	WVP (× 10^{-5} g·m/m²·day·Pa)
A 1	465.6465 ± 10.22	0.5941 ± 0.0219
A 2	501.0501 ± 16.38	0.7671 ± 0.0393
A 3	607.5607 ± 20.48	1.1162 ± 0.0502
A 4	554.7554 ± 12.15	1.2260 ± 0.0484
A 5	576.9576 ± 18.26	1.5854 ± 0.0718
C 1	659.1659 ± 14.46	0.8410 ± 0.0185
C 2	689.4689 ± 22.54	1.0600 ± 0.0345
C 3	649.8650 ± 21.91	1.1900 ± 0.0402
C 4	625.8630 ± 21.91	1.3600 ± 0.0301
C 5	3618. ± 19.58	1.7900 ± 0.0559

Note. WVTR = water vapour transmission rate; WVP = water vapour permeability.

The colour properties of the Ambul and Cavendish banana corm starch-based films were evaluated using the *L**, *a** and *b** CIE colour space coordinates, which determine

lightness, chromaticity and overall aesthetic appeal, factors critical for packaging applications and for the protection of light-sensitive goods. The corresponding RGB values, hex codes and shade descriptions for the Ambul and Cavendish films are summarised in Table 3.

Table 3

Colour Analysis Evaluation for Ambul and Cavendish Corm Starch Films

Sample No.	*L**	*a**	*b**	RGB Coordinates	HEX Codes	Shade Description
A 1	62.28	14.29	19.00	183, 141, 118	B78D76	Warm clay brown
A 2	65.55	13.80	18.48	192, 150, 127	C0967F	Soft beige-brown
A 3	60.93	15.72	22.76	183, 136, 108	B7886C	Sand brown
A 4	68.32	12.31	15.23	196, 158, 140	C49E8C	Light peach brown
A 5	66.84	11.46	18.02	191, 155, 131	BF9B83	Warm tan
C 1	71.18	11.12	13.86	201, 167, 150	C9A796	Clay beige
C 2	74.22	10.41	14.32	209, 175, 157	D1AF9D	Soft beige
C 3	72.69	10.57	14.11	205, 171, 153	CDAB99	Light sand
C 4	71.61	11.07	14.32	202, 168, 150	CAA896	Warm tan
C 5	74.84	9.92	13.02	209, 177, 161	D1B1A1	Creamy beige

Conclusions and Implications

This study confirms that starch extracted from discarded Ambul and Cavendish banana corms can form functional biodegradable biopolymer films, providing a sustainable alternative to synthetic plastics. The findings reveal that increasing the glycerol content and adding Ambul banana rib fibres significantly increase film thickness and WVP. Glycerol improves chain mobility, while hydrophilic fibres allow higher moisture transmission. Visually, the films display protective earthy tones. By repurposing agricultural waste, this research establishes an eco-friendly matrix suitable for packaging light-sensitive goods while addressing the global pollution crisis. Further research is recommended to reduce the WVTR and WVP of banana corm starch-based films and thereby improve their barrier performance for broader packaging applications.

***Keywords*:** Agricultural waste valorisation, banana corm starch, biopolymer film, sustainable materials, water vapour permeability

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Transforming Hospitality Feedback into Decision Support Insights Using Fine-Tuned Transformers and Zero-Shot Inference

Alagarathnam N.* and Krishnamenan R.
Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka
*Corresponding author (email: nethikaa.aln@gmail.com)

Introduction

Online review platforms such as TripAdvisor, Booking.com and Google Hotels receive a vast number of posts and reviews every year, and visitors regularly read them before choosing a hotel (Adikari et al., 2024). However, many tools reduce each review to a star rating or a single sentiment label, and hotels receive more reviews than they can read. This is the main limitation of existing sentiment analysis. A review often praises one thing and criticises another ("helpful staff, but a noisy room"), so a single label shows that a guest is unhappy, but not about what, or what to fix first. To overcome this, aspect-based sentiment analysis (ABSA) was developed, which assigns a sentiment to each service aspect, such as room, staff or food (Hoang et al., 2019).

Two gaps remain. First, zero-shot large language models (LLMs) performed well on hotel reviews without the need for labelled data (Guidotti et al., 2025), whereas fine-tuned RoBERTa showed an improvement over prompted GPT models in hospitality review classification (Botunac et al., 2024). Such comparisons are often reported using accuracy on imbalanced data and rarely with the paired significance tests recommended for comparing classifiers. Second, most studies stop at extracting sentiment and topics, leaving their decision value largely untapped (Adikari et al., 2024).

Recent frameworks generate recommendations through prompted LLM reasoning (Gkaripis et al., 2026). The research question addressed here is whether fine-tuning can achieve better results than zero-shot inference. Both approaches are evaluated on the same human-annotated dataset, which exhibits class imbalance, and the study also examines how model predictions can inform management priorities. The study aims (1) to compare fine-tuned BERT and RoBERTa with zero-shot BART-large-MNLI on human-annotated hotel data using imbalance-aware metrics and paired tests, and (2) to convert the best model's predictions into an actionable priority list. It provides a rule to rank predictions and link them to the responsible unit.

Methodology

The research was carried out on seven aspects: Room Quality, Staff and Service, Food and Beverage, Location, Facilities, Value for Money and Overall. In an earlier version of this study, the data were labelled automatically using a ready-made DistilBERT sentiment model. These labels were replaced because BERT and RoBERTa were able to learn to copy them (making the comparison with BART unfair) and because DistilBERT cannot assign neutral labels. The models are now trained and tested on the hotel part of the OATS dataset, in which TripAdvisor review sentences were labelled by human annotators (Chebolu et al., 2024). There are 11,468 sentence–aspect pairs, with their categories mapped to the seven aspects, of which 8,009 pairs are used for training, 1,767 pairs for

validation and 1,692 pairs for evaluation. The labels were highly imbalanced (82.9% positive, 14.9% negative and 2.2% neutral, with 38 neutral test pairs).

For the application, a total of 31,402 reviews were gathered randomly from TripAdvisor, Booking.com and Google Reviews and transferred to an Excel sheet as one dataset. After cleaning, 31,219 reviews remained. Using a keyword lexicon, sentences were tagged with aspects, resulting in 467,861 aspect-tagged sentences without sentiment labels, which were used only for ranking. BERT-base-uncased and RoBERTa-base were fine-tuned as sentence-pair classifiers that receive the sentence and the aspect together (Hoang et al., 2019), using AdamW (learning rate 2×10^{-5}, weight decay 0.01), a batch size of 16, four epochs and a 10% linear warm-up, and the checkpoint with the best validation macro-F1 was retained.

The class imbalance was handled with inverse-frequency class weights in the cross-entropy loss (positive 0.402, negative 2.236, neutral 14.998). The BART-large-MNLI model was used without any parameter tuning, and each sentence was compared with the hypothesis "This review contains {positive/negative/neutral} sentiment regarding {aspect}" to select the most entailed label.

Macro-F1 was used as the main evaluation metric because it weights each sentiment class equally, which is required given the very strong imbalance towards the positive class. Pairwise differences between models were tested with McNemar's test. The best model was then applied to all tagged sentences. For each aspect a, the priority score was $P(a) = 100 \times R(a) / N$, where $R(a)$ is the number of reviews with at least one sentence tagged a and predicted negative, and $N = 31{,}219$.

To build the priority ranking, each review was split into sentences, and each sentence was linked to one or more aspects using a keyword list (e.g. room, bed, bathroom and noisy for Room Quality). RoBERTa then predicted the sentiment of all 467,861 sentence–aspect pairs. The priority score for each aspect is the percentage of all 31,219 reviews with at least one negative sentence about that aspect.

Results and Discussion

RoBERTa achieved the best macro-F1 and accuracy (Table 1). The "always positive" baseline shows why accuracy alone is misleading here. McNemar's test showed that RoBERTa was significantly better than BERT ($p = .019$), but neither fine-tuned model differed significantly from zero-shot BART ($p = .155$ for BERT; $p = .448$ for RoBERTa).

Table 1

Model Performance on the OATS Hotel Test Set

Model	Accuracy	Macro-F1	F1 Positive	F1 Negative	F1 Neutral
Always "positive" (baseline)	0.817	0.300	0.899	< 0.001	< 0.001
BERT-base-uncased	0.908	0.667	0.954	0.769	0.278
RoBERTa-base	0.923	0.721	0.963	0.799	0.400
BART-large-MNLI (zero-shot)	0.917	0.664	0.955	0.795	0.241

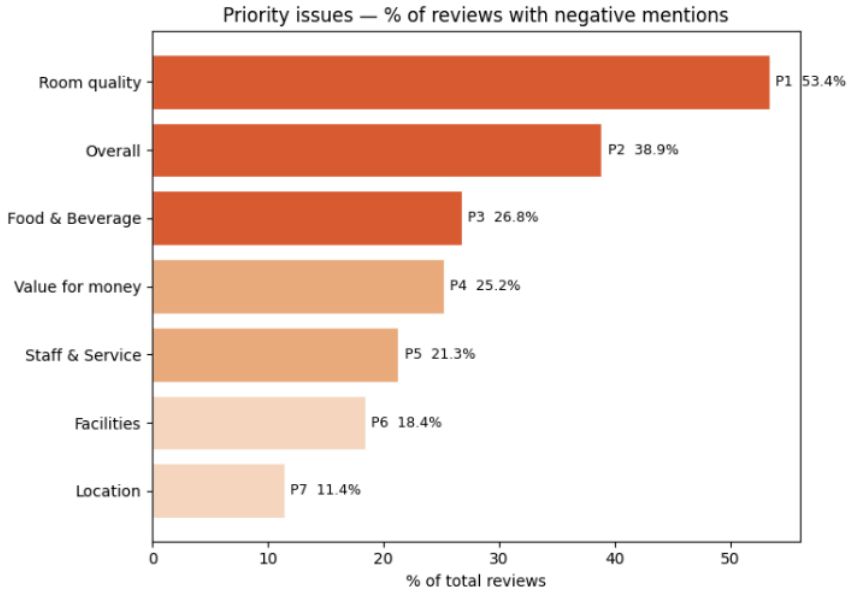
Note. $n = 1{,}692$ test pairs (1,382 positive, 272 negative, 38 neutral). The baseline always predicts positive.

All models performed well on positive and negative sentences; the main difference lay in the neutral class. RoBERTa identified 18 of the 38 neutral cases, BERT 11 and BART only 7, because the class weights pushed the fine-tuned models to predict neutral more often. These results agree with Botunac et al. (2024), who found fine-tuned RoBERTa more accurate than prompted large language models and far cheaper to run. A fine-tuned model is also better suited to large-scale use, as it needs only one forward pass per sentence.

The ranking in Figure 1 was obtained by applying RoBERTa to the application corpus. Applying the model across the full 31,219-review corpus produced 467,861 aspect–sentiment predictions. Room Quality ranked first, with negative mentions in 53.4% of reviews. Value for Money showed the highest complaint-to-discussion ratio (25.2% of reviews from only 8.3% of tagged sentences).

Figure 1

Aspect Priority Ranking by Share of Reviews with Negative Mentions



In practice, a manager starts with the top-ranked aspect, reads the negative sentences behind it to identify the exact problem, such as noise or broken air conditioning, and passes it to the responsible team: housekeeping and maintenance for Room Quality, the food and beverage team for Food and Beverage, management for Value for Money (a pricing issue), the front office and human resources for Staff and Service, and engineering for Facilities. In this study, the aspect ranking appears more reliable than the reported percentages.

Conclusions and Implications

Compared against human gold-standard labels, fine-tuned RoBERTa was the best model, and fine-tuning had a positive effect on neutral-class detection and inference cost. However, its accuracy did not differ significantly from that of zero-shot BART. Therefore, hotels with no labelled data can rely on zero-shot inference, whereas fine-tuned models are better suited to routine monitoring at scale. The pipeline provides a clear priority list derived from the predictions and has been deployed as a web dashboard.

Limitations include the small neutral class, single training runs and keyword-based aspect tagging; the pipeline is therefore a screening tool rather than a measurement instrument. Future research could employ a learned aspect classifier instead of keyword tagging, report bootstrap confidence intervals for macro-F1 over repeated training runs, calibrate the zero-shot model, expand the neutral class and validate the ranking with hotel managers on a live stream of reviews.

Keywords**:** Aspect-based sentiment analysis, decision support, hospitality reviews, transformer fine-tuning, zero-shot learning

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A Cost-Effective Real-Time Driver Drowsiness Detection System Using Facial Landmarks and Eye Aspect Ratio

Gunathilake M.D.C.J.[1,*] and Amirthalingam S.[2]
[1]*Uva Wellassa University, Sri Lanka,* [2]*Department of Information Technology, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka, Mihintale, Sri Lanka*
*Corresponding author (email: mdcjgune@gmail.com)

Introduction

Road traffic accidents remain a major global public safety concern, causing substantial fatalities, injuries and economic losses. Among the many contributing factors, driver fatigue and drowsiness have emerged as critical determinants of accident risk, particularly during long-distance travel, night-time driving and extended working hours. Drowsy drivers typically exhibit reduced alertness, slower reaction times, impaired decision-making and diminished situational awareness, all of which considerably increase the likelihood of collisions.

Traditional drowsiness detection approaches have relied heavily on physiological measurements such as electroencephalography (EEG), electrocardiography (ECG) and heart-rate monitoring. Although these methods provide reliable fatigue indicators, they require specialised equipment and direct contact with the driver, limiting their practicality for real-world deployment. Advances in computer vision and image processing have since enabled non-intrusive monitoring systems that analyse facial characteristics and behavioural cues associated with fatigue, with facial landmark detection, eye-closure monitoring and yawning analysis attracting particular interest owing to their cost-effectiveness and ease of implementation.

Despite this progress, many existing drowsiness detection systems still depend on costly hardware, wearable sensors or computationally demanding deep-learning architectures, making them impractical for resource-limited settings. Sustaining real-time performance on consumer-grade hardware while maintaining reliable detection also remains a persistent challenge. This study therefore addresses the need for a lightweight, economically viable solution capable of identifying fatigue-related behaviour without specialised apparatus.

The study first aims to develop a low-cost, real-time driver drowsiness detection system using computer vision techniques. It further aims to detect fatigue-related behaviour through eye-closure analysis using the Eye Aspect Ratio (EAR) method, to identify yawning events through facial landmark-based mouth analysis, and to generate timely warning alerts when drowsiness indicators exceed predefined thresholds. Finally, it seeks to evaluate the feasibility of a non-intrusive driver monitoring system using standard camera hardware.

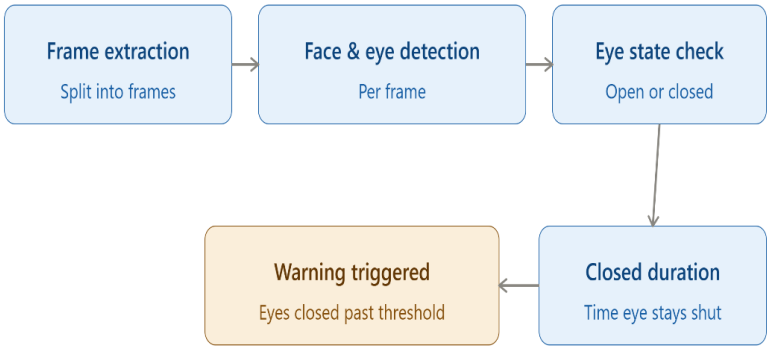
Methodology

This research adopts a design-and-development methodology to construct a real-time driver drowsiness detection system based on computer vision. The system continuously

monitors facial characteristics associated with fatigue and produces warning alerts when drowsiness indicators are detected, integrating face detection, facial landmark extraction, eye-closure analysis, yawning detection and alert generation within a unified processing pipeline (Figure 1).

Figure 1

Eye Detection System for Drowsiness Prevention



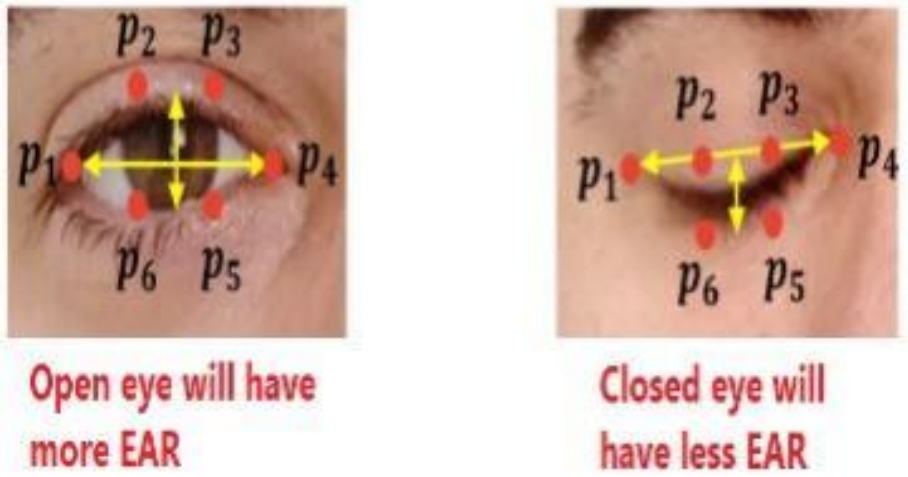
Note. Sequential workflow of the real-time eye detection pipeline, depicting frame extraction, per-frame face and eye detection, eye state determination (open/closed), closed-duration tracking and warning alert generation when threshold limits are exceeded.

The proposed architecture comprises six major components: a video acquisition module, a face detection module, a facial landmark detection module, an EAR analysis module, a yawning detection module and an alert generation module. A webcam continuously captures video frames of the driver; each frame is processed using Haar Cascade classifiers to detect the facial region, after which Dlib-based facial landmark extraction locates key points around the eyes and mouth.

Eye closure is assessed using the EAR, computed from the distances between specific eye landmarks (Figure 2), as given in Equation (1), where p_1 to p_6 are the eye landmark points. A sustained decline in EAR below a predefined threshold across successive frames is interpreted as a potential indicator of fatigue. Yawning is identified by measuring the vertical and horizontal distances between mouth landmarks; when the degree of mouth opening exceeds a specified threshold for a continuous duration, a yawning event is recorded.

Figure 2

Eye Aspect Ratio Equation Based on Eye Landmarks



Note. Calculation of the Eye Aspect Ratio (EAR) using facial landmark key points located around the eye region.

$$\text{EAR} = \frac{\| p_2 - p_6 \| + \| p_3 - p_5 \|}{2 \| p_1 - p_4 \|} \qquad (1)$$

The system combines the eye-closure and yawning indicators to determine the driver's alertness state, with drowsiness recognised when one or more fatigue indicators exceed their thresholds. Combining multiple indicators improves detection reliability and reduces false alarms. Upon detecting drowsiness, the system immediately triggers an audible alert, which remains active until the driver's facial indicators return to a normal state.

Results and Discussion

System performance was evaluated under varying environmental and behavioural conditions. Increased ambient illumination was found to progressively reduce detection performance, eventually to the point of complete detection failure, as excessive external light alters the measured pixel intensity of the eyes and lips and interacts adversely with the camera's own illumination. This effect can be mitigated by carefully increasing the illumination directed at the driver's face, provided that the intensity remains low enough to avoid distracting or discomforting the driver.

Conversely, reduced ambient illumination also degraded performance, with detections declining to zero under very low light, since the system relies on visible-light imaging and is therefore not well suited to night-time conditions without supplementary lighting. Controlled, indirect illumination of the driver's cabin was identified as a means of improving contrast for night-time operation, again with care taken to avoid interference with the camera or discomfort to the driver.

Detection accuracy was further affected by inter-individual variation in eye and mouth size, which influences light reflection and complicates the measurement of EAR and mouth-opening distances. Facial occlusions, such as a hand covering the mouth or the use of a mask, also hindered yawning detection, and the system was unable to distinguish yawning from other mouth movements such as eating, drinking or talking, occasionally leading to missed or false alerts.

Frame rate was identified as another critical performance factor. Higher frame rates improved the accuracy of ocular measurements and enabled finer-grained detection of blink frequency and duration, but they also increased memory and processing demands, which is significant for resource-constrained or embedded deployments. Excessively high frame rates combined with fast processing shortened the effective observation window, increasing sensitivity and the risk of frequent, potentially annoying alerts; this could be mitigated by increasing the number of frames considered within each decision window, particularly on lower-powered embedded systems.

Conclusions and Implications

This study presented a cost-effective, real-time driver drowsiness detection system based on facial landmark analysis and EAR monitoring, combining face detection, facial landmark extraction, eye-closure assessment, yawning identification and alert generation in a single framework. By relying on standard webcam hardware rather than wearable sensors, the system offers a practical and economical alternative to physiological monitoring approaches, while the fusion of eye-closure and yawning cues improves the reliability of fatigue detection compared with single-feature methods.

Nonetheless, the system's performance is sensitive to lighting conditions, facial occlusions, pronounced head movement and accessories such as sunglasses, and its threshold-based decision mechanism may not fully capture individual variation in facial attributes and fatigue behaviour. These limitations have practical implications for deployment, suggesting a need for adaptive thresholds and supplementary illumination strategies in real-world vehicles.

Future work will focus on incorporating deep learning approaches, including convolutional neural networks and transformer-based vision architectures, to improve feature extraction and classification robustness, alongside evaluation on larger and more diverse datasets collected under authentic driving conditions. The integration of infrared cameras, adaptive thresholding and cloud-based monitoring may further enhance performance and support deployment within intelligent transportation and advanced driver-assistance systems, contributing to broader efforts to reduce fatigue-related road accidents.

Keywords**:** Computer vision, driver fatigue, eye aspect ratio, facial landmark detection, yawning detection

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Brain Tumour Segmentation Using Multi-Modal MRI: A Modality Ablation Study with 2D U-Net

Jayasekara D.L.P.*, Wijewardane H.O. and Samaranayake S.A.
Department of Physical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: jayasekaralaksha@gmail.com)

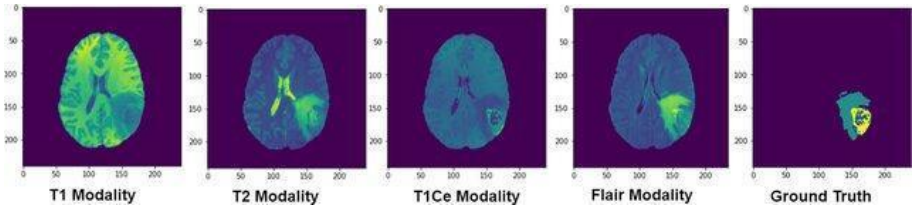
Introduction

Brain tumours are among the deadliest diseases, and despite advances in technology, diagnosing them remains challenging. There are over 150 documented types of brain tumour, but they fall into two main categories: primary and secondary. Primary brain tumours start in brain tissue, whereas secondary brain tumours contain cancerous cells that originate elsewhere in the body; secondary tumours are much more common than primary tumours. Doctors use computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET) and biopsies to diagnose brain tumours. Among these, MRI has become the leading method because of its excellent soft-tissue contrast and its ability to capture various tissue properties through different acquisition sequences. Unlike CT, MRI does not use ionising radiation and provides detailed information when multiple sequences are acquired simultaneously.

In brain tumour assessment, four MRI modalities are typically used together. As shown in Figure 1, T1-weighted (T1) imaging highlights anatomical structure and tissue shape. T1 contrast-enhanced (T1ce) imaging is acquired after a gadolinium-based contrast agent is injected. The T2-weighted (T2) sequence highlights both the tumour and the surrounding swelling, resulting in a bright signal in the affected areas. Fluid-attenuated inversion recovery (FLAIR) is a T2-based sequence that suppresses the signal from cerebrospinal fluid. Each modality provides valuable biological information, and using them together gives a clearer picture of the tumour's size and internal structure than relying on a single modality. However, in clinical practice, the ideal four-sequence MRI protocol is not always achievable. Therefore, this study adopts a multimodal approach to obtain diverse information by combining these modalities.

Figure 1

Visualisation of T1, T1ce, T2, FLAIR and Ground Truth



Note. Visualisation of magnetic resonance imaging (MRI) images from BraTS 2020 of the subject with ID BraTS20-Training-004, showing (A) T1, (B) T2, (C) T1ce, (D) FLAIR and (E) the segmented label.
Source: Fiaz et al. (2021)

Segmenting brain tumours is difficult because tumours vary in size and shape and have blurred boundaries, and because of class imbalance (e.g. the enhancing tumour), misaligned modalities, patient and scanner variability, and high cost. The encoder–decoder architecture of U-Net, with skip connections, addresses these challenges by preserving the spatial detail needed for precise boundary delineation, making it the dominant approach in the Brain Tumour Segmentation (BraTS) challenge. This study implements a 2D U-Net (Ronneberger et al., 2015) with a composite focal–Dice loss (per-class weighted) and evaluates six modality configurations to identify the combination that best segments each tumour sub-region, thereby guiding both model design and clinical imaging protocols.

Methodology

This study develops a 2D U-Net for multimodal brain tumour segmentation using the BraTS 2020 dataset. The pipeline covers dataset preparation, data preprocessing, data augmentation, model design, loss function formulation, training and a modality ablation study. As shown in Figure 1, each BraTS 2020 case includes four co-registered MRI modalities (T1, T1ce, T2 and FLAIR), along with an expert-annotated ground-truth segmentation mask, all stored in NIfTI (.nii) format. The raw segmentation mask uses four integer labels (0, 1, 2 and 4), which are transformed into three overlapping binary channels corresponding to the clinically meaningful tumour sub-regions defined by the challenge (Table 1).

Table 1

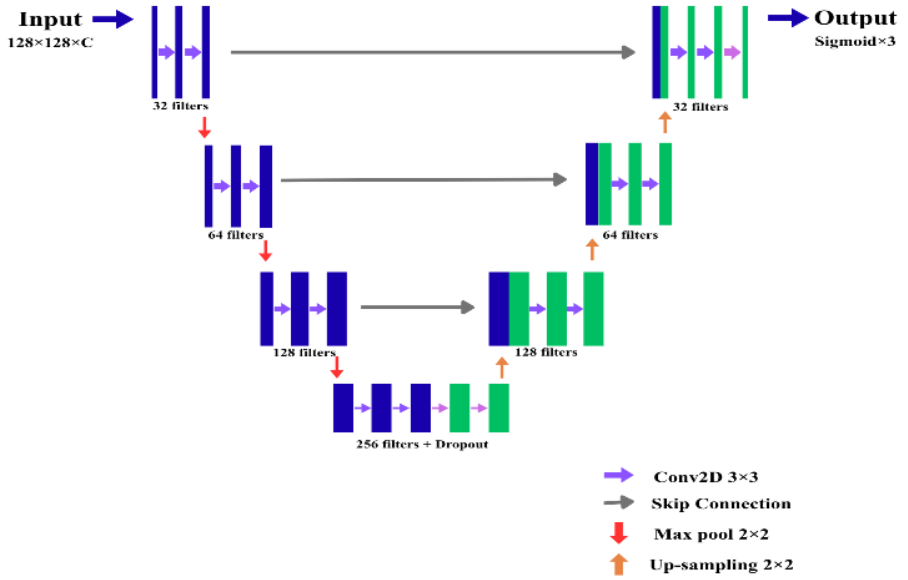
Primary Brain Tumour Segmentation Classes: Whole Tumour (WT), Tumour Core (TC) and Enhancing Tumour (ET)

Class	Description	Source Labels
Whole Tumour (WT)	All tumour tissue, including all sub-regions	> 0
Tumour Core (TC)	Necrotic core and active enhancement	1 and 4
Enhancing Tumour (ET)	Actively enhancing tissue only	4 only

The architecture of the 2D U-Net model is shown in Figure 2. A 2D slice-based approach was selected instead of full 3D volumetric processing to keep computation manageable on the available hardware (Google Colab). This decision made it possible to run a six-configuration ablation study within a reasonable training time; as Çiçek et al. (2016) point out, models with full 3D convolutions require much more computing power.

Figure 2

2D U-Net Model Architecture



Each 3D volume was split into axial slices, and only slices containing tumour were retained to address the class imbalance caused by empty background slices. Slices underwent *z*-score standardisation and were resized to 128 × 128 pixels. This lower resolution, compared with the original 240 × 240, kept memory usage and training time practical across all six modality configurations, although it reduced boundary precision. Finally, the modalities were combined into a multi-channel tensor with dimensions [128, 128, *C*]. Data augmentation (horizontal flip, vertical flip, random rotation, intensity scaling and Gaussian noise) was applied to better reflect scanner and patient variability, rather than solely for regularisation. The data were split at the patient level (70/15/15) to prevent slice leakage, as slices from the same patient are closely related. A fixed seed (42) was used to ensure reproducibility across experimental set-ups.

The model was trained using the Adam optimiser (learning rate = 1×10^{-4}) with a batch size of 8, which was limited by the available graphics processing unit (GPU) memory. Training was conducted for up to 50 epochs and incorporated early stopping, learning-rate decay and checkpointing. Six ablation configurations (T1, T1ce, T1ce+FLAIR, T2, T2+FLAIR and all four modalities) were selected to reflect realistic clinical scenarios, with the Dice coefficient per region and the mean Dice coefficient used to assess the contribution of each modality.

Results and Discussion

Based on Table 2, the 2D U-Net with the combined focal–Dice loss achieved a mean Dice score of 0.5964 across all four modalities, supporting the effectiveness of the pipeline. These results are lower than the range already achieved in BraTS 2020 (WT: 0.91–0.98,

TC: 0.85–0.99, ET: 0.80–0.99). This outcome is expected because top-performing methods such as nnU-Net use full 3D data at native resolution, whereas this study intentionally accepted some loss in accuracy to make a six-way ablation feasible.

Table 2

Test Set Dice Coefficients Across Modality Configurations

Modality	WT	TC	ET	Average
T1	0.6388	0.4651	0.3049	0.4187
T1ce	0.6217	0.5569	0.6242	0.5207
T1ce+FLAIR	0.8072	0.5760	0.5339	0.5793
T2	0.7352	0.4465	0.2785	0.4326
T2+FLAIR	0.7805	0.5017	0.3340	0.4648
ALL	0.8097	0.6100	0.5924	0.5964

Note. Image size = 128, number of classes = 3, batch size = 8, epochs = 50, seed = 42, patients = 101. WT = whole tumour; TC = tumour core; ET = enhancing tumour.

T1ce alone gave the highest ET Dice score, reflecting its sensitivity to gadolinium uptake (Zhou et al., 2019). T2+FLAIR achieved the strongest WT Dice score of 0.7805, reflecting joint sensitivity to peritumoral oedema. T1ce+FLAIR achieved a mean Dice score of 0.5793, just 0.0171 lower than that of the full four-modality model, suggesting that these two sequences capture most of the useful information in the full set. This result supports the finding of Abraham and Khan (2019) that attention-refined U-Net models gain most of their advantage from the contrast-enhanced and FLAIR channels rather than needing all modalities, and it extends that finding by directly measuring the gap in a non-attention 2D model. It also supports the observation of Çiçek et al. (2016) that adding more modalities yields diminishing benefit once the key ones are included. The ablation therefore clearly identifies the core subset for BraTS-style tumour segmentation.

The full model achieved the best overall result, but not the best ET score. This suggests that there may be some competition between sub-regions when all four channels are optimised together, an issue not addressed by the original architecture of Ronneberger et al. (2015), which was not designed for a multi-region composite loss. Limitations of this approach include the loss of inter-slice context compared with 3D methods, less precise boundaries owing to the lower resolution, and the absence of post-processing.

Conclusions and Implications

The full four-modality model achieved the highest overall performance and is recommended as the optimal configuration. When all four modalities are not available, T1ce alone is best suited for ET and T1ce+FLAIR for WT. Future work should prioritise a 3D U-Net architecture, a higher native resolution (240 × 240) for fine boundaries, and modality-aware attention to address gradient competition. Post-processing techniques such as connected-component analysis can provide modest performance improvements with minimal additional effort. Transformer hybrid models and missing-modality handling are deprioritised owing to insufficient evidence of their effectiveness on small datasets and their focus on deployment rather than performance. Clinical validation

should be postponed until the proposed architectural and resolution enhancements have been implemented, to ensure a meaningful assessment of real-world applicability.

***Keywords*:** Brain tumour, deep learning, magnetic resonance imaging, multimodal imaging, U-Net

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Effect of Thermal Pre-Treatment and Acid Leaching on the Electrochemical Characterisation of Pulmoddai Zircon Mineral

Sewwandi R.M.N.M.[1], Dharmagunawardhane H.A.N.[2] and Herath H.M.A.M.C.[1,*]
[1]*Department of Chemical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Department of Materials Technology, Faculty of Technology, Rajarata University of Sri Lanka, Mihintale, Sri Lanka*
*Corresponding author (email: ajithch037@gmail.com)

Introduction

Zircon ($ZrSiO_4$), an industrially valuable orthosilicate prized for its thermal and chemical resilience (Silva & Perera, 2021), contains structural iron oxide impurities in natural Sri Lankan Pulmoddai sands that degrade its performance (Al-Annes & Rahman, 2018). Traditional purification applies acid leaching to dissolve grain-boundary contaminants (Mendoza & Santos, 2018) or calcination to redistribute internal lattice strain (Carter & White, 2015). However, a critical knowledge gap exists regarding the microscopic surface electronic properties governing these processing treatments (Kumar & Singh, 2019), making interfacial electroactive evaluations vital for validating impurity extraction (Patel & Joshi, 2020). To address this gap, this study uses cyclic voltammetry (CV) as a sensitive probe on zircon-modified glassy carbon electrodes. By capturing micro-level faradaic current profiles that conventional solid-state tools miss (Wang & Zhang, 2016), CV maps local coordination environments and mass transport boundaries. This investigation systematically compares leaching agents (HCl and H_2SO_4), acid concentrations, digestion times and calcination temperatures in order to optimise refinement pathways.

Methodology

Sri Lankan Pulmoddai zircon samples were prepared as a fine powder sieved through a 600 µm mesh and divided into four thermal groups: a room-temperature (RT) control and three groups calcined in a muffle furnace at 200 °C, 500 °C and 800 °C for 2 hours. Hydrometallurgical leaching was performed at 80 °C under 300 rpm magnetic stirring using a 1:5 solid-to-liquid ratio (20.0 g zircon to 100.00 mL acid) to test varying acid concentrations, namely 20% v/v (HCl: 2.28 mol dm^{-3}; H_2SO_4: 3.67 mol dm^{-3}), 40% v/v (HCl: 4.57 mol dm^{-3}; H_2SO_4: 7.34 mol dm^{-3}) and 60% v/v (HCl: 6.85 mol dm^{-3}; H_2SO_4: 11.01 mol dm^{-3}), prepared from 35.4% w/w HCl and 98.09% w/w H_2SO_4 stocks, and varying contact digestion times (2 and 6 hours). The isolated solid residues were washed to a neutral pH and oven-dried at 80 °C.

For the electrochemical analysis, a three-electrode system was built using a platinum wire counter electrode, an Ag/AgCl (3 M KCl) reference electrode and a glassy carbon electrode modified with 40 mg of zircon powder bound by a drop of Nafion 117 solution. Cyclic voltammograms were recorded at a scan rate of 50 mV/s within a potential window of −0.4 V to +1.0 V in a 10 mL glass cell containing 6 mL of N_2-purged 0.1 M HCl (pH 1.0) background electrolyte. The leaching efficiency was systematically investigated by varying the HCl concentration (20%, 40% and 60% v/v HCl) and contact time (2 and 6 hours), with iron removal quantified by ultraviolet–visible (UV-Vis) spectroscopic

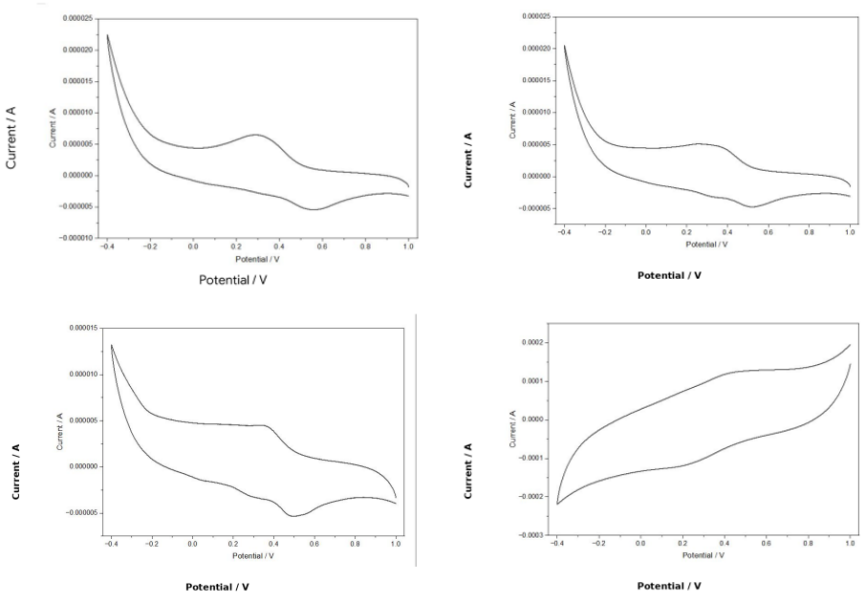
analysis of the collected HCl leachate using the potassium thiocyanate (KSCN) method to detect the resulting Fe^{3+} complex.

Results and Discussion

The electrochemical profile of unrefined Sri Lankan zircon exhibited redox features that may be associated with electroactive surface iron species (Patel & Joshi, 2020). As shown in Figure 1, raw room-temperature zircon displayed a cathodic reduction peak at +0.29 V (6.5×10^{-6} A). Thermal processing altered this baseline: at 200 °C, the peak current dropped by 20.3% (5.1×10^{-6} A) at +0.27 V, while at 500 °C, a +0.06 V shift moved the peak to +0.35 V with a 29.7% current drop (4.5×10^{-6} A). At 800 °C, the faradaic peaks disappeared into a featureless, quasi-capacitive loop as the background current increased to the 10^{-4} A range (1.2×10^{-4} A at +0.4 V), reflecting thermal modifications to the surface electrochemical behaviour.

Figure 1

Cyclic Voltammograms of Raw and Thermally Treated Zircon at Progressive Temperatures



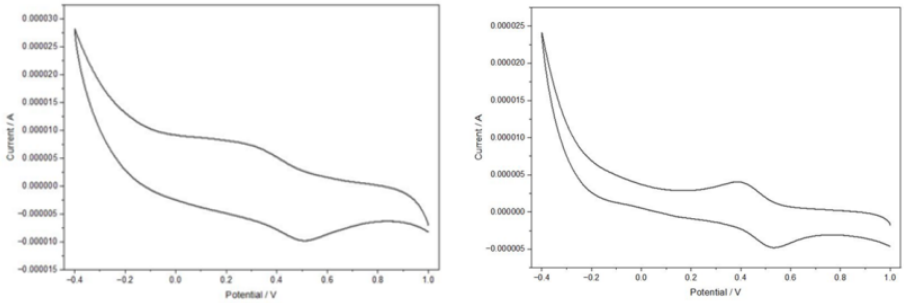
Note. Panels from left to right: RT, 200 °C, 500 °C and 800 °C.

Hydrometallurgical extraction revealed contrasting dissolution mechanisms between the two acid systems (Kumar & Singh, 2019). At equal parameters (60%, 2 hours, RT) in HCl and H_2SO_4, HCl treatment led to the suppression of redox peaks in the cyclic voltammogram (Figure 2). This suppression indicated the selective dissolution, or the modification of the oxidation state, of electroactive surface iron species. When the two treatments were compared, H_2SO_4 maintained a distinct redox feature between 0.4 V and

0.6 V, whereas the HCl treatment more effectively passivated or stripped these surface-accessible signals, in agreement with macroscopic surveys (Al-Annes & Rahman, 2018).

Figure 2

Cyclic Voltammograms of Zircon Comparing HCl and H_2SO_4 Acid Leaching



Note. Left: HCl; right: H_2SO_4.

UV-Vis spectroscopic results, verified by the KSCN colorimetric assay on 0.2 mL aliquots drawn from acid leachates at 20% (2.28 M), 40% (4.57 M) and 60% (6.85 M) HCl concentrations after 2 hours and 6 hours, showed that the absorbance intensity of the iron thiocyanate complex varies with the treatment parameters. Specifically, the 20% and 40% HCl treatments yielded original iron concentrations of 115.03 mg/L and 235.11 mg/L, respectively, while 60% HCl yielded 343.30 mg/L (2 hours) and 679.11 mg/L (6 hours). These spectra confirmed that higher acid concentration and prolonged exposure facilitate more effective targeted dissolution of surface-bound iron species. This surface leaching behaviour correlated with the suppressed CV redox signals, indicating that optimised HCl treatment modifies electroactive surface impurities (Mendoza & Santos, 2018).

Conclusions and Implications

This investigation shows that cyclic voltammetry effectively tracks the electrochemical response and surface-state changes of Pulmoddai zircon, indicating the presence of electroactive surface iron species. Thermal treatment alters these responses, but confirming lattice incorporation or contaminant locking requires complementary structural and chemical evidence; future work will therefore incorporate X-ray diffraction and inductively coupled plasma analyses. HCl leaching strips surface iron more efficiently than H_2SO_4. Consequently, optimising acid leaching parameters provides an effective pathway for surface impurity modification.

Keywords**:** Acid leaching, calcination, cyclic voltammetry, iron extraction, zircon ($ZrSiO_4$)

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Green Synthesis of *Syzygium cumini*-Derived Copper Nanoparticles for Selective CO and H_2 Adsorption Towards Syngas Separation

Weerawansha G.D., Senevirathne S.A. and Jayaratna N.B.*
Department of Chemical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: naleen@as.rjt.ac.lk)

Introduction

Syngas, consisting primarily of carbon monoxide (CO) and hydrogen (H_2), is a vital industrial feedstock for the production of synthetic fuels, methanol, ammonia and other value-added chemicals. However, the selective separation of CO from syngas remains a significant challenge owing to the high energy demand and operational costs associated with conventional technologies such as cryogenic distillation and pressure swing adsorption. Therefore, developing sustainable, efficient and cost-effective adsorbent materials for selective gas separation has become increasingly important (Li et al., 2009).

Copper nanoparticles (CuNPs) possess unique surface properties and strong interactions with gaseous molecules, making them promising candidates for gas adsorption applications. However, conventional synthesis approaches often rely on toxic chemicals and hazardous reducing agents, highlighting the need for greener alternatives. Plant-mediated synthesis using *Syzygium cumini* leaf extract provides an environmentally sustainable route, in which phytochemicals such as flavonoids, tannins and polyphenols act as natural reducing and stabilising agents. Despite the growing interest in green nanomaterials, the adsorption behaviour of plant-derived CuNPs towards CO and H_2 remains largely unexplored. Hence, this study investigates *S. cumini*-mediated CuNPs for selective CO and H_2 adsorption towards potential syngas separation applications (Din et al., 2023).

Methodology

Fresh *S. cumini* leaves were washed, cut into small pieces and heated with distilled water at 60–70 °C for 25 min to prepare the leaf extract. The extract was filtered through Whatman No. 1 filter paper and divided into separate portions for phytochemical screening and CuNP synthesis. One portion was subjected to qualitative phytochemical screening to identify the phytochemicals present (Pestryakov et al., 2004). Another portion was slowly added dropwise to a $CuSO_4$ precursor solution at a 1:4 ratio under continuous stirring. The pH of the reaction mixture was adjusted to 8.5, and the mixture was then heated at 60–65 °C for one hour to complete the nanoparticle synthesis. The resulting CuNPs were separated by centrifugation, washed twice with water to remove unreacted copper sulfate and excess leaf extract molecules, and dried in an oven at 50–60 °C for 1 hour. The dried CuNPs were ground to a fine powder, which was used for Fourier transform infrared (FTIR) spectroscopy and thermogravimetric analysis (TGA), while an aqueous dispersion of the CuNPs was used for UV–visible spectroscopic analysis and particle size analysis.

In the gas adsorption studies, CO and H_2 gases were purged separately into the adsorption chamber of a laboratory-scale gas adsorption set-up containing the dried powdered CuNP sample at room temperature for 20, 40 and 60 min to determine the adsorption rate and to investigate the adsorption behaviour and selectivity of the synthesised CuNPs.

Results and Discussion

Phytochemical screening revealed the presence of flavonoids, tannins and polyphenolic compounds in the *S. cumini* extract (Table 1), which acted as reducing and stabilising agents for the nanoparticles (Hasanuzzaman et al., 2016).

Table 1

Phytochemical Screening Test

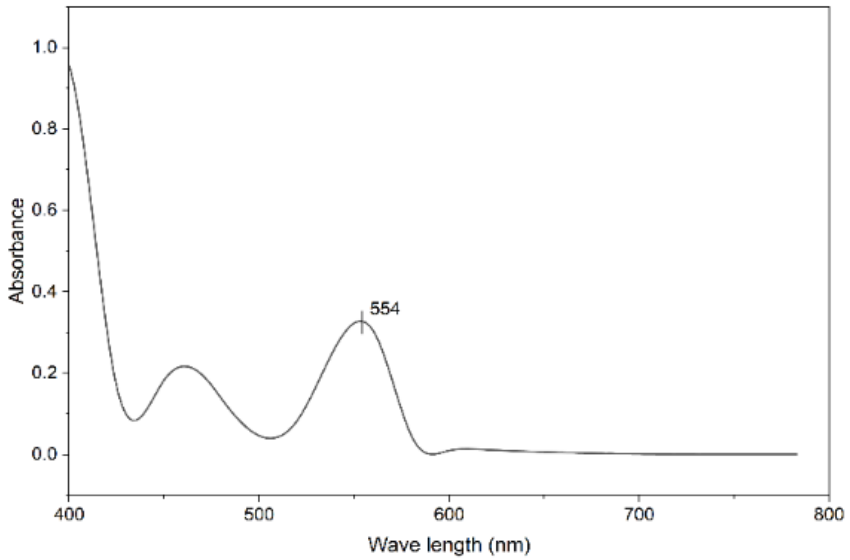
Phytoconstituents	Test	Results
Flavonoids	Ammonia test	+
Tannins/polyphenols	Ferric chloride test	+
Terpenoids	Salkowski test	−
Saponins	Froth test	−
Carbohydrates	Molisch's test	−
Alkaloids	Mayer's test	−

Note. + = present; − = absent.

The UV–visible spectrum showed two absorption bands (Figure 1): a distinct peak at 554 nm corresponding to the surface plasmon resonance associated with the formation of CuNPs, and an additional band at approximately 465 nm arising from electronic transitions involving phytochemicals during the green synthesis, indicating the contribution of plant-derived components in the sample (Pestryakov et al., 2004).

Figure 1

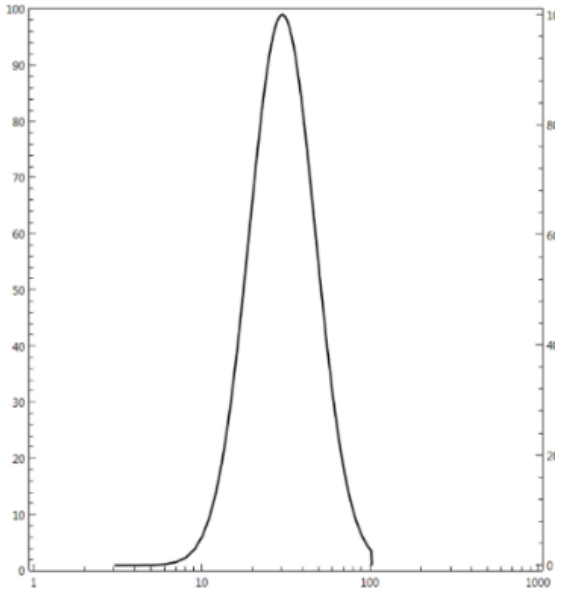
UV–Visible Spectrum of Green-Synthesised Copper Nanoparticles



Particle size analysis revealed an average particle size of about 30 nm (Figure 2), indicating the successful formation of copper nanoparticles in the nanoscale range.

Figure 2

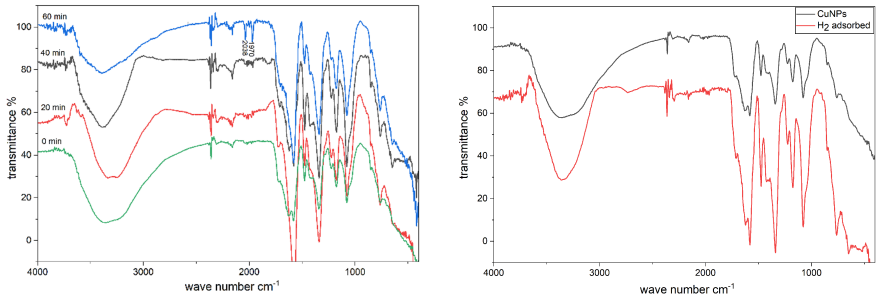
Particle Size Distribution of CuNPs



FTIR analysis revealed that CO adsorption increased with time (Figure 3). Significant peaks were observed at 2038 cm^{-1} for linear binding and 1970 cm^{-1} for bridging binding at 60 min, whereas no significant peaks were observed for H_2. This indicates a stronger interaction of CO molecules with the CuNP surface than of H_2, via σ donation from CO to the Cu surface and π back-donation from the Cu surface to CO. However, further advanced surface characterisation studies are required to confirm the detailed adsorption mechanism (Schröter et al., 2004).

Figure 3

FTIR Spectra for CO- and H_2-Adsorbed CuNPs

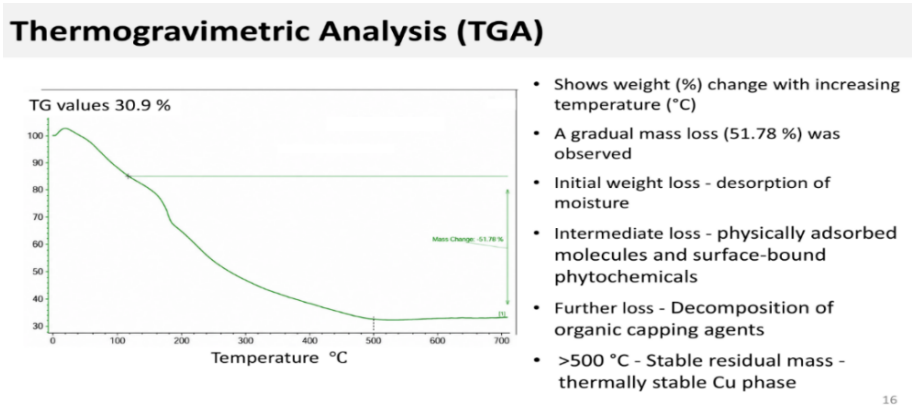


Note. Left: CO adsorption at 0, 20, 40 and 60 min; right: CuNPs before and after H_2 adsorption.

Thermogravimetric analysis of the CO-adsorbed CuNPs revealed a gradual mass loss of 51.78% with increasing temperature (Figure 4), attributed to the desorption of moisture and surface-bound species and to the thermal decomposition of biomolecular capping agents. The thermal behaviour further indicated moderate stability of the phytochemical-coated nanoparticles after gas exposure.

Figure 4

Thermogravimetric Analysis of CO-Adsorbed CuNPs



Conclusions and Implications

This study successfully demonstrated the green synthesis of copper nanoparticles using *S. cumini* leaf extract as a sustainable reducing and stabilising agent. The synthesised CuNPs showed more spectroscopic changes in the presence of CO than of H_2 under the conditions studied, indicating a relatively stronger interaction of CO with the CuNP surface. The findings highlight the potential of green-synthesised CuNPs as environmentally friendly adsorbent materials for sustainable gas purification applications. Further advanced adsorption and surface characterisation studies are recommended to better understand the adsorption mechanism and improve separation performance.

***Keywords*:** CO adsorption, copper nanoparticles, green synthesis, syngas separation

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Poster Presentations

Sustainable Agriculture

Advancing Climate Resilience, Food System & Livelihoods

ISymRU 2026

"Sustainability Nexus: Climate Actions, Technological Innovations, and Global Collaborations"

Study of Characterisation of *Kithul* (*Caryota urens* L.) Pith Flour as a Functional Food Ingredient in Matara District in Sri Lanka

Jayamanne V.S.* and Karunaratne K.A.P.N.
Department of Food Science and Technology, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya 81100, Sri Lanka
*Corresponding author (email: vsjayamanne@fst.ruh.ac.lk)

Introduction

The utilisation of underutilised plant resources is a critical strategy for developing sustainable food systems and supporting rural economic growth. *Kithul* (*Caryota urens* L.), a palm native to tropical Asia, has long been a staple for producing traditional sap-based sweeteners such as *jaggery* and treacle. Despite this cultural value, the flour extracted from its inner pith is often ignored by the modern food industry. This lack of exploitation is largely due to a shortage of scientific data on its nutritional and functional characteristics. Recent studies have highlighted the increasing importance of underutilised plant pith flours as functional ingredients owing to their nutritional and techno-functional properties (Kumar et al., 2024).

Furthermore, the functionality of starch-based ingredients is strongly influenced by extraction methods and structural characteristics (Zhang et al., 2024), while naturally occurring phenolic compounds contribute significantly to antioxidant activity in plant-derived foods (Li et al., 2025). To address the gap in practical application, this research investigates the physicochemical traits, proximate composition and antioxidant capacity of *Kithul* pith flour while comparing water-assisted and dry extraction methods. Additionally, the study explores the practical use of this flour in food products and its stability over time. By providing a thorough characterisation of this neglected resource, the study aims to facilitate its integration into mainstream food production (Wijesinghe et al., 2015).

Methodology

Pith samples were obtained from *Kithul* trees in the Matara District of Sri Lanka. Two extraction methods were tested: (i) a water-assisted blending process followed by sedimentation and drying, and (ii) a mechanical dry-grating technique. The resulting flour was passed through a 355 µm sieve and kept frozen until analysis. Key physicochemical indicators, namely pH, bulk density, solubility and iodine reactivity, were measured to assess starch quality.

Proximate analysis covering moisture, protein, fat, fibre, ash and carbohydrates followed the standard protocols of the Association of Official Analytical Chemists (AOAC, 1990). Methanolic extracts were prepared to measure total phenolic content (TPC) by the Folin–Ciocalteu method (Singleton et al., 1999). Antioxidant performance was verified using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Dudonné et al., 2009) and 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) (Re et al., 1999) radical scavenging assays. For functional property testing, the flour was used to prepare *rotti* formulations, which were evaluated by 30 untrained panellists in a triangle sensory test. Finally, shelf life was

monitored through yeast and mould count and aerobic plate count under room temperature (30 ± 2 °C), refrigerated (5 ± 2 °C) and deep-frozen (−18 °C) storage. The study maintained rigorous standards consistent with modern starch analysis (Zhang et al., 2024).

Results and Discussion

Water-assisted extraction proved more efficient, yielding 28.70% flour, whereas dry extraction yielded only 11.73%, suggesting that hydration aids the release of starch from pith cells. Both variants were odourless, water-insoluble and reacted positively to iodine, confirming that they were primarily starch. The pH values were near-neutral (7.1–7.2), and bulk density ranged from 0.68 to 0.72 g/cm³, making the flour suitable for industrial handling. These functional trends are consistent with recent findings on how processing affects starch quality (Zhang et al., 2024).

Nutritional analysis showed high carbohydrate levels (>86%) with minimal protein, fat and ash. Moisture levels were consistently below 12%, which is ideal for storage. Interestingly, the dry extraction method yielded higher protein, fibre and phenolic content, probably because these components were not lost through water leaching. TPC was 37.62 mg gallic acid equivalents (GAE)/100 g for dry extraction, compared with 33.21 mg GAE/100 g for water extraction (Singleton et al., 1999). The antioxidant results showed higher activity in the ABTS assay than in the DPPH assay, indicating a mix of hydrophilic and lipophilic antioxidants, which aligns with current research on the functional roles of plant-based antioxidants (Li et al., 2025; Re et al., 1999). Sensory testing revealed that *Kithul* pith products were well received and often preferred by consumers. Deep-frozen storage at −18 °C was the most effective, maintaining microbial safety for up to nine months.

Conclusions and Implications

Kithul pith flour demonstrates significant potential as a functional food ingredient owing to its favourable physicochemical and antioxidant properties, including its functional properties. While water extraction maximises yield, dry extraction is superior for retaining bioactive functional compounds. Its successful use in traditional food and its stability during storage highlight its commercial viability. This research supports the sustainable use of underutilised resources to improve rural livelihoods and promote agro-based product development.

***Keywords*:** Antioxidant activity, *Caryota urens*, functional food, *Kithul* flour, value addition

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Govi Mithuru: A Smart Farming Mobile Application to Empower Small-Scale Farmers in Sri Lanka

Jayathissa T.M.I.M.*, Layassruthy S. and Johanan I.S.E.
Department of Marketing, Faculty of Management Studies and Commerce, University of Jaffna, Sri Lanka
*Corresponding author (email: sivalayam1009@gmail.com)

Introduction

Small-scale farmers in Sri Lanka, particularly in regions such as Anuradhapura and Polonnaruwa, face significant challenges that adversely affect agricultural sustainability and income. Common issues include the oversupply of certain vegetables, which reduces market prices, crop wastage due to inefficient planning, exploitation by middlemen, and a lack of accurate information on market demand trends (Shrimpton et al., 2025; Zhou & Deng, 2025). Digital technologies, including mobile applications, have emerged as transformative tools in agriculture, enabling smallholder farmers to access real-time market information, connect with buyers, and make informed planting decisions (Dilleen, 2023; Villanueva et al., 2025). Despite the growing adoption of agricultural mobile applications globally, limited research addresses their role in farmer networking and collective market intelligence in the Sri Lankan context (Gong & Bellingeri, 2025).

This study addresses the research gap of integrating crop planning, peer knowledge sharing, and direct market access into a single mobile platform tailored to low-literacy, multilingual Sri Lankan farmers. The research question guiding this study is: *How can a mobile application reduce crop wastage and improve economic outcomes for small-scale Sri Lankan farmers through digital networking and predictive intelligence?* The objectives of this study are (1) to design and develop a mobile application with crop planning, predictive price reporting, social knowledge sharing, and direct marketplace features; (2) to evaluate its usability and decision-making impact through pilot testing with target farmers; and (3) to assess the economic and agricultural outcomes achieved. The study is justified by the urgent need to empower smallholder farmers with accessible, data-driven tools that reduce dependency on middlemen and improve supply chain efficiency. It presents Govi Mithuru, a mobile application designed to empower farmers by providing data-driven crop planning, predictive price reports, knowledge sharing, and direct access to buyers, with inclusive access through Sinhala and Tamil language interfaces and voice input for farmers with limited literacy.

Methodology

This research adopts a design, development, and evaluation approach, using the Govi Mithuru mobile application as a case study. The research framework is grounded in the principles of agricultural informatics and rural digital empowerment (Dilleen, 2023; Shrimpton et al., 2025). The methodology involved four main stages. First, a needs assessment was conducted through structured surveys administered to farmers in the Anuradhapura and Polonnaruwa districts to identify challenges in crop planning, marketing, and technology use, drawing on participatory rural appraisal methods (Shrimpton et al., 2025). Second, the Govi Mithuru mobile application was developed

using agile prototyping, with features including crop planning inputs, predictive price reports derived from aggregated farmer data, social knowledge sharing, direct marketplace access, weather alerts, and offline functionality to address connectivity constraints (Dilleen, 2023). Third, the application was pilot-tested with a purposive sample of 15 farmers, who interacted with it over four weeks and provided feedback on usability, functionality, and decision-making impact through structured interviews and observation protocols (Villanueva et al., 2025). Finally, qualitative and quantitative outcomes were assessed, including farmer engagement rates, the accuracy of price predictions, usability scores, and the economic benefits achieved through direct sales channels (Gong & Bellingeri, 2025). The methodology emphasises practical relevance, ensuring that the platform aligns with farmers' literacy levels, local language preferences, and connectivity constraints.

Results and Discussion

The development and evaluation of the Govi Mithuru mobile application yielded several key findings. During the development phase, the needs assessment surveys revealed that 78% of farmers identified middleman dependency as their primary income constraint, while 65% reported crop oversupply as the leading cause of income loss. These findings directly informed the application's feature set. The pilot evaluation further demonstrated multiple benefits for small-scale farmers (Dilleen, 2023). In terms of crop planning and market efficiency, farmers enter the crop type, area, and quantity, and the application predicts potential oversupply and recommends alternative crops (e.g., suggesting carrots when tomatoes are oversupplied), thereby reducing economic losses and balancing local supply and demand (Gong & Bellingeri, 2025). Regarding predictive price reports, aggregated data from pilot farmers enabled crop price forecasts, facilitating informed planting decisions. Price prediction accuracy reached 72% during the evaluation period, preventing overproduction and helping to maintain fair market prices (Zhou & Deng, 2025). The application also supports knowledge sharing: farmers exchanged cultivation techniques, fertiliser methods, and pest management strategies via its social feed. Peer-to-peer knowledge sharing, as noted by Dilleen (2023), is critical for building trust in smart farming networks, and pilot participants reported improved yield quality through collaborative learning. In addition, the application provides direct marketplace access, enabling farmers to sell produce directly to shops, supermarkets, and consumers while bypassing middlemen. During pilot testing, Farmer C sold 100 kg of beans directly to a local shop, reporting a 25% increase in profit compared with previous sales through intermediaries (Villanueva et al., 2025).

Additional features further support farmers' needs. Real-time price alerts for nearby markets keep producers informed of live market fluctuations, while seasonal crop guidance aligns farming schedules with actual market demand. Weather notifications help to mitigate environmental crop losses, and an offline mode ensures continuous usability in areas with connectivity challenges. A user-friendly interface featuring icons and voice input also accommodates farmers with limited literacy.

For example, Farmer A planned to plant tomatoes, but predictive insights suggested oversupply. After switching to carrots, Farmer A used cultivation tips shared through the social feed, grew the crop, and received direct orders from a local shop. As a result, the farmer avoided losses, earned a fair profit, and learned new techniques.

Several enhancements to the application are possible. Artificial intelligence-based forecasting could improve the accuracy of price and demand predictions. Establishing partnerships with supermarkets, hotels, and exporters could also expand farmers' market reach. The platform could further benefit from integrating essential financial services, such as microloans and crop insurance. In addition, incorporating sustainability scoring could actively promote eco-friendly farming practices, while gamification elements could encourage regular data input and active knowledge sharing among users.

Conclusions and Implications

This study developed and evaluated Govi Mithuru, a mobile application that demonstrates measurable potential to address the crop wastage and middleman exploitation faced by small-scale Sri Lankan farmers. The pilot evaluation confirmed that the application's integration of predictive crop planning, peer knowledge sharing, and direct market access can reduce oversupply risks and improve farmer incomes. These findings align with evidence from Dilleen (2023) and Zhou and Deng (2025) that digital networking tools can meaningfully transform rural agricultural communities. For farmers, the application provides enhanced market intelligence, reduced dependency on middlemen, and new direct selling opportunities, supporting greater economic independence. For the economy, predictive crop planning can stabilise food prices, improve supply chain efficiency, and reduce wastage, contributing to sustainable agricultural development (Gong & Bellingeri, 2025). For policy and government, aggregated farmer data generated through such platforms can support evidence-based national agricultural planning and targeted subsidy allocation (Shrimpton et al., 2025). For society, the multilingual, voice-enabled interface promotes digital literacy and the inclusion of marginalised farming groups, contributing to rural poverty reduction (Villanueva et al., 2025).

The application also has limitations and risks. Low participation in data entry may reduce forecast accuracy, elderly farmers may face barriers to technology adoption, and middlemen may resist the platform because of the potential loss of profits. This study demonstrates that integrating technology, social collaboration, and market intelligence through a purpose-built mobile application can transform small-scale agriculture, providing sustainable and profitable solutions for farmers in Sri Lanka. Future research should focus on scaling the application and conducting longitudinal assessments of its impact on farmer incomes and food security.

Keywords**:** Crop planning, rural development, small-scale farmers, smart farming, sustainable agriculture

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IoT-Based Multi-Sensor and Image Processing Early Warning System for Elephant Intrusion to Mitigate Human–Elephant Conflict in Sri Lanka

Silva W.J.K.C. and Yuvanraj S.*
Department of Mechanical and Manufacturing Technology, Faculty of Technology, Wayamba University of Sri Lanka
*Corresponding author (email: yuvanrajs@wyb.ac.lk)

Introduction

Human–elephant conflict (HEC) causes devastating crop destruction, property damage and severe psychological trauma in rural Sri Lankan communities (Barua et al., 2013; Gunaratne & Premarathne, 2006). Conventional electric fences often fail as passive, contact-based barriers because intelligent elephants eventually learn to endure or breach them (Fernando et al., 2007). While active sensor-based systems offer early warning capabilities, they remain highly unreliable owing to frequent environmental false alarms (Firdhous, 2021). Conversely, camera-trap deep learning perimeters require high edge-computing power or introduce substantial transmission latencies when streaming raw video over weak agricultural networks (Chappidi & Sundaram, 2024).

A critical research gap therefore exists for a low-cost, decentralised, pre-contact early warning perimeter that combines rapid localised triggers with low-overhead, cloud-hosted visual verification. This study aims to bridge this gap through three aligned objectives: first, to design and implement a decentralised multi-node ESP32 and ESP32-CAM network synchronised via the lightweight Message Queuing Telemetry Transport (MQTT) protocol; second, to develop a cloud-hosted visual verification pipeline using the Claude Haiku application programming interface (API) with a 75.0% confidence threshold to eliminate false alarms; and third, to evaluate the end-to-end trigger-to-alert response latency and multi-species selectivity under realistic field conditions.

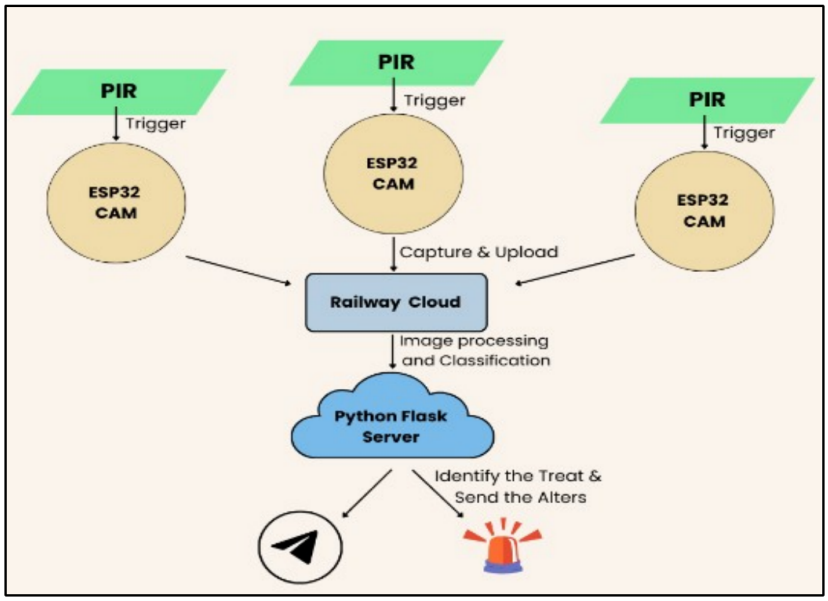
Methodology

To reduce HEC, this research developed an intelligent intrusion detection system operating in three phases: sensing and acquisition, intelligent verification, and active deterrence. The sensing layer establishes a multi-node, decentralised Internet of Things (IoT) framework using ESP32 microcontrollers and ESP32-CAM modules (Rajalashmi et al., 2021). To conserve battery power and minimise bandwidth in remote fields, the camera nodes remain in low-power standby mode rather than streaming continuously.

The primary ESP32 node (Node 1), fitted with a passive infrared (PIR) sensor, is calibrated to a 5 m detection radius over 135°. Upon detecting movement, it wakes from deep sleep to publish an MQTT trigger to Adafruit IO. Once awoken, the secondary ESP32-CAM nodes (Node 2) execute a frame-buffer flushing routine, fire their built-in high-intensity white flash light-emitting diodes (LEDs) to illuminate the perimeter under zero-light conditions (avoiding expensive thermal hardware) and capture a fresh JPEG snapshot. These snapshots are transmitted via secure HTTPS chunked transfer encoding over a portable on-site Wi-Fi router to a Railway-hosted Flask server. The overall system framework is shown in Figure 1.

Figure 1

System Framework



The server processes the images via the Claude Haiku API to classify the species and filter out environmental noise (Chappidi & Sundaram, 2024). If the visual confidence score exceeds the safety threshold of 75%, the system automatically actuates local relay outputs (sirens and strobe lights) and dispatches real-time Telegram alerts to operators. During network drops, the microcontrollers switch to edge fallback, triggering alarms directly upon PIR detection.

Results and Discussion

The statistical performance and species selectivity of the system were assessed first. System validation over a 3-day trial at the Pinnawala Elephant Orphanage generated 250 independent trigger events, for which ground truth was established through synchronous manual audits. To prevent double-counting of slow-moving animals, a 2-minute hardware cooldown was enforced. As shown in the confusion matrix (Figure 2), the system correctly classified 235 true positives (elephant present) and 15 true negatives (elephant absent), with zero false alarms. The inference confidence scores across the sequential trigger events are shown in Figure 3.

Figure 2

Boundary Validation of the System

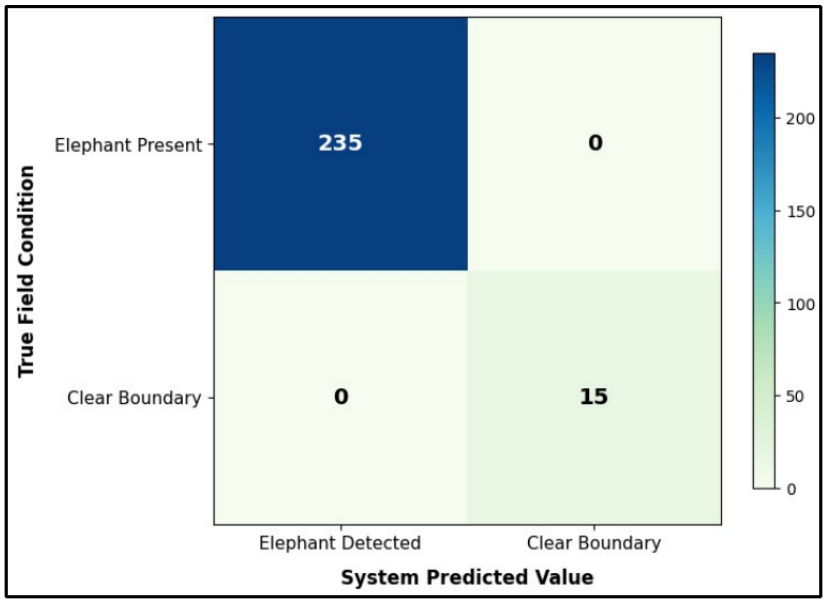
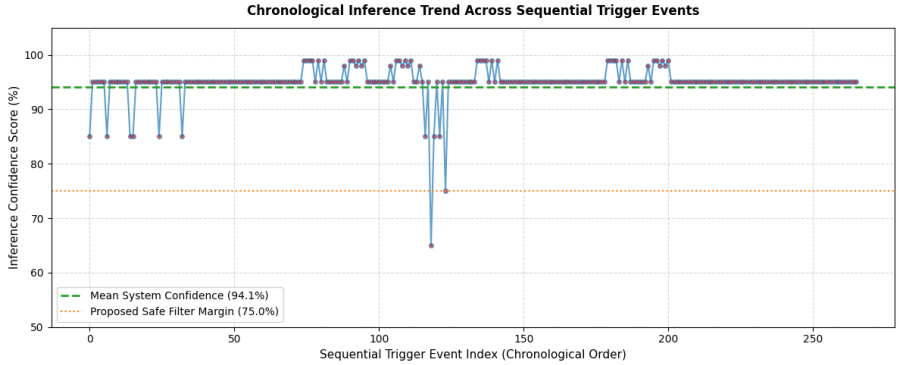


Figure 3

Chronological Inference Trend Across Sequential Trigger Events



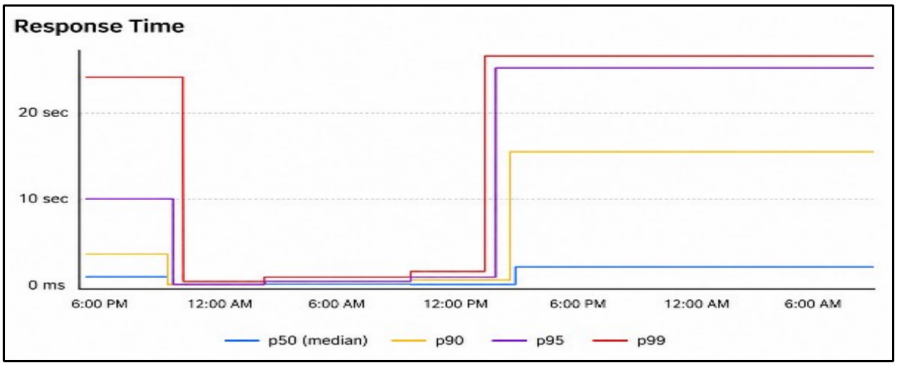
Because the dataset is highly imbalanced, with elephants present in 94.0% of all events, a statistical confidence analysis was conducted. It shows that, while the system's ability to detect elephants is established with high certainty (a confidence margin above 98%), the small number of elephant-absent events (15 trials) gives the confidence margin for avoiding false alarms a wider range (down to 79.6%). This interpretation avoids overclaiming "perfect" performance in unconstrained wild landscapes.

The latency profile and the limitations of the system were then examined. End-to-end response latency averaged 8.40 s. The 36-hour latency distribution (Figure 4) shows that, while typical speeds remained stable, peak-interval spikes exceeded 20 s. These long-tail

delays occurred during simulated rain as a result of cellular network attenuation and Wi-Fi packet retransmissions. Several operational limitations apply: testing was restricted to habituated elephants in cleared understoreys; the spatial radius of the PIR sensor is limited to 5 m; and severe downpours can coat the camera lens, temporarily dropping confidence below 75% and triggering edge fallback.

Figure 4

Server Response Time of Image Uploading



Conclusions and Implications

The proposed framework overcomes the limitations of traditional electric fences by detecting elephant intrusions before physical boundary breaches occur. Combining a decentralised network of PIR sensors and ESP32-CAM microcontrollers with the Claude Haiku API enables rapid, multi-angle visual threat classification, overcoming single-camera limitations such as rear-side view failures.

While the prototype demonstrated high technical feasibility with an 8.15 s median latency, these findings are strictly restricted to the semi-controlled, positively skewed conditions (94.0% elephant-present triggers) at the Pinnawala Elephant Orphanage. The limited number of negative trials mathematically bounds the statistical confidence for false-alarm rejection (down to a 79.6% specificity margin), meaning that perfect detection cannot be generalised to unconstrained wild landscapes.

Consequently, while this proactive safeguard offers considerable benefits to *chena* and paddy farmers in mitigating the socio-economic impacts of HEC, future real-world deployments must upgrade the 5 m PIR sensors to long-range light detection and ranging (LiDAR) or active infrared sensors (25–30 m) and validate the visual model against unhabituated wild herds.

***Keywords*:** Claude Haiku API, early warning system, human–elephant conflict, Internet of Things

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Factors Affecting the Adoption of Commercial and Self-Prepared Poultry Feed: Evidence From Kurunegala District, Sri Lanka

Kumara L.A.K.G., Kuruppu I.V.* and Guruge T.P.S.R.
Department of Agribusiness Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila (NWP) 60170, Sri Lanka
*Corresponding author (email: virajithkuruppu@wyb.ac.lk)

Introduction

Poultry farming is a key component of the agricultural economy of Sri Lanka, supplying affordable animal protein through meat and egg production while supporting feed manufacturing, processing and veterinary services (Perera, 2023; Ravindran & Cyril, 1995). The industry consists of broiler farming, which focuses on rapid growth and feed efficiency, and layer farming, which emphasises nutrition for egg production and shell quality. Farms are categorised as small (<500 birds), medium (500–1,000 birds) and large (>1,000 birds) (De Zoysa et al., 2025).

Feed is the highest operational cost in poultry production (Perera, 2023). Farmers generally use either self-prepared feed (SPF), made from locally available ingredients but often associated with inconsistent nutritional quality, or commercial poultry feed (CPF), which is nutritionally balanced but more expensive (Mathavan et al., 2011). Feed choice is influenced by socio-economic characteristics, farm conditions, economic considerations and institutional support such as extension services and access to credit (Ravindran & Cyril, 1995). Despite the economic importance of feed decisions, empirical evidence on the factors influencing the choice between commercial and self-prepared poultry feed remains limited in Sri Lanka. This study examined the proportion of farmers using CPF and SPF in Bingiriya and identified the socio-economic, farm-specific and economic factors influencing their feed choice.

Methodology

The study was conducted in the Bingiriya Divisional Secretariat Division, Kurunegala District, North Western Province, Sri Lanka. The conceptual framework identified the feed type adopted (CPF = 1, SPF = 0) as the dependent variable, with four categories of independent variables: farmer-related factors (age, gender, education and farming experience), farm characteristics (farm size, bird number, production type and scale), economic factors (feed cost, farm income and expected profitability) and institutional factors (access to credit, extension services, markets and training). Four hypotheses were developed to test the influence of these factors on CPF adoption.

A stratified random sampling technique was used to represent different farm sizes and production types. The population of approximately 627 farmers was divided into small, medium and large farm strata (De Zoysa et al., 2025). Using the Cochran formula at a 95% confidence level and a 5% margin of error, a sample of 240 farmers was selected.

Primary data were collected through structured interviews and four focus group discussions. The questionnaire gathered information on farmer and farm characteristics,

feed adoption status, economic factors, institutional support, perceptions of feed systems and adoption challenges. Hybrid feed users were excluded, resulting in a final sample of 240 farmers. Binary logistic regression (BLR) was applied to identify the determinants of CPF adoption, and odds ratios (ORs) with 95% confidence intervals (CIs) were estimated. Data analysis was conducted using SPSS 26.0.

Results and Discussion

The socio-demographic profile of the respondents (n = 240) comprised 52% male and 48% female participants. The largest group (31%) was aged 51–60 years, and 40% held Advanced Level qualifications. Layer farming was the dominant production system (54%), and most farmers (53%) operated large flocks exceeding 1,001 birds. Monthly income fell most commonly in the range of 50,001–100,000 Sri Lankan rupees (LKR) (44%), and 66% reported poultry farming as their primary income source. Of the sampled farmers, 55.8% adopted SPF and 44.2% adopted CPF. All four Likert-scale constructs demonstrated acceptable internal consistency (Cronbach's α = 0.774–0.828).

Table 1 presents the BLR results. The overall model was statistically significant ($\chi^2(21)$ = 51.966, p < .001; Nagelkerke R^2 = 0.261; Hosmer–Lemeshow p = .931; accuracy = 67.9%). Three variables emerged as statistically significant determinants of CPF adoption. Farming experience was the strongest predictor (p = .001; OR = 1.068; 95% CI [1.027, 1.111]), indicating that each additional year of experience increased the odds of CPF adoption by 6.8%. Feed cost perception was the second significant predictor (p = .002; OR = 1.966; 95% CI [1.277, 3.025]), meaning that farmers who perceived feed cost as a critical decision factor were approximately 1.97 times more likely to adopt CPF. Economic factors (composite Likert score) also significantly influenced adoption (p = .029; OR = 1.814; 95% CI [1.062, 3.099]), with farmers reporting higher concern for income stability and expected profitability being 1.81 times more likely to adopt CPF. This finding aligns with rational economic behaviour theory (Feder et al., 1985): more cost-conscious farmers are more likely to evaluate feed value comprehensively, including productivity outcomes such as weight gain and feed conversion efficiency, ultimately favouring CPF for its superior returns despite its higher unit cost.

Table 1

Binary Logistic Regression Results for Determinants of CPF Adoption

Factor	Variable	Category	p	OR	95% CI for OR	
					Lower	Upper
FF	Age category	<30 years (reference)	–	–	–	–
		31–50 years	.466	1.395	0.570	3.412
		51–60 years	.434	1.399	0.603	3.241
		≥61 years	.707	1.166	0.523	2.599
	Gender	Male (reference)	–	–	–	–
		Female	.344	0.750	0.414	1.360
	Education level	No formal schooling (reference)	–	–	–	–
		Up to O/L	.364	2.738	0.311	24.137
		Up to A/L	.608	1.323	0.455	3.849

Factor	Variable	Category	*p*	OR	95% CI for OR	
					Lower	Upper
		Higher education	.761	0.857	0.317	2.316
		Any other education	.583	1.371	0.445	4.227
	Farming experience	Years (continuous)	.001**	1.068	1.027	1.111
	Farmer factor	Composite score	.356	1.222	0.798	1.871
FC	Production system	Broiler (reference)	–	–	–	–
		Layer	.977	1.014	0.386	2.665
		Both (mixed)	.226	0.567	0.226	1.422
	Flock size	<500 birds (reference)	–	–	–	–
		501–1,000 birds	.155	2.107	0.755	5.883
		>1,001 birds	.629	0.855	0.452	1.616
EF	Monthly income	<25,000 LKR (reference)	–	–	–	–
		25,001–50,000 LKR	.498	0.623	0.159	2.447
		50,001–100,000 LKR	.197	1.806	0.736	4.433
		>100,001 LKR	.854	1.085	0.458	2.568
	Feed cost perception	Average Likert score	.002**	1.966	1.277	3.025
	Economic factors	Average Likert score	.029*	1.814	1.062	3.099
IF	Institutional factors	Average Likert score	.943	1.016	0.658	1.569

Note. *$p < .05$; **$p < .01$. CPF = 1; SPF = 0 (reference). OR = odds ratio; CI = confidence interval; FF = farmer factors; FC = farm characteristics; EF = economic factors; IF = institutional factors; O/L = Ordinary Level; A/L = Advanced Level. Model fit: $\chi^2(21) = 51.966$, $p < .001$; Nagelkerke $R^2 = 0.261$; Hosmer–Lemeshow $p = .931$; overall accuracy = 67.9%.

Importantly, feed cost perception in this study does not measure affordability but rather the degree to which cost considerations drive feed choice. Institutional factors were non-significant ($p = .943$; OR = 1.016), indicating that access to credit, extension services and market linkages did not meaningfully differentiate CPF from SPF adopters. Demographic variables, including gender, age, education level, production system type, flock size, monthly income and income source, were non-significant ($p > .05$). The significance of feed cost perception suggests that farmers consider not only the purchase price of feed but also its expected contribution to production performance.

Conclusions and Implications

This study identified farming experience, feed cost perception and economic factors as the main determinants of CPF adoption among poultry farmers in the Bingiriya Divisional Secretariat Division, Kurunegala District. In contrast, socio-demographic characteristics, production system type, flock size and institutional factors showed no significant influence on feed adoption decisions. The findings provide practical insights for policymakers, extension officers and feed manufacturers. Extension programmes should focus on improving farmers' understanding of feed formulation and cost–benefit evaluation, enabling them to make more informed feed selection decisions. Feed manufacturers should enhance product quality and ensure the availability of nutritionally balanced feed options that meet farmers' production and economic requirements. The study contributes to the literature on agricultural technology adoption by demonstrating that economic considerations and farming experience are the primary drivers of feed

choice among poultry farmers, whereas institutional support remains relatively underutilised.

***Keywords*:** Binary logistic regression, economic factors, feed adoption, poultry farming

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Economic and Crop Losses From Seasonal Flooding on Paddy Yield and Farmers' Livelihoods in Polonnaruwa District, Sri Lanka

Wimalasekra D.R.*, Bandara A.L.J. and Herath H.M.L.K.
Department of Agribusiness Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila (NWP), 60170, Sri Lanka
*Corresponding author (email: dilsharuwandi99@gmail.com)

Introduction

Seasonal floods represent a critical climate-induced threat to global agriculture, accounting for approximately 40% of weather-related crop losses between 2000 and 2023, with South and Southeast Asia bearing the greatest burden (Food and Agriculture Organization, 2025). Sri Lanka faces heightened flood vulnerability. With 34% of agricultural land under paddy cultivation, supporting approximately 1.8 million households, the Maha and Yala planting seasons frequently coincide with heavy rainfall, exposing rice crops to losses of up to 50% due to irrigation overflow. Polonnaruwa District is extremely prone to flooding because of its numerous canals and tank cascades in a low-lying area, and floods occurred there in 2017, 2021 and 2023.

This study therefore quantitatively assesses the effects of seasonal flooding on paddy production and farmers' socioeconomic conditions in Polonnaruwa District using primary data from paddy-farming households. The study examined differences in paddy yield and yield losses between flood-affected and non-flood-affected farmers, assessed the economic consequences of production losses, and evaluated the socioeconomic impacts on farmers' livelihoods. Accordingly, the objectives were to quantify paddy yield losses associated with seasonal flooding in Polonnaruwa District, to assess the economic losses arising from flood-related paddy production losses, and to evaluate the socioeconomic impacts of seasonal flooding on farmers' livelihoods.

Methodology

A mixed-methods research design was adopted. Stratified random sampling was used to select 269 paddy farmers from seven Divisional Secretariat divisions in Polonnaruwa District based on their flood exposure (flood-prone and low flood-prone areas). Data were collected through field surveys, using quantitative information from semi-structured questionnaire items and qualitative responses to three open-ended questions. Primary data were obtained through structured questionnaires administered in face-to-face interviews after the 2024/2025 Maha season harvest. The questionnaire was pre-tested with 15 farmers before administration. Qualitative responses were coded thematically and used to complement the quantitative findings. The survey was conducted using KoboToolbox. Secondary data on paddy production in the Yala and Maha seasons from 1978 to 2025 were obtained from the Department of Census and Statistics.

Three multiple linear regression (MLR) models were estimated to address the study objectives. The first model estimated the contribution of flood characteristics to paddy yield loss, following the analytical approach of Shrestha et al. (2024):

$$\mathrm{PYL}_i = \beta_0 + \beta_1(\mathrm{FOGS}) + \beta_2(\mathrm{FF}) + \beta_3(\mathrm{LA}) + \beta_4(\mathrm{FD}) + \beta_5(\mathrm{FDP}) + \beta_6(\mathrm{FSE}) + \beta_7(\mathrm{IA}) + \beta_8(\mathrm{FE}) + \beta_9(\mathrm{PV}) + \beta_{10}(\mathrm{LO}) + \varepsilon$$

where PYL is paddy yield loss (kg/ha), FOGS is flood occurrence in the growing stage, FF is flood frequency, LA is land area, FD is flood duration in days, FDP is flood depth, FSE is flood spatial extent, IA is irrigation access/source, FE is farming experience (years), PV is paddy variety type, LO is land ownership status and ε is the error term. The second model examined the effect of paddy yield loss and flood characteristics on the total economic losses faced by farmers:

$$\mathrm{EL}_i = \beta_0 + \beta_1(\mathrm{FF}) + \beta_2(\mathrm{FD}) + \beta_3(\mathrm{FDP}) + \beta_4(\mathrm{FSE}) + \beta_5(\mathrm{LO}) + \beta_6(\mathrm{EDU}) + \beta_7(\mathrm{FE}) + \beta_8(\mathrm{LA}) + \beta_9(\mathrm{IL}) + \beta_{10}(\mathrm{IA}) + \beta_{11}(\mathrm{PYL}) + \varepsilon$$

where EL is total economic loss (LKR), EDU is the education level of the farmer and IL is income level. The third MLR model examined the influence of flood-related variables and farmers' socioeconomic characteristics on the Socioeconomic Impact Index (SII), which was constructed to capture the overall effect of seasonal flooding on farmers' livelihoods and used as the dependent variable. The SII comprised four items measuring effects on household food security, children's education expenses, household debt, and stress/anxiety. Each item was scored from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating a greater perceived socioeconomic impact. Internal consistency was assessed using Cronbach's alpha (α = .881). As no formal construct validation was conducted, the SII is interpreted as perceived socioeconomic impact rather than validated vulnerability. The third model was specified as follows:

$$\mathrm{SII}_i = \beta_0 + \beta_1(\mathrm{FF}) + \beta_2(\mathrm{FD}) + \beta_3(\mathrm{FDP}) + \beta_4(\mathrm{FSE}) + \beta_5(\mathrm{G}) + \beta_6(\mathrm{A}) + \beta_7(\mathrm{EDU}) + \beta_8(\mathrm{THM}) + \beta_9(\mathrm{FE}) + \beta_{10}(\mathrm{IL}) + \beta_{11}(\mathrm{LA}) + \beta_{12}(\mathrm{EL}) + \varepsilon$$

where $\mathrm{SII_i}$ is the Socioeconomic Impact Index, G is gender, A is age and THM is the total number of household members.

For the statistical and qualitative analysis, the 269 farmers initially selected were classified according to their reported flood experience, resulting in 240 flood-experienced and 29 non-flood farmers; the groups were not allocated separately before sampling. Before the group comparisons, the normality of the key variables (actual paddy yield, the SII and household monthly income) was assessed separately for the flood-experienced (n = 240) and non-flood (n = 29) groups using the Shapiro–Wilk test. The Mann–Whitney U test (Wilcoxon rank-sum test) was used as the appropriate nonparametric alternative to compare the two groups. The SII, constructed as the mean score of four sub-indicators on a five-point Likert scale, was also compared at the sub-indicator level to assess the dimensionality of the socioeconomic impacts.

To capture the qualitative aspects of floods, an open-ended question was included in the survey questionnaire to elicit the most challenging situation participants had faced due to seasonal floods. The 269 responses were analysed through thematic analysis using

inductive coding, as suggested by Braun and Clarke (2006), and thematic categories were then developed based on the challenges reported.

All statistical analyses were conducted using RStudio statistical software (Version 4.6.0). Regression assumptions were assessed using residual-versus-fitted plots for linearity and homoscedasticity, Q–Q plots for residual normality, and variance inflation factors for multicollinearity. Reference categories for categorical predictors were specified in the regression models.

Results and Discussion

Turning first to the regression analysis, the predictors in Model 1, as a group, did not significantly explain the variation in yield loss among the sampled farmers. Land area was the only statistically significant predictor ($\beta = 272.79$, $p < .001$). Because the dependent variable was measured in kg/ha, the positive coefficient indicates an association between land area and the yield-loss measure rather than a higher absolute total production loss. The non-significance of the other flood-related variables (e.g., flood occurrence in the growing stage [FOGS]) may reflect variations in flood timing and crop growth stages. For instance, floods during land preparation may cause less crop damage than those during sensitive growth stages (Li et al., 2025; Mahamane, 2026). In some contexts, such as India's Pennar Basin, flood events under specific climatic conditions have been associated with yield benefits due to rapid drainage and reduced submergence duration (Li et al., 2025).

Model 2, examining total economic loss, did not reach statistical significance ($F = 1.651$, $p = .079$, adjusted $R^2 = .032$), with the predictor set explaining only 3.2% of the variance in farmers' total economic losses. However, irrigation source category 3, representing the Mahaweli system, emerged as a statistically significant predictor ($\beta = 30{,}142.2$, $p = .009$). Table 1 summarises the fit statistics for all MLR models.

Table 1 shows that Model 3 was statistically significant ($F = 5.456$, $p < .001$, adjusted $R^2 = .221$), explaining 22.1% of the variance in the SII. Three predictors were statistically significant. Gender was significant, with female-headed households reporting lower socioeconomic vulnerability than male-headed households. All three education categories were significant, with higher education paradoxically associated with a greater perceived impact. Land area was also significant, with larger landholdings associated with lower vulnerability.

Table 1

MLR Model Fit Summary

Model	R^2	Adj. R^2	F	p
1	.086	.032	1.606	.0847
2	.082	.032	1.651	.0794
3	.270	.221	5.456	$< .001^{***}$

Note. MLR = multiple linear regression. $^{***}p < .001$. $^{**}p < .01$. $^{*}p < .05$.

For the comparison between flood-affected and non-flood-affected farmers, the Shapiro–Wilk test was first used to assess the normality of actual paddy yield, the SII and household monthly income for the flood-experienced and non-flood groups. The results indicated significant deviations from normality ($p < .001$); the Mann–Whitney U test was therefore used to compare the two independent groups. The sample included 240 flood-experienced and 29 non-flood farmers, classified by reported flood experience after the initial 269 farmers had been selected. There was no statistically significant difference in actual paddy yield between flood-experienced and non-flood farmers (W = 3,530, p = .900). In contrast, flood-experienced farmers had significantly higher SII scores (W = 5,890.5, $p < .001$), and all four socioeconomic impact indicators also differed significantly between the groups ($p < .001$). Household monthly income did not differ significantly between flood-experienced and non-flood farmers (W = 3,487.5, p = .985). These results are summarised in Table 2.

Table 2

Mann–Whitney U Test Results

Variable	Flood	Non-flood	*U*	*p*
Actual yield	8111	8581	3530	.900
SII	4.30	2.67	5890	< .001***
Household income	5.22	5.10	3487	.985

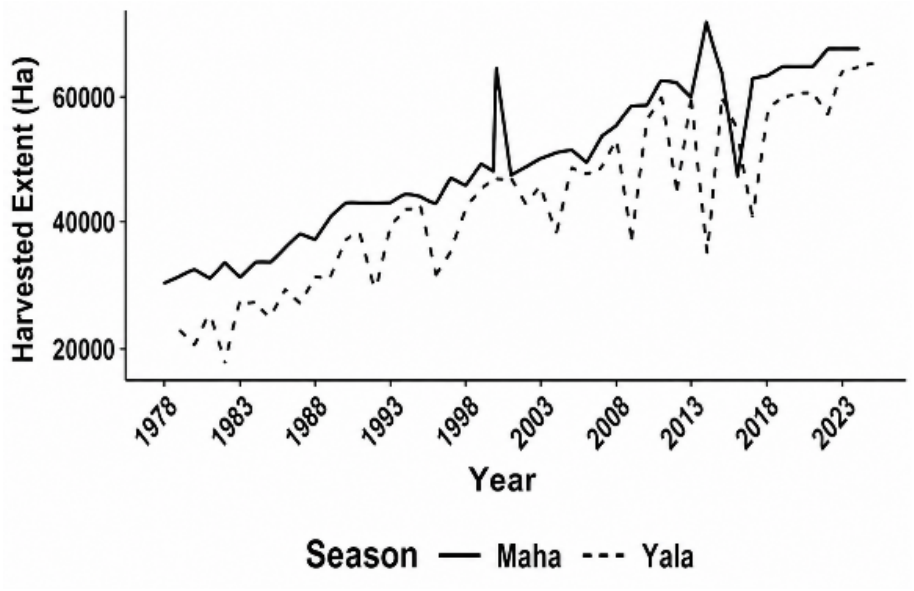
Note. SII = Socioeconomic Impact Index. Flood group n = 240; non-flood group n = 29. ***$p < .001$.

Thematic analysis of the open-ended responses revealed that paddy yield destruction was the most frequently reported challenge (74.3%), followed by waterlogging and field inundation (14.9%) and infrastructure damage (4.8%). Financial losses, soil erosion and input losses were also noted at lower frequencies. The near-universal reporting of flood-related challenges across respondents underscores the pervasive adverse impact of seasonal flooding on paddy farming livelihoods in Polonnaruwa District.

Figure 1 shows the historical trend in paddy harvested extent (ha) in Polonnaruwa District across the Maha and Yala cultivation seasons from 1978 to 2025. Overall, both seasons exhibit a marked long-term upward trend, reflecting the progressive expansion of paddy cultivation in the district over the past four decades. However, periodic fluctuations and notable declines are evident, particularly in the Yala season, coinciding with major flood events in 2017, 2021 and 2023, as well as other climate-related disruptions affecting agricultural productivity (Disaster Management Centre, 2023).

Figure 1

Historical Trend of Harvested Extent in the Polonnaruwa District



Conclusions and Implications

Seasonal flooding poses a considerable challenge to paddy farming livelihoods in Polonnaruwa District. Flood-affected farmers reported mean yield losses of 192.74 kg/ha in the Maha season and 181.67 kg/ha in the Yala season. While the differences in yield and income between flood-affected and non-flood farmers were not significant, flood-affected farmers had higher Socioeconomic Impact Index scores, indicating broader impacts on welfare and food security. Models 1 and 2 did not provide statistically significant evidence that the selected factors influenced yield losses or socioeconomic outcomes. Key factors influencing vulnerability included gender, education and paddy land area. The findings therefore support continued attention to flood-related livelihood risks through improved flood preparedness, resilient agricultural practices and appropriate social protection measures for vulnerable farming households in Polonnaruwa District.

***Keywords*:** Economic loss, livelihood impact, paddy yield loss, Polonnaruwa District, seasonal flood

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Qualitative and Quantitative Assessment of Cellulase Activity in Endophytic Fungi Associated With *Aquilaria crassna*

Navodika K.U.I.S.[1], Wickramasinghe J.A.A.N.[2], Chandrasekera T.V.[2], Withana W.T.G.S.L.[1] and Athapaththu A.M.M.H.[1,*]

[1]*Biotechnology Section, Industrial Technology Institute, 363 Bauddhaloka Mawatha, Colombo 07, Sri Lanka,*

[2]*Business Management School, 591 Galle Road, Colombo 06, Sri Lanka*

*Corresponding author (email: maheshi@iti.lk)

Introduction

Aquilaria crassna (Thymelaeaceae) is a tropical tree valued for producing agarwood, a fragrant resin used in perfumery, incense and traditional medicine. Agarwood forms as a defence response of *Aquilaria* trees to physical injury or microbial infection. Its natural formation is slow and unpredictable, which has led to the development of artificial induction techniques (Tan et al., 2019). Biological induction using endophytic microorganisms has gained attention, as they can stimulate host defence responses and secondary metabolite production similar to the natural process (Bhore et al., 2013). Successful colonisation involves the secretion of extracellular enzymes such as cellulases, which degrade plant cell wall components. Several fungal genera, including *Fusarium*, *Aspergillus* and *Xylaria*, have been associated with agarwood formation. However, few studies have evaluated the functional traits of endophytic fungi relevant to agarwood induction. Assessing cellulase activity may facilitate the selection of promising fungal isolates for biological agarwood induction. Therefore, this study aimed to isolate endophytic fungi associated with *A. crassna* and to evaluate their cellulase activity using qualitative and quantitative assays.

Methodology

This study was conducted at the Biotechnology Section, Industrial Technology Institute (ITI), Colombo 07, Sri Lanka, from August 2025 to January 2026. Blackened resinous wood tissues and agarwood resin samples were collected from *A. crassna* trees previously subjected to agarwood induction treatment in a plantation at Delgoda, Sri Lanka. Samples were surface-sterilised using 10% (v/v) sodium hypochlorite and 70% ethanol, rinsed with sterile distilled water and cultured on potato dextrose agar (PDA) supplemented with tetracycline (10 mg L^{-1}). Plates were incubated at 28 °C until fungal growth was observed. Distinct fungal colonies were purified through successive subculturing on water agar and PDA to obtain axenic cultures.

Cellulase activity was assessed qualitatively on carboxymethyl cellulose (CMC) agar using the Congo red plate assay. Each CMC agar plate was divided into four equal sectors, and a 5 mm diameter mycelial plug of a fungal isolate was inoculated onto the centre of each sector. Plates were incubated at 28 °C for 7 days before being flooded with 0.1% (w/v) Congo red solution for 30 min and subsequently destained with 1 M NaCl to visualise cellulose hydrolysis zones. Cellulase activity was expressed as the hydrolytic index (HI), calculated as follows:

$$\text{Hydrolytic index (HI)} = \frac{\text{Diameter of the hydrolysis zone (cm)}}{\text{Diameter of the colony (cm)}}$$

For the quantitative assay, mycelial plugs from actively growing cultures were inoculated into Czapek–Dox broth supplemented with 1% (w/v) CMC and incubated at 28 °C for 7 days under shaking conditions (150 rpm). Culture supernatants were recovered by centrifugation at 10,000 rpm for 10 min at 4 °C and used as crude extracellular enzyme. Cellulase activity was determined using the 3,5-dinitrosalicylic acid (DNS) reducing sugar assay. Crude enzyme extract (200 µL) was incubated with 1 mL of 1% (w/v) CMC at 45 °C for 30 min. The reaction was terminated by adding DNS reagent and boiling for 5 min. After cooling, absorbance was measured at 540 nm using a UV–visible spectrophotometer. A glucose standard series (0.10–1.00 mg mL^{-1}) was prepared under identical assay conditions to construct a linear calibration curve ($y = 0.8624x + 0.1118$, $R^2 = 0.981$), where y is the absorbance at 540 nm and x is the glucose concentration (mg mL^{-1}). The resulting regression equation was used to determine the glucose-equivalent concentration of reducing sugars released during the enzyme reactions. Cellulase activity was expressed in units per millilitre:

$$\text{Enzymatic activity } \left(\text{U mL}^{-1}\right) = \frac{\mu\text{mol of reducing sugars released}}{\text{Incubation time (min)} \times \text{Enzyme volume (mL)}}$$

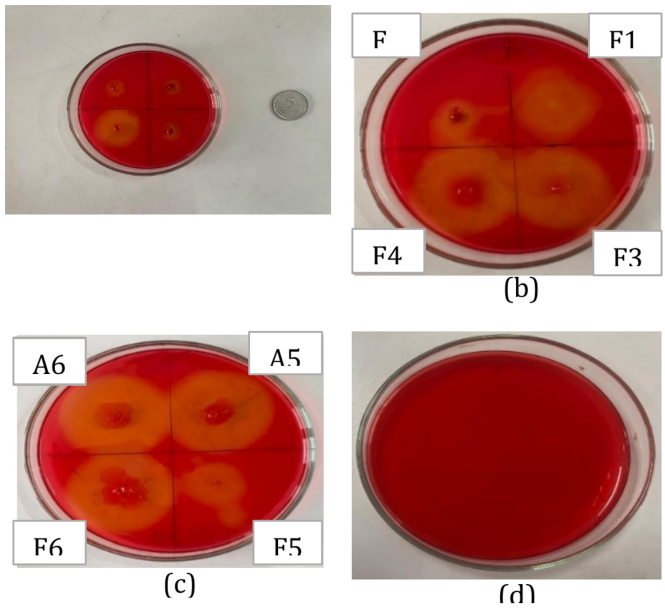
All assays were conducted in triplicate. HI values are presented as mean ± standard deviation (SD). Differences among isolates were evaluated by one-way analysis of variance (ANOVA), followed by Tukey's honestly significant difference (HSD) test at $p < .05$. Data analysis was conducted using IBM SPSS Statistics 26.0.

Results and Discussion

A total of twelve fungal isolates were obtained. Six isolates (A1–A6) were recovered from fully formed agarwood resin, while the remaining six (F1–F6) were isolated from the blackened internal tissues of *A. crassna* trees. The cellulase activity of the isolates was assessed qualitatively using the Congo red plate assay (Figure 1).

Figure 1

Qualitative Assessment of Cellulase Activity on CMC Agar After Congo Red Staining



Note. Clear zones (halos) around colonies indicate cellulose degradation. Panels (2 × 2 grid, left to right, top to bottom): (a) isolates A1–A4; (b) isolates F1–F4; (c) isolates A5, A6, F5 and F6; (d) the negative control plate.

All twelve fungal isolates produced visible, clear hydrolysis zones on CMC agar following Congo red staining, confirming that all isolates were capable of degrading cellulose. The HI varied substantially among the isolates, ranging from 2.00 to 5.80 (Table 1), and isolate A5 exhibited the highest HI. Compared with the lignocellulolytic bacterial isolates evaluated by Fitriasari et al. (2021), which showed a maximum HI value of 2.02, the higher HI values observed in this study suggest greater cellulose-degrading potential among the endophytic fungal isolates. A higher HI suggests greater extracellular enzyme secretion and lateral diffusion through a solid matrix. However, a fast-growing fungus with low enzyme production can yield the same HI as a slow-growing fungus with high enzyme production. Therefore, cellulase activity was further quantified using the DNS assay.

Table 1

Qualitative Cellulase Activity of Endophytic Fungal Isolates Based on the Hydrolytic Index

Fungal isolate	Diameter of hydrolysis zone (cm)	Diameter of fungal colony (cm)	HI (mean ± SD)
A1	1.0	0.5	2.00 ± 0.00^{g}
A2	1.2	0.6	2.00 ± 0.00^{g}
A3	1.4	0.5	2.81 ± 0.02^{f}
A4	2.5	0.5	5.07 ± 0.12^{b}
A5	2.9	0.5	5.80 ± 0.00^{a}
A6	3.0	0.6	5.00 ± 0.17^{bc}
F1	2.4	0.6	4.00 ± 0.00^{d}

Fungal isolate	Diameter of hydrolysis zone (cm)	Diameter of fungal colony (cm)	HI (mean ± SD)
F2	1.3	0.4	3.25 ± 0.00^{e}
F3	3.0	0.6	5.00 ± 0.17^{bc}
F4	2.9	0.9	3.26 ± 0.06^{e}
F5	2.3	0.5	4.67 ± 0.12^{c}
F6	3.2	1.0	3.18 ± 0.27^{e}

Note. HI = hydrolytic index. Means followed by the same letter within the HI column are not significantly different ($p > .05$) based on Tukey's HSD test (HSD = 0.34).

The quantitative assay results varied considerably among the fungal isolates. Isolate A5 exhibited the highest enzyme activity (0.595 U mL^{-1}), followed by F4 (0.472 U mL^{-1}) and A6 (0.463 U mL^{-1}) (Table 2). These findings were consistent with the qualitative assessment, in which A5 recorded the highest HI. Compared with the cellulase activities reported by Sangareswari et al. (2016) for *Aquilaria* endophytes (converted to U mL^{-1}), isolate A5 outperforms several field strains, such as *Fusarium* RFRI5 (0.457 U mL^{-1}) and *Chaetomium* AR15 (0.540 U mL^{-1}). However, its activity is lower than that of their top reference strains, *Aspergillus* AR13 (1.182 U mL^{-1}) and *Aspergillus* K1 (1.141 U mL^{-1}).

Table 2

Quantitative Assessment of Cellulase Activity in Endophytic Fungal Isolates

Fungal isolate	Absorbance against the control	Net glucose concentration (mg mL^{-1})	Glucose released into the medium (µmol)	Enzyme activity (U mL^{-1})
A1	0.162	0.01	0.085	0.014
A2	0.158	0.00	0.028	0.005
A3	0.203	0.05	0.666	0.111
A4	0.188	0.04	0.454	0.076
A5	0.408	0.29	3.571	0.595
A6	0.352	0.23	2.778	0.463
F1	*	*	*	*
F2	0.168	0.01	0.170	0.028
F3	*	*	*	*
F4	0.356	0.23	2.834	0.472
F5	0.298	0.16	2.012	0.335
F6	0.345	0.22	2.679	0.446
Substrate blank	0.156	0.05		

Note. * No quantitative data were obtained for isolates F1 and F3 because no fungal growth was observed in CMC broth under the assay conditions.

According to Tamuli et al. (2008), fungal infection in *Aquilaria* stems can influence the activities of cell wall-degrading enzymes. This may explain the variation in cellulase activity observed among the fungal isolates in the present study.

Conclusions and Implications

This study demonstrated variation in cellulase activity among endophytic fungi associated with *A. crassna*. Isolate A5 exhibited the highest cellulase activity in both the qualitative and quantitative assays. These findings suggest that cellulase activity may serve as a useful preliminary criterion for identifying promising fungal isolates for biological agarwood induction. Future studies should focus on the molecular identification of these isolates and their potential for developing a microbial inoculum.

***Keywords*:** Agarwood induction, carboxymethyl cellulose, endophytic fungi

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Investigation of Natural Radioactivity Distribution at Wahawa Geothermal Field

Navodya T.M.D.[1,*], Harankahawa S.B.[2], Weligepola W.K.G.V.[2], Chathurya K.A.D.D.[1], Wijewardane H.O.[1], Dahanayake U.[1] and Samaranayake S.A.[1]

[1]*Department of Physical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Geological Survey and Mines Bureau, Pitakotte, Sri Lanka*

*Corresponding author (email: navodya.tmd@gmail.com)

Introduction

Geothermal hot springs are significant geological phenomena, yet the exact heat mechanisms driving many of these systems remain a subject of scientific inquiry. In Sri Lanka, the Wahawa geothermal hot springs in Padiyathalawa have been used for generations, but the primary source of their thermal energy remains unclear (Samaranayake et al., 2022). While deep groundwater circulation and tectonic faulting are traditionally considered the primary drivers of such non-volcanic geothermal systems (Dissanayake & Jayasena, 1988), the potential contribution of radiogenic heat has remained largely unexplored in this region. The radioactive decay of naturally occurring uranium (U), thorium (Th) and potassium (K) contributes to crustal heat production, particularly in radioelement-rich rocks such as some granitic and gneissic lithologies (Dentith & Mudge, 2014).

Specific gaps in knowledge exist regarding the localised radiometric profile of the Wahawa field. No prior study has systematically mapped near-surface radiation levels in this region to evaluate their spatial relationship with the thermal discharge locations. Therefore, the primary objective of this study is to investigate the possible contribution of natural radioactivity to the Wahawa hot water system by mapping the spatial distribution of gamma radiation and comparing it with the locations of hot spring discharge. Accordingly, the study evaluates whether a spatial association exists between radioelement enrichment and thermal discharge.

Methodology

The field investigation at the Wahawa geothermal hot springs used a 2 km survey grid to assess the spatial distribution of natural radioactivity around the geothermal field. In situ radiometric measurements were acquired using an RS-125 Super-SPEC gamma-ray spectrometer. This high-precision instrument uses a thallium-activated sodium iodide (NaI(Tl)) crystal detector, a photomultiplier tube and a 1024-channel multichannel analyser to perform pulse height analysis, thereby isolating the characteristic gamma-ray emission peaks (Radiation Solutions Inc., 2006). A dual-mode data acquisition strategy was employed: Survey Mode mapped continuous macroscopic total gamma radiation in counts per minute (cpm), while Assay Mode used longer stabilisation times for precise isotopic discrimination, quantifying localised concentrations of potassium (K, %), equivalent uranium (eU, ppm) and equivalent thorium (eTh, ppm). A total of 485 continuous measurements were collected across the study area with real-time Global Positioning System (GPS) coordinate logging. Following data cleaning and coordinate transformation to the metric Universal Transverse Mercator (UTM) system, geographic

information system (GIS) software was employed for spatial modelling. Inverse distance weighting (IDW) and ordinary kriging interpolation methods were used to transform the discrete field data into continuous spatial distribution maps (Ersoy & Yunsel, 2015). Finally, a spatial overlay analysis was conducted by comparing the interpolated radiometric hotspots with the locations of the thermal discharge points.

Results and Discussion

The radiometric assessment of the Wahawa geothermal field revealed considerable spatial variation in near-surface gamma radiation. The spatial interpolation of the continuous survey data revealed a distinct high-intensity radiation anomaly concentrated in the northern and north-eastern sectors of the 2 km grid. Compared with the background radiation of the surrounding terrain, the core of this primary hotspot exhibited a peak raw gamma activity of 19,201.5 cpm. This distinct anomaly may indicate the presence of a radioelement-enriched lithological or mineralised zone; however, further geological and mineralogical investigations are required to identify its source.

To identify the specific isotopic drivers of this anomaly, the targeted elemental assays were interpolated, and eTh emerged as the dominant radioelement associated with the principal radiometric anomaly. The spatial model for eTh concentration exhibited a pronounced gradient, reaching a maximum of 243.2 ppm within the north-eastern zone.

Both eU and K also exhibited localised enrichment, reaching maximum concentrations of 17.1 ppm and 3.9%, respectively, and their spatial distributions broadly coincided with the wider eTh anomaly. This geographic overlap suggests that the radioelement enrichments may share a common geological control. However, radiometric measurements alone cannot determine whether this control is magmatic, metamorphic or related to secondary mineralisation. The elevated eU, eTh and K concentrations indicate the potential for enhanced radiogenic heat production within the anomalous zone; however, radiogenic heat production should be quantified before its contribution to the geothermal system is evaluated.

The most significant finding of this study emerges when this subsurface radiometric dataset is directly correlated with the region's surface thermal manifestations. Baseline ambient soil temperatures in the surveyed area stabilised at approximately 29.3 °C, whereas a maximum surface temperature of 40.8 °C was recorded near the primary hot spring outlets. The high-temperature zones occur within or close to the radiometric hotspots identified in Figures 1 and 2, and the thermal discharge points are situated within or adjacent to zones of elevated eTh and eU concentrations. This spatial association indicates a possible relationship between the thermal manifestations and the radioelement anomaly. However, spatial association alone does not demonstrate that radiogenic heat is the direct cause of groundwater heating. One possible interpretation is that geological structures control groundwater circulation through or adjacent to radioelement-enriched rocks, although subsurface structural and hydrogeological data are required to confirm this interpretation. Therefore, the results suggest that natural radioactivity may provide a localised contribution to the Wahawa geothermal system; the magnitude of this

contribution relative to deep groundwater circulation and regional geothermal heat remains to be determined.

Figure 1

Interpolated Spatial Distribution of Continuous Survey Radiation

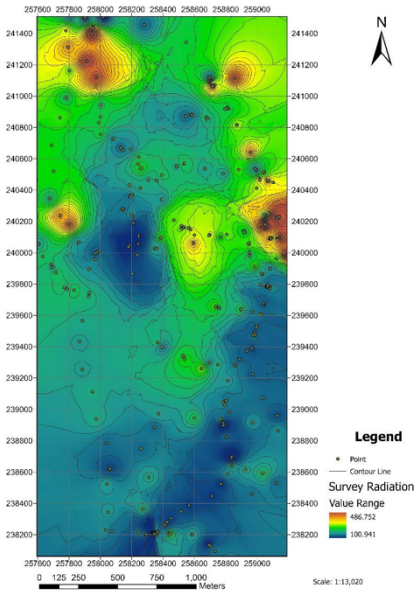
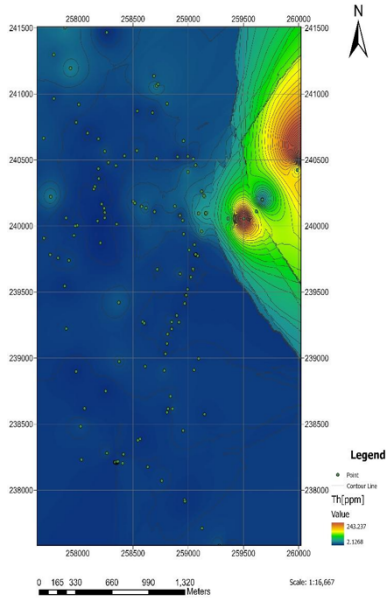


Figure 2

Localised Spatial Concentration of Thorium (ppm)



Conclusions and Implications

This study established a radiometric baseline for the Wahawa geothermal field and identified a pronounced near-surface radioelement anomaly associated with the thermal discharge zone. Gamma-ray spectrometry and GIS-based spatial interpolation revealed a radiometric anomaly characterised by maximum concentrations of 243.23 ppm eTh, 17.08 ppm eU and 3.89% K. A spatial association was observed between the radiometric hotspots and the localised thermal anomaly. The results suggest that local radiogenic heat may be considered an additional component of the geothermal system, together with structurally controlled groundwater circulation. Further subsurface investigations are required to determine whether the radioelement-enriched material extends to sufficient depth and volume to make a significant contribution to the geothermal heat budget. The results also indicate that surface radiometric mapping may provide a useful complementary tool for identifying radioelement-enriched zones during preliminary geothermal investigations. Furthermore, the elevated dose rate recorded within the radiometric hotspot warrants further environmental radiological assessment to determine its potential implications for long-term human exposure.

Because the present gamma-ray measurements predominantly characterise near-surface radioelement distributions, the vertical continuity and extent of the radiometric anomaly at depth remain unresolved. To resolve fully the three-dimensional geometry and mechanics of the Wahawa field, future research must progress to subsurface exploration. Key recommendations include combining this radiometric baseline with deep-penetrating geophysical imaging, such as magnetotellurics or electrical resistivity tomography, to map vertical fault structures, and conducting targeted subsurface sampling or core drilling to characterise the radioelement-enriched lithology directly and quantify its radiogenic heat production.

Keywords**:** Gamma-ray spectrometry, geothermal systems, natural radioactivity, radiometric mapping, Wahawa hot springs

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Physicochemical Characterisation of Honey Produced by Different Bee Species in Sri Lanka

Wijesinghe T.[1], Karunanayake C.[2], Perera N.[1], Daulagala H.[2] and Perera A.[1,*]
[1]*Department of Botany, University of Peradeniya, Peradeniya, Sri Lanka,* [2]*Department of Botany, Open University of Sri Lanka, Nawala, Sri Lanka*
*Corresponding author (email: anomap@sci.pdn.ac.lk)

Introduction

Bee honey is an important natural food product with increasing global commercial demand and well-documented medicinal properties (Bartkiene et al., 2019; Viuda-Martos et al., 2008). Sri Lanka is home to nearly 149 bee species, of which three, *Apis cerana* (Asian hive honey bee), *Apis dorsata* (giant honey bee) and *Apis florea* (dwarf honey bee), are recognised as true honey bees (Punchihewa, 1994). In addition, three stingless bee species, namely *Tetragonula iridipennis*, *Tetragonula praeterita* and *Lisotrigona cacciae*, have been reported in Sri Lanka (Silva et al., 2018). Honey produced by *Apis cerana* is widely consumed and commercially available in Sri Lanka; however, it is often adulterated with honey from *Apis dorsata* or with sugar syrups. Comprehensive physicochemical characterisation of honey produced by different bee species of known origin is therefore essential for establishing baseline quality standards, verifying product authenticity, and supporting the sustainable development and commercialisation of the local honey industry.

Few studies have investigated the physicochemical characteristics of honey produced by different bee species in Sri Lanka. Tennakoon et al. (2023) evaluated selected physicochemical parameters, including pH, colour, electrical conductivity, free acidity, water content and hydroxymethylfurfural content, in 14 honey samples collected only from *Apis cerana* and *Apis dorsata*. Their findings indicated that the two honey types exhibited similar physicochemical characteristics for all examined parameters except water content. This study therefore aimed to characterise five honey types (honey of *Apis cerana*, *Apis dorsata*, *Apis florea*, *Tetragonula* spp. and the tear-drinking bee *Lisotrigona cacciae*) based on their physicochemical properties. In addition, the study sought to differentiate adulterated from unadulterated *Mee pæni* (*Apis cerana* honey) using physicochemical characteristics.

Methodology

A total of 42 honey samples were collected from different regions of Sri Lanka (Kandy, Dambulla, Theldeniya, Polonnaruwa, Mannar, Kotiyagala, Ritigala, Kantale, Matara, Welimada, Sinharaja, Udkiruwa and Monaragala) for physicochemical analysis. These comprised 11 *Mee pæni* samples obtained directly from bee hives or from highly trustworthy persons, 19 honey samples of *Apis cerana* purchased from shops and roadside vendors, three honey samples of *Apis dorsata*, two honey samples of *Apis florea*, one honey sample of *Lisotrigona cacciae* and six honey samples of *Tetragonula* spp.

All samples were filtered to remove debris and other extraneous materials before analysis. One gram of each honey sample was used for the determination of physicochemical

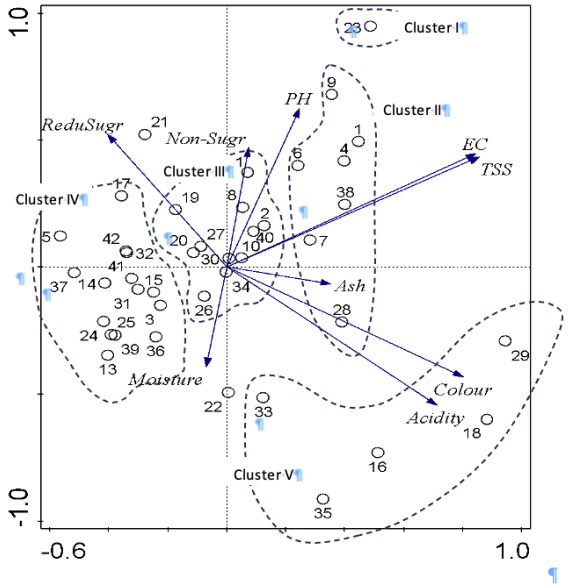
parameters, with all analyses performed in triplicate. The parameters evaluated included pH, electrical conductivity (EC), total soluble solids (TSS), acidity, colour and sugar composition (reducing sugars, non-reducing sugars and total sugars), following standard analytical procedures (AOAC, 2000).

Results and Discussion

Principal component analysis (PCA) ordination of the 42 honey samples revealed five distinct clusters. The first two principal components explained 54.11% of the total variation in physicochemical characteristics, with PC1 and PC2 accounting for 32.85% and 21.26% of the variation, respectively (Figure 1). Two honey samples of *Apis cerana*, one with an exceptionally high sugar content (Sample No. 21) and another with an unusually high moisture content (Sample No. 22), were identified as outliers and excluded from subsequent analyses and interpretation.

Figure 1

PCA Ordination Plot Showing the Distribution of 42 Honey Samples and the Clustering Pattern Based on Eight Physicochemical Parameters



Significant differences among clusters were observed for pH, EC, TSS, acidity and colour ($p < .05$). The honey sample produced by *Lisotrigona cacciae* (Sample No. 23; Cluster I in Figure 1) was clearly separated from all other honey samples, indicating its distinct physicochemical characteristics. With the exception of Sample No. 38, all *Kaneyya pæni* (*Tetragonula* spp. honey) samples (Sample Nos. 16, 18, 29, 33 and 35; Cluster V in Figure 1) formed a distinct cluster separate from the other honey types. These samples were characterised by significantly higher acidity ($p = .011$) and darker colour intensity (very dark to blackish amber; $p < .001$). In contrast, the honey samples of *Apis cerana* were distributed among three principal clusters (Clusters II, III and IV), with EC and TSS

contributing strongly to their separation. No significant differences were observed among clusters for reducing sugars, non-reducing sugars, total sugars, moisture content or ash content ($p > .05$). Six honey samples of *Apis cerana* grouped within Cluster I were collected directly from bee hives and were characterised by significantly higher EC and TSS values ($p < .001$) than the other honey samples. Interestingly, one honey sample of *Tetragonula* spp. (Sample No. 38) was grouped within this cluster rather than with the other *Kaneyya pæni* samples. This unusual placement may indicate possible adulteration of the sample with high-quality honey of *Apis cerana*, resulting in physicochemical characteristics similar to those of authentic *Apis cerana* honey.

Most honey samples purchased from roadside vendors and retail shops were clustered within Cluster III. This cluster was characterised by significantly lower EC and TSS than the other clusters ($p < .001$). The honey sample obtained from captive, sugar syrup-fed *Apis cerana* colonies (Sample No. 17), which exhibited a markedly higher sugar content, as well as all three honey samples of *Apis dorsata*, were also included in this cluster. The clustering pattern suggests possible adulteration of some commercially available *Mee pæni* samples with sugar syrup and/or *Bambara pæni* (*Apis dorsata* honey). However, this hypothesis requires further verification through complementary analyses, including antioxidant profiling, pollen density assessment and melissopalynological (pollen composition) analysis.

Conclusions and Implications

This study demonstrates clear physicochemical variability among honey types produced by different bee species in Sri Lanka. Stingless bee honey (*Tetragonula* spp. and *Lisotrigona cacciae*) shows strong separation from *Apis cerana*-derived honey and other honey types, primarily due to differences in acidity, electrical conductivity and total soluble solids. Commercially available honey samples of *Apis cerana* showed considerable heterogeneity, with some clustering closely with *Apis dorsata* honey, honey from sugar-fed *A. cerana* colonies or non-authentic samples, indicating possible adulteration or mixing with sugar syrups or other honey sources.

Keywords**:** Adulteration, *Apis dorsata*, bee honey, *Lisotrigona cacciae*, physicochemical characteristics

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Determination of Crude Total Polyphenols From Sri Lankan Marine *Sargassum ilicifolium* Using Folin–Ciocalteu Assay

Fernando H.*
Faculty of Medicine, University of Kelaniya, Sri Lanka
*Corresponding author (email: fernandoeranga@yahoo.com)

Introduction

Sargassum species are prominent marine macroalgae known to possess multiple bioactivities. Extracts of *Sargassum* display strong antioxidant activity associated with their high phenolic and flavonoid content (Tsou et al., 2022). However, the phenolic composition of *Sargassum* can vary among species and geographical populations owing to differences in environmental and physiological conditions. Although *Sargassum* spp. have been investigated in Sri Lankan coastal waters and the total polyphenol content (TPC) of the species has been reported from other geographical regions, quantitative information on the TPC of *S. ilicifolium* specifically from the Bathigama algal bed on the southern coast of Sri Lanka remains limited. The objective of this study is to address this knowledge gap by quantifying the TPC of *S. ilicifolium* using the Folin–Ciocalteu assay.

Methodology

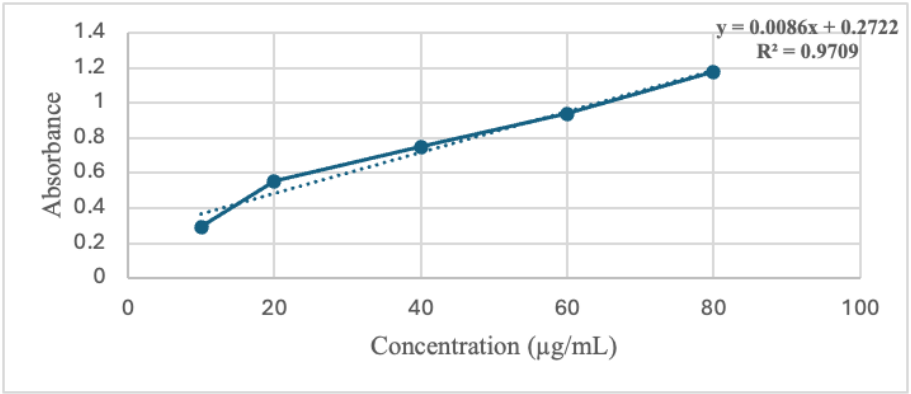
A crude aqueous extract of *S. ilicifolium* (1 mg/mL) was prepared. Total polyphenols were measured by a 96-well Folin–Ciocalteu microplate assay. A 7.5% (w/v) Na_2CO_3 solution (7.5 g/100 mL) and gallic acid (GA) standards (0–100 µg/mL) were prepared. Sample or standard (20 µL) was mixed with 100 µL of the diluted Folin–Ciocalteu reagent, and 80 µL of Na_2CO_3 was added, in triplicate. Absorbance was measured at 765 nm. Total polyphenol content was calculated from the standard curve, accounting for the sample dilution factor, and expressed as mg gallic acid equivalents (GAE)/g extract. Independent biological and technical triplicates were performed.

Results and Discussion

A linear GA standard curve was obtained ($R^2 = .97$; $y = 0.0086x + 0.2722$; Figure 1). The *S. ilicifolium* extract gave a blank-corrected absorbance of 0.328; considering the dilution factor, this yielded a TPC of 65.12 ± 0.014 mg GAE/g of dry extract. This value, obtained from the native species, greatly exceeds previously reported values for *S. ilicifolium*: according to Arguelles (2021), *S. ilicifolium* yielded 4.86 ± 0.07 mg GAE/g. However, differences in geographical origin, sample characteristics and extraction procedures may contribute to variation between studies.

Figure 1

Gallic Acid Standard Calibration Curve Generated Using the Folin–Ciocalteu Assay



Note. Total polyphenol content was determined using the Folin–Ciocalteu colorimetric method. Gallic acid was used as the reference standard, and sample phenolic concentrations were interpolated from the calibration equation ($y = 0.0086x + 0.2722$).

Comparative studies demonstrate substantial variation in phenolic content among *Sargassum* species and populations. For example, a recent study of seven Sargassaceae species collected in India, including *S. ilicifolium*, *S. wightii*, *S. tenerrimum* and *S. plagiophyllum*, reported TPC values ranging from 76.76 to 143.56 mg GAE/g in polyphenolic extracts (George et al., 2026). Similarly, *S. polycystum* collected from the South China Sea showed considerable variation in TPC depending on the extraction solvent, with 70% acetone yielding 91.54 ± 2.03 mg GAE/100 g dry weight (Wu et al., 2022). These findings highlight the influence of species, geographical origin and extraction conditions on the measured TPC and support the importance of characterising the phenolic content of specific *Sargassum* populations under defined extraction conditions.

Previous studies have also demonstrated antioxidant activity in *Sargassum* extracts with measurable phenolic content. Arguelles (2021) reported a 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging IC_{50} of 15.78 µg/mL for *S. ilicifolium*, while Kok and Wong (2022) reported DPPH and 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical-scavenging activities of 77.57% and 88.01%, respectively, for *S. polycystum*. These findings provide a biological context for investigating phenolic-rich *Sargassum* extracts for their antioxidant and other bioactivities.

Conclusions and Implications

This study showed that the crude aqueous extract of *S. ilicifolium* has a total polyphenol content of 65.12 mg GAE/g. This preliminary finding establishes a baseline TPC for *S. ilicifolium* from the Bathigama algal bed and supports further investigation of its individual phenolic constituents and antioxidant activity. Future studies incorporating direct antioxidant assays and phenolic profiling are warranted to determine the relationship between the measured TPC and biological activity.

***Keywords*:** Folin–Ciocalteu assay, gallic acid, polyphenols, *Sargassum ilicifolium*, total polyphenolic content

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Investigation of the Photovoltaic Performance of Dye-Sensitised Solar Cells Consisting of Mn-N Co-Doped TiO_2 Photoelectrodes

Silva W.H.H.[1,*], Thotawatthage C.[1] and Jaseetharan T.[2]

[1]*Department of Physical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Department of Physical Sciences, Faculty of Applied Sciences, South Eastern University of Sri Lanka, Sri Lanka*

*Corresponding author (email: harithahimasha9851@gmail.com)

Introduction

A solar cell, or photovoltaic cell, is a device that converts solar energy into electricity through the photovoltaic effect. Solar cells can be categorised into four generations, and dye-sensitised solar cells (DSSCs) belong to the third generation. Compared with conventional silicon solar cells, DSSCs offer ease of fabrication, low cost and eco-friendliness, making them a contemporary technology for converting solar energy into electricity (Dissanayake et al., 2016). A DSSC consists of three parts: the photoanode, the counter electrode and the electrolyte. TiO_2 is the most successful semiconductor material for DSSCs (Rajaramanan et al., 2020). DSSCs operate through four basic steps: light absorption, electron injection, charge transport and dye regeneration. The efficiency of a solar cell is the percentage of incident power that it can convert into electricity. The relaxation of the oxidised dye, recombination processes involving the charge carriers and the wide band gap (3.2 eV) of TiO_2 hinder the performance of DSSCs (Dette et al., 2014). Doping and the selection of efficient sensitising dyes can be used to overcome these drawbacks, and doping TiO_2 is an alternative strategy for enhancing the efficiency of DSSCs (Rajaramanan et al., 2021).

Numerous studies have explored the doping of TiO_2 with transition metals such as Ag, Co, Mn, Zn, Cr, Nb, W, Cu, Y and Sc and investigated their opto-electric properties (Rajaramanan et al., 2020). These studies have shown that properties of TiO_2 such as the band gap energy, band position, Fermi level and d-electron configuration are modulated by doping with transition metal ions. Additionally, doping TiO_2 with non-metals such as N, C, B, S and F has been shown to narrow the band gap and enhance light absorption in the visible spectrum. However, co-doping TiO_2 with both transition metals and non-metals is rare (Rajaramanan et al., 2021). In this research, the efficiency of DSSCs is investigated by co-doping TiO_2 with Mn and N. The elements were selected on the basis of the literature review: both Mn and N have shown better photovoltaic performance when doped separately into TiO_2 (Guo et al., 2011; Ünlü & Özacar, 2020).

Methodology

P25-TiO_2 nanopowder purchased from Evonik; ethanol, HNO_3, $MnCl_2{\cdot}4H_2O$, acetylacetone, Triton X-100, NH_4OH, ethylene carbonate (EC), acetonitrile (ACN), tetrapropylammonium iodide ($Pr_4N^+I^-$) and iodine (I_2) purchased from Sigma-Aldrich; and fluorine-doped tin oxide (FTO)-coated glass substrates, N719 dye and the platinum (Pt)-coated counter electrode purchased from Solaronix were used as the materials.

Initially, 1.0 g of P25-TiO_2 nanopowder was dispersed in 20 mL of ethanol, and the resulting TiO_2 precursor was stirred for 1 hour using a magnetic stirrer. $MnCl_2 \cdot 4H_2O$ (0.0255 g, assay 97%) was dissolved in ethanol, and the prepared Mn^{2+} solution was treated with the TiO_2 precursor. The resulting solution was stirred vigorously for 2 hours and then vacuum-dried at 60 °C. The dried sample was ground well using an agate mortar and pestle. Finally, the product was calcined at 500 °C for 4 hours to obtain Mn-doped TiO_2 nanoparticles.

The nitrogen doping method of Sandamali et al. (2022) was modified to synthesise N-doped TiO_2 and Mn-N co-doped TiO_2. P25-TiO_2 nanopowder (1.0 g) was added to a mixture of 8 mL of NH_4OH and 16 mL of deionised water placed in an ice bath under vigorous stirring. The resulting mixture was stirred for a further 1 hour in the ice bath, dried at 80 °C for 2 hours and ground well using an agate mortar and pestle. The powder was sintered at 450 °C for 4 hours to obtain off-white N-doped TiO_2. To obtain Mn-N co-doped TiO_2 powder, 1.0 g of the prepared Mn-doped TiO_2 was added to a mixture of 8 mL of NH_4OH and 16 mL of deionised water placed in an ice bath under vigorous stirring, and the same procedure as for N-doped TiO_2 was followed.

The electrolyte was prepared by mixing 1.8 mL of EC, 0.5 mL of ACN, 0.3690 g of $Pr_4N^+I^-$ and 0.0300 g of I_2. Then, 0.25 g of each sample (un-doped TiO_2, Mn-doped TiO_2, N-doped TiO_2 and Mn-N co-doped TiO_2) was weighed and transferred to the mortar, 1 mL of 0.1 M HNO_3 was added dropwise, and the mixture was ground well using the pestle, with a drop of Triton X-100 added during grinding. Thereafter, the nanoparticle pastes were coated on the conductive side of cleaned FTO glass by the doctor-blade technique. After sintering, the samples were soaked in a solution of 0.3 M N719 dye. Finally, the DSSCs were assembled by injecting the I^-/I_3^- electrolyte between the dye-coated photoanode and the Pt counter electrode for all individual cells, and each assembled cell was connected to the external circuit using crocodile clips.

Results and Discussion

The fabricated DSSCs were studied for their structural, morphological, optical and electrical properties using various techniques. P25-TiO_2 nanopowder is bright white in colour, whereas N-doped TiO_2, Mn-doped TiO_2 and Mn-N co-doped TiO_2 are off-white, light brown and brown in colour, respectively, after doping.

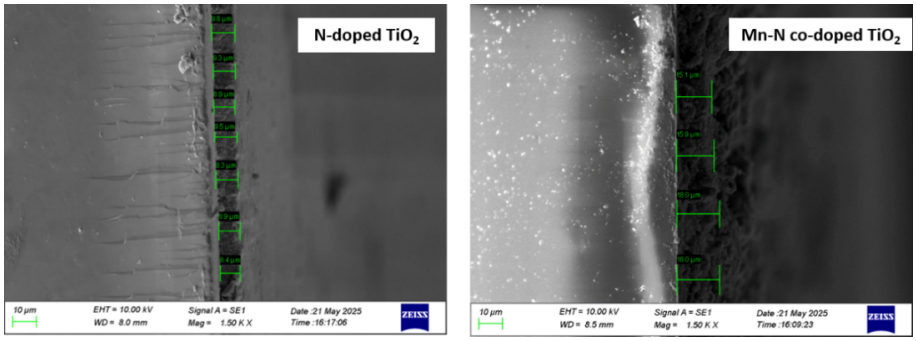
Energy-dispersive X-ray spectroscopy (EDX) was performed to confirm the doping and to quantify the elements in the Mn-N co-doped TiO_2 nanoparticles. It revealed the presence of N, O, Ti and Mn in the sample, with weight percentages of 3.53 wt% N, 33.84 wt% O, 61.78 wt% Ti and 0.86 wt% Mn, and atomic percentages of 6.85 at% N, 57.60 at% O, 35.12 at% Ti and 0.43 at% Mn.

Scanning electron microscopy (SEM) was used to obtain cross-sectional images of the un-doped, N-doped, Mn-doped and Mn-N co-doped TiO_2 photoanodes, and the thickness and uniformity of each thin film were analysed. The average thicknesses of the un-doped, N-doped, Mn-doped and Mn-N co-doped TiO_2 layers are 7.4 µm, 9.1 µm, 24.9 µm and

16.75 µm, respectively. The SEM images of the N-doped TiO_2 and Mn-N co-doped TiO_2 samples are shown in Figure 1.

Figure 1

Cross-Sectional SEM Images of N-Doped TiO_2 and Mn-N Co-Doped TiO_2 Photoanodes



The current density–voltage (J–V) characteristics of the solar cells were used to investigate their performance. The un-doped, N-doped, Mn-doped and Mn-N co-doped TiO_2 photoanodes were tested under simulated illumination (100 mW cm^{-2}, 1 sun) with an air mass 1.5 (AM 1.5) filter. The results are summarised in Table 1.

Table 1

Summary of J–V Characteristics

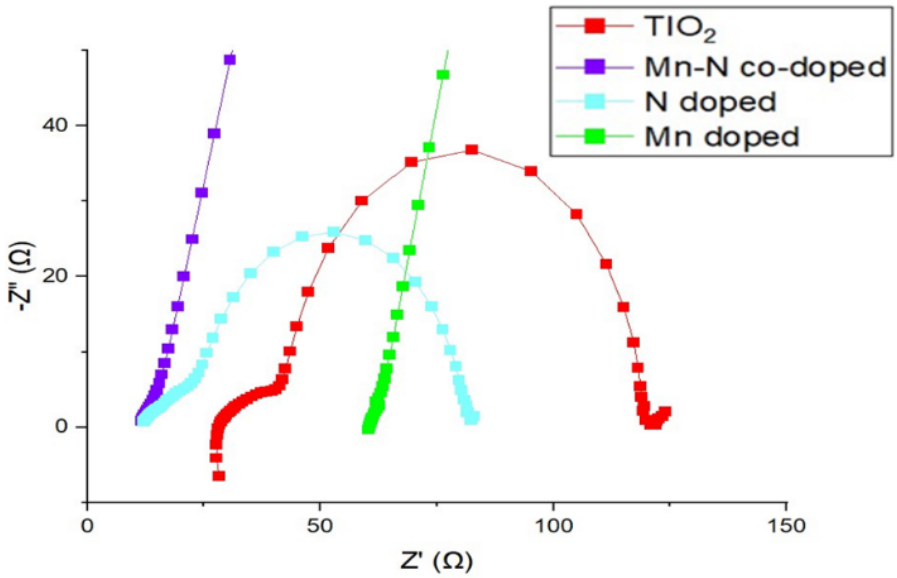
Photoanode	Un-doped TiO_2	N-doped	Mn-doped	Mn-N co-doped
I_{sc} (mA)	1.52	2.12	0.02	0.03
J_{sc} (mA cm^{-2})	6.09	8.47	0.06	0.10
V_{oc} (V)	0.72	0.74	0.58	0.62
Fill factor	0.67	0.68	0.33	0.42
Efficiency (%)	2.93	4.16	0.01	0.03
P_{max} (mW)	0.73	1.04	0.003	0.01
I_{max} (mA)	1.33	1.89	0.008	0.02
V_{max} (V)	0.55	0.55	0.35	0.41

Note. I_{sc} = short-circuit current; J_{sc} = short-circuit current density; V_{oc} = open-circuit voltage; P_{max}, I_{max} and V_{max} = power, current and voltage at the maximum power point.

Electrochemical impedance spectroscopy (EIS) measurements were carried out from 10^{-2} to 512 kHz under 100 mW cm^{-2} illumination using a Metrohm Autolab potentiostat/galvanostat to probe the influence of doping on the interfacial resistance of DSSCs assembled with un-doped, Mn-doped, N-doped and Mn-N co-doped TiO_2 photoanodes. The Nyquist plots of the EIS spectra of the DSSCs are shown in Figure 2.

Figure 2

Nyquist Plots of the EIS Spectra of the DSSCs



The J–V characteristics suggest that co-doping TiO_2 with Mn and N does not enhance efficiency compared with un-doped TiO_2. The results also show no efficiency enhancement for Mn-doped TiO_2 photoelectrodes, which contradicts previous studies that reported efficiency enhancement with Mn-doped TiO_2 (Ünlü & Özacar, 2020). However, the results for N-doped TiO_2 photoanodes align with previous studies (Mousa et al., 2018), showing the greatest efficiency enhancement, with an efficiency of 4.16% under standard simulated illumination with an AM 1.5 filter (100 mW cm^{-2}, 1 sun). The EIS results also align with those of the J–V characterisation. The EDX analysis shows the presence of Mn and N in the co-doped nanoparticles, confirming successful doping. The SEM images suggest a relationship between the uniformity and the thickness of the photoanodes, and higher uniformity and lower thickness of the photoanodes may enhance efficiency; however, further research is required to confirm these relationships. Although the successful incorporation of dopants was confirmed by the characterisation techniques, these findings highlight the complexity of dopant interactions within TiO_2 and indicate that optimisation of the dopant concentration and synthesis conditions is necessary to achieve significant performance improvements. Additional characterisation techniques, such as X-ray diffraction (XRD) and ultraviolet–visible (UV–Vis) spectroscopy, may help clarify the effects of doping and co-doping by investigating the phases of TiO_2, light absorption and variation in the TiO_2 band gap.

Conclusions and Implications

In this research, N-doped TiO_2, Mn-doped TiO_2 and Mn-N co-doped TiO_2 nanoparticles were synthesised using P25-TiO_2 nanopowder and then structurally and electrically characterised. The power conversion efficiencies (PCEs) of the un-doped, N-doped, Mn-

doped and Mn-N co-doped TiO_2 photoanodes are 2.93%, 4.16%, 0.01% and 0.03%, respectively. The results suggest that doping TiO_2 nanoparticles with Mn and co-doping them with Mn and N hinder the PCE of DSSCs, while N-doped TiO_2 shows the highest PCE under standard simulated illumination with an AM 1.5 filter (100 mW cm^{-2}, 1 sun). The presence of Mn and N in the Mn-N co-doped TiO_2 nanoparticles was evident from the EDX analysis, and the uniformity and thickness of the thin films were analysed using SEM images. The EIS measurements showed different charge transport resistances for the doped and co-doped photoanodes, in agreement with the J–V characteristics. Previous studies have shown efficiency enhancement when N and Mn are doped into TiO_2; in this research, N doping agrees with the previous studies, but Mn doping does not. The results suggest a correlation between the uniformity and thickness of the coated layers and the efficiency of the solar cells, with higher thickness and lower uniformity having hindered efficiency. However, further research and additional characterisation techniques are required to understand the observed results and optimise them.

Keywords**:** Co-doping, nanoparticles, photovoltaic, recombination, sintering

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An Incremental Look-Ahead Artificial Bee Colony (ILA-ABC) Algorithm for the Travelling Salesman Problem

Akthar M.N.H.*, Kellar S.S. and Ekanayake E.M.U.S.B.
Department of Physical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: hassanakthar.ntr@gmail.com)

Introduction

The travelling salesman problem (TSP) asks for the minimum-cost Hamiltonian cycle over a set of n cities and is among the most widely studied NP-hard combinatorial optimisation problems (Dantzig et al., 1954). Because the size of the feasible region grows factorially with n, exact methods become impractical for even moderately sized instances, and metaheuristics are routinely used to obtain near-optimal tours within acceptable computational budgets.

The artificial bee colony (ABC) algorithm, introduced by Karaboga for continuous optimisation (Karaboga & Basturk, 2007), is a swarm intelligence method that models the foraging behaviour of a honey bee colony through employed, onlooker and scout bees. Applying ABC to the TSP requires the food source to be redefined as a permutation and the neighbourhood operator to be made discrete. Existing discrete variants achieve this with swap, insertion and inversion operators (Khan & Maiti, 2019; Kiran et al., 2013), with acceptance criteria borrowed from threshold acceptance (Zhong et al., 2017) and, most recently, with fixed-neighbourhood 2-opt refinement of the onlooker and scout phases (Li et al., 2024). Comparable permutation-coded redesigns have been reported for other swarm methods, including the discrete tree-seed algorithm (Cinar et al., 2020) and the bees algorithm with dedicated local search operators (Hamza et al., 2023).

Two limitations recur across these studies. First, each iteration manipulates complete tours of length n, so a single operator application changes a solution that is globally coupled; the resulting search is expensive in objective function evaluations and prone to premature loss of population diversity. Second, the initial population is generated either at random or by a purely greedy nearest-neighbour rule. Random initialisation starts the search far from any structurally sound tour, whereas the nearest-neighbour rule commits to locally cheap edges and systematically defers expensive cities to the end of the tour. In both cases, the quality of the initial feasible solution, which is known to dominate the outcome of population-based methods, is left largely to chance.

This study proposes the incremental look-ahead artificial bee colony (ILA-ABC) algorithm, in which the food source is redefined as a bounded sub-trajectory of length L rather than a complete tour, and the tour is built one committed city at a time under a look-ahead evaluation of the next L candidate moves. The contribution is therefore structural rather than parametric: the bee phases are relocated from the space of complete permutations to the space of partial extensions, and greedy construction is recovered as the special case $L = 1$. The objectives of the study are (i) to formalise the incremental look-ahead reformulation of the ABC phases, (ii) to characterise its per-step

computational cost and (iii) to test, on TSPLIB benchmark instances, whether it yields shorter tours and faster convergence than a randomly initialised standard ABC and other established metaheuristics.

Methodology

The proposed ILA-ABC framework departs from a global exploration model, in which complete tour permutations are manipulated simultaneously, and instead adopts a sequential, constructive multi-stage search process. Traditional discrete ABC architectures are prone to early structural stagnation because they initialise and modify complete candidate Hamiltonian cycles of length n throughout every computational cycle; generating full random or greedy paths from the outset introduces systemic noise and rapidly depletes population diversity. The ILA-ABC framework instead decomposes the large factorial search domain into local candidate configurations evaluated at consecutive time steps, following a nine-step procedure.

In the first step, the problem state is represented. Each artificial agent maintains a dynamic internal state comprising a current terminal-node variable, S_{last}, denoting the vertex at which the salesman is currently positioned, and a live tabu memory set, $V_{visited}$, containing all previously traversed vertices to prevent loop violations. The set of candidate nodes available to the swarm at any given step is dynamically filtered as $U = V \setminus V_{visited}$. In the second step, the food source is redefined as a look-ahead horizon. Rather than representing a static, complete tour vector, each food source is a localised sub-trajectory, $\vec{p}$, spanning a bounded look-ahead horizon of length L, formalised as $\vec{p} = [v_1, v_2, \ldots, v_L]$, where $v_k \in U$; that is, $\vec{p}$ is the expected short sequence of next moves and each v_k is a single node of the next move. A single-step horizon ($L = 1$) reduces to a purely greedy nearest-neighbour rule, which tends to leave costly nodes until the end of the tour, whereas a longer horizon ($L \geq 3$) lets the colony weigh the short-term consequences of each choice before committing to it.

In the third step (employed bee phase), candidate horizons are constructed: working from the current node S_{last}, employed bees generate several candidate horizons $\vec{p}$ from the unvisited pool. Each candidate is then refined using a discrete swap-mutation operator, which reorders the L nodes within the horizon in search of a shorter local path. In the fourth step, each candidate horizon is scored using a fitness value, f_i, defined in Equation (1) as the reciprocal of its total local travel distance, including the initial transition from the current node:

$$f_i = \frac{1}{C(s_{last}, v_1) + \sum_{k=1}^{L-1} C(v_k, v_{k+1})} \qquad (1)$$

In the fifth step (onlooker bee phase), the best direction is selected: the fitness scores are shared with the onlooker bees, which apply roulette-wheel selection, a probabilistic rule that favours higher-fitness (shorter) horizons, to identify the most promising trajectory, $\vec{p}^{*} = [v_1^*, v_2^*, \ldots, v_L^*]$. In the sixth step, the next node is committed and the state is updated. Only the first node of the winning horizon, v_1^*, is permanently locked into the

global tour sequence, and the state variables are then updated such that $S_{last} \leftarrow v_1^*$ and $V_{visited} \leftarrow V_{visited} \cup \{v_1^*\}$. In the seventh step, the look-ahead horizon is cleared, the candidate pool is refiltered against the updated $V_{visited}$, and Steps 2–6 are repeated to select the next node in the tour. In the eighth step, the construction loop continues sequentially until the unvisited subset is exhausted ($U = \emptyset$), at which point the tour closes by returning directly to the original depot node, completing the Hamiltonian cycle. Finally, in the ninth step, this construction-guided procedure was implemented in MATLAB and applied to standard TSPLIB-format benchmark instances; the resulting configuration of experimental parameters is summarised in Table 1.

Results and Discussion

The TSP is one of the liveliest and most interesting problems in operations research, and a number of researchers have dedicated themselves to solving it using various approaches. This study recognises this limitation and proposes a method called ILA-ABC to obtain an initial feasible solution. On the other hand, the PIP-ABC obtains better initial feasible solutions (IFSs) for TSPs with less computational time.

The empirical performance of the ILA-ABC methodology was validated through 30 independent simulation runs on a 12th Gen Intel Core i3 laptop (1.20 GHz, 8 GB RAM) using MATLAB across distinct TSPLIB instances. As shown in Table 1, the ILA-ABC approach achieves the known optimum across multiple benchmarks, matching the target values for berlin52 (7542) and st70 (675), while proving highly resilient on larger instances such as ch130 (6208) compared with standard metaheuristics.

Table 1

Solution Quality Assessment Across Algorithms

Instance	Optimum	ILA-ABC (best)	Standard ABC	GA	ACO	MPSO
berlin52	7542	7542	7621	7598	7604	7548
st70	675	675	685	692	688	679
ch130	6110	6208	6285	6321	6254	6157

Note. ILA-ABC = proposed incremental look-ahead artificial bee colony; ABC = artificial bee colony; GA = genetic algorithm; ACO = ant colony optimisation; MPSO = modified particle swarm optimisation.

The convergence and run-time profiles in Table 2 show a marked reduction in iteration overhead. The ILA-ABC algorithm converges efficiently, reaching its best solution within 450 iterations on average and running significantly faster than the standard genetic algorithm (GA) and ant colony optimisation (ACO) configurations.

Table 2

Convergence and Run-Time Profiles

Algorithm	Average iterations to reach best	Execution time (s)
Standard ABC	1200	4.52
Genetic algorithm (GA)	2500	6.10
Ant colony optimisation (ACO)	950	8.25
ILA-ABC	450	2.15

Note. ILA-ABC = proposed incremental look-ahead artificial bee colony; ABC = artificial bee colony.

Conclusions and Implications

The ILA-ABC framework successfully addresses structural stagnation in swarm optimisation by implementing an incremental path construction technique. By maintaining an active, diverse elite population and delaying final route assignments, the algorithm bypasses localised sub-optimal loops. The practical implications of this model are highly valuable for modern supply chain engineering, as it offers a scalable tracking framework to coordinate complex, real-world fleet routing and distribution operations safely and efficiently. Future research can extend this incremental layout to asymmetric variants and multi-depot routing constraints.

***Keywords*:** Artificial bee colony, combinatorial optimisation, k-nearest neighbours, swarm intelligence, travelling salesman problem

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A Hybrid Artificial Bee Colony Algorithm Incorporating Exact Cycle-Cancelling for Capacitated Transshipment

Kellar S.S.*, Akthar M.N.H. and Ekanayake E.M.U.S.B.
Department of Physical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: hassanakthar.ntr@gmail.com)

Introduction

The transshipment problem is an operations research optimisation problem concerning the movement of goods from multiple sources to multiple destinations via intermediate transshipment nodes. The capacitated transshipment problem (CTP) adds capacity limits on network edges, each indicating the maximum flow that an edge can carry. This variant is highly relevant to logistics and supply chain management, where transshipment facilities must minimise the total transportation and handling cost while respecting capacity limitations. Established solution methods include linear programming, the network simplex method and the stepping-stone method; a modified Vogel's approximation method has also been extended to the transshipment problem.

The artificial bee colony (ABC) algorithm, developed by Karaboga (Karaboga & Basturk, 2007), was inspired by honey bee foraging behaviour, in which employed bees and onlookers exploit routes based on neighbouring information. As a swarm-based technique, the traditional ABC can become trapped in local optima, and because it targets continuous optimisation, it is not directly compatible with the discontinuous constraints of the CTP (supply-node balance, transshipment capacity limits and integer flow requirements). This study addresses that gap with a hybrid algorithm that embeds a deterministic, priority-biased path-construction decoder within the employed–onlooker–scout bee cycle and couples every candidate solution with an exact cycle-cancelling local search. The hybrid is compared with a standard ABC that searches directly over integer arc flows and treats infeasibility through a penalty term, run with the same population size, abandonment limit and penalty constant, and with an exact network simplex solver.

Methodology

The proposed framework models a capacitated transshipment network comprising supply nodes (S), transshipment hubs (H) and demand nodes (D), connected by capacitated arcs with unit cost c_{ij} and capacity u_{ij}. The procedure comprises twelve steps. In Step 1 (problem formalisation), the network is defined as a directed graph with three node subsets: supply, hub and demand. Each arc (i, j) has unit cost c_{ij} and capacity u_{ij}. The goal is a flow $X = \{x_{ij}\}$ that meets all demand, respects the capacities ($0 \leq x_{ij} \leq u_{ij}$) and flow conservation at every hub, and minimises the total cost $\Sigma c_{ij}x_{ij}$.

In Step 2 (bias-vector encoding), each food source is a real-valued vector $\theta \in [0, 2]^A$, with one entry per arc, which biases arc attractiveness during construction rather than encoding a raw flow. This gives the ABC a continuous, searchable parameter space instead of a single one-shot random draw. In Step 3 (decoding to a feasible flow), given θ, the flow is built by successive path construction so that hub-to-hub arcs (e.g. A→B in Example 1)

can be used as well as supply→hub and hub→demand arcs. Each arc is weighted as follows:

$$\text{weight}(i,j) = \frac{\theta_{ij}\left(u_{ij} - x_{ij}\right)}{c_{ij}}$$

While any supply node *s* has unshipped supply, a path is grown from *s*: at each node, the outgoing arcs that still have residual capacity and lead to a node not already on the path are tried in decreasing order of weight, and the search backtracks when a node has no admissible arc, until a demand node with unmet demand is reached. Because a node may not be revisited, every path is loop-free even when hubs are interconnected. The bottleneck quantity, min{remaining supply, unmet demand, smallest residual capacity on the path}, is then pushed along the path and the procedure repeats. Flow is only ever added within residual capacity, so every decoded flow respects arc capacities and conserves flow at every hub; if no further path exists while supply remains, the shortfall is recorded as ψ in Step 5. Setting $\theta = 1$ everywhere reproduces the capacity-weighted inverse-cost rule as a seed.

In Step 4 (cycle-cancelling refinement), the residual graph of the decoded flow is searched for negative-cost cycles, each of which is cancelled by rerouting flow around it until none remain. For linear costs, a cycle-free residual graph certifies global optimality, turning a stochastic construction into a solution with a genuine optimality guarantee. In Step 5 (fitness evaluation), the refined flow is scored as shown below, where ψ is the unmet supply or demand (zero when capacity suffices) and α is a large penalty constant, so that infeasible outcomes are always dominated by feasible ones:

$$\text{Fitness}(\theta) = \frac{1}{1 + \text{cost}(X) + \alpha \cdot \psi(X)}$$

In Step 6 (population initialisation), N food sources $\theta_1, \ldots, \theta_N$ are generated (e.g. all ones plus a small perturbation, bounded in [0, 2]), decoded, cycle-cancelled and scored, and the best becomes the global best. In Step 7 (employed bee phase), for each source θ_i, one random dimension is perturbed as shown below, where $\varphi \sim U(-1, 1)$ and k is a randomly chosen other source. The candidate is decoded, cycle-cancelled and evaluated, and it is kept only if it improves on θ_i; otherwise, the stagnation counter is incremented.

$$\theta'_{ij} = \theta_{ij} + \varphi \cdot \left(\theta_{ij} - \theta_{kj}\right)$$

In Step 8 (onlooker bee phase), the selection probabilities p_i are computed as below, and sources are chosen in proportion to p_i (roulette-wheel selection); the same perturb–decode–cancel–evaluate procedure is applied, biasing the search towards promising regions of the θ-space.

$$p_i = \frac{\text{fitness}_i}{\sum_j \text{fitness}_j}$$

In Step 9 (scout bee phase), any source whose stagnation counter exceeds a fixed limit L is discarded and reinitialised with a fresh random θ, preventing stagnation. In Step 10 (global-best update), the best current source is compared with the stored global best in each iteration, and the lower-cost solution is retained, so the reported solution never regresses. In Step 11 (stopping criterion), Steps 7–10 are repeated until a maximum iteration count T is reached or the global best shows no improvement for a set number of consecutive iterations. Finally, in Step 12 (output), the global-best flow X^* and its total cost are returned as the final solution.

Results and Discussion

The proposed hybrid ABC–cycle-cancelling methodology was implemented in MATLAB and tested on capacitated and uncapacitated transshipment instances of varying network size, hub connectivity and arc-capacity structure. Across every instance, the algorithm converged to a flow whose residual graph contained no negative-cost cycle, which is the formal certificate of global optimality for a linear-cost minimum-cost flow problem (Ahuja et al., 1993). Two representative instances are detailed below: a larger uncapacitated multi-hub network (Example 1) and a smaller capacitated benchmark with tight arc capacities (Example 2).

Example 1 is a multi-hub distribution network in which three supply nodes (S1, S2 and S3) connect to two demand nodes (X and Y) through three interconnected transshipment hubs (A, B and C), giving the decoder a richer set of candidate routes than a strictly layered network. The supply nodes S1, S2 and S3 supply 1,100, 600 and 1,300 units of flow, respectively; the hubs A, B and C are pure transshipment nodes (0 units); and the demand nodes X and Y require 1,800 and 1,200 units, respectively. The hybrid algorithm converged to a certified minimum total cost of 661,000 (population size $N = 20$, iteration budget $T = 100$). Table 1 lists the arcs carrying non-zero flow in the returned optimum; all remaining arcs, including every hub-to-hub connection, carried zero flow.

Table 1

Optimal Flow Routing for Example 1 (Total Cost = 661,000)

Arc	Flow	Maximum capacity	Unit cost	Arc cost
S1 → C	1,100	3,000	40	44,000
S2 → B	600	3,000	40	24,000
S3 → A	1,300	3,000	35	45,500
A → X	600	3,000	210	126,000
A → Y	700	3,000	175	122,500
B → Y	600	3,000	150	90,000
C → X	1,100	3,000	190	209,000

Notably, the optimal solution routes each supply node to a single hub (S1→C, S2→B and S3→A) and uses none of the hub-to-hub arcs, even though the decoder and the cycle-cancelling routine were free to use them. This indicates that the direct single-hub routes already form the least-cost sub-network and that cycle-cancelling correctly left the redundant hub interconnections unused.

Example 2 is a capacitated two-hub network that tests the methodology under binding arc capacities. Two supply nodes (S1 and S2) feed two demand nodes (D1 and D2) through two hubs (H1 and H2), with every arc capacity smaller than the corresponding node's total supply or demand, forcing the flow to split across paths. The supply nodes S1 and S2 supply 50 and 60 units, respectively; the hubs H1 and H2 are pure transshipment nodes (0 units); and the demand nodes D1 and D2 require 70 and 40 units, respectively. The hybrid algorithm converged to a certified minimum total cost of 980. Table 2 lists the resulting optimal flow with the capacity of each arc; several key arcs are saturated at their strict bounds (S1→H1, S2→H2, H1→D2 and H2→D1), demonstrating that the framework performs effectively under constrained topologies.

Table 2

Optimal Flow Routing for Example 2 (Total Cost = 980)

Arc	Flow	Maximum capacity	Unit cost	Arc cost
S1 → H1	30	30	4	120
S1 → H2	20	40	6	120
S2 → H1	30	40	5	150
S2 → H2	30	30	3	90
H1 → D1	30	50	7	210
H1 → D2	30	30	4	120
H2 → D1	40	40	3	120
H2 → D2	10	40	5	50

The method was also benchmarked against an exact solver and a standard ABC. An independent exact network simplex solver, cross-checked with a linear programming solution, returned the identical minimum cost of 980 for Example 2 in under 2 milliseconds, confirming the optimum in Table 2. The standard ABC used in Table 3 follows the employed–onlooker–scout cycle of Karaboga and Basturk (2007) but encodes each food source directly as an integer flow vector within the arc capacity bounds, perturbs one dimension per move as $x_{ij}' = \text{round}[x_{ij} + \varphi(x_{ij} - x_{kj})]$, and handles violated supply, demand or conservation constraints through the same penalty term $\alpha \cdot \psi$ used in Step 5. Both methods used $N = 20$ food sources, an abandonment limit $L = 40$ and $\alpha =$ 1,000, and each was run 30 times with independent random seeds on Example 2; iterations are the completed colony cycles before the global best first equalled 980, with 0 meaning that the optimum was already obtained during initialisation.

Table 3

Iteration Comparison of the Standard ABC and the Hybrid ABC

Instance	Method	Cost found	Iterations (s)
P1 (2 supply, 2 hub, 2 demand)	Standard ABC	141	375
P1 (2 supply, 2 hub, 2 demand)	Hybrid ABC	141	30
Example 2 (capacitated two-hub)	Standard ABC	980	290
Example 2 (capacitated two-hub)	Hybrid ABC	980	25

Note. Example 2; 30 independent runs per method; $N = 20$, $L = 40$, $\alpha = 1{,}000$; 1,000-iteration budget.
†Mean over the 24 standard ABC runs that ended feasible (range 983–1,113); the other six ended with unmet supply or demand.

Under this protocol, the standard ABC did not reach 980 in any of the 30 runs within 1,000 iterations: 24 runs ended with a feasible flow whose cost averaged 1,042.3 (range 983–1,113), and six ended with unmet supply or demand. The hybrid reached 980 in all 30 runs, in every case at initialisation, because decoding the seed $\theta = 1$ yields a feasible flow with a cost of 1,040 and one cycle-cancelling pass reduces it to 980. In an instance this small, the gain therefore comes mainly from the exact local search rather than from the swarm; the swarm components matter when decoding fails to produce a feasible flow or when the cost structure becomes non-linear and cycle-cancelling no longer certifies optimality. Because network simplex is faster still for linear costs, the case for the hybrid rests on that wider setting rather than on speed in the linear case. Casting the optimisation as a continuous, searchable bias space (θ) rather than rigid discrete allocations lets the solver avoid infeasible solutions in most cases, combining metaheuristic flexibility with mathematical precision.

This gain stems from eliminating "blind guessing": a standard swarm algorithm searches directly for flow values x_{ij}, and since x_{ij} must be integer and capacity-bounded, most random adjustments yield illegal networks. The proposed method instead searches a smooth, continuous bias space (θ) in which every position maps, via the decoder, to a valid, capacity-respecting layout. The embedded cycle-cancelling step also acts as an instant local optimisation filter: whereas a standard ABC bee needs many generations for a random mutation to erase an inefficient internal loop (e.g. inventory routed backwards through a hub), the hybrid method immediately reroutes such loops optimally, compressing convergence.

Conclusions and Implications

This study validates a hybrid ABC methodology for the capacitated transshipment problem that integrates a priority-biased decoder with an exact cycle-cancelling local search. Compared with existing frameworks, it provides a verifiable global-optimality certificate, which traditional swarm models lack, and, on the capacitated benchmark tested, it reached the optimum at initialisation, whereas a standard ABC with direct flow encoding did not reach it within 1,000 iterations. The practical implication is a metaheuristic framework that matches the precision of a classical solver on linear problems and offers a basis for extension to non-linear logistics networks, where cycle-cancelling would act as a local improvement step rather than an optimality certificate and linear programming no longer applies directly.

***Keywords*:** Artificial bee colony, capacitated transshipment problem, cycle-cancelling, network optimisation, swarm intelligence

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Green Synthesis of Silver Nanoparticles Using *Azadirachta indica* for the Adsorptive Separation of Syngas

Bandara H.M.H.S., Jayaratna N.B.* and Senevirathne S.A.
Department of Chemical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: naleen@as.rjt.ac.lk)

Introduction

Synthesis gas (syngas) is an important industrial gas mixture that serves as a raw material for the production of fuels and many valuable chemicals, including methanol and ammonia. It is mainly composed of carbon monoxide (CO), hydrogen (H_2) and carbon dioxide (CO_2). Efficient separation of these components is important for improving process efficiency and product quality. Conventional separation methods, such as cryogenic distillation and pressure swing adsorption, are widely used but generally involve high energy input and high operating costs (Zhang et al., 2019). Therefore, the development of more sustainable and energy-efficient approaches to gas separation is of increasing interest.

Among the emerging alternatives, adsorption using nanomaterials has gained considerable attention because nanoparticles provide a large surface area and surface characteristics that can be tailored for specific gas interactions (Rahman et al., 2022). Silver nanoparticles (AgNPs) are of particular interest owing to their high surface reactivity and their ability to interact selectively with certain gas molecules, which makes them promising candidates for adsorption-based gas separation. Furthermore, the use of plant extracts for nanoparticle synthesis offers a simple, environmentally friendly and cost-effective approach, avoiding hazardous chemicals and reducing the environmental impact associated with conventional synthesis methods.

Although the green synthesis of AgNPs using *Azadirachta indica* has been widely reported, comparatively little attention has been given to the interactions of green-synthesised AgNPs with CO and H_2 in the context of syngas-related applications. Therefore, this study investigates the preliminary interactions of CO and H_2 with green-synthesised AgNPs and compares their relative gas–surface interactions using spectroscopic characterisation. The findings provide preliminary insight into the preferential interaction of CO with AgNPs and establish a basis for further investigation of their potential in syngas separation.

Methodology

The AgNPs were first synthesised from a neem leaf extract. Fresh *Azadirachta indica* (neem) leaves (40 g) were heated in 200 mL of distilled water at 60–70 °C for 45 min to prepare the plant extract. AgNPs were synthesised by mixing the plant extract with 10 mM silver nitrate solution at a 1:4 ratio and shaking at 120 rpm for 4 h (Tripathy et al., 2010). The synthesised nanoparticles were purified by centrifugation, washed with distilled water and oven-dried at 50 °C.

For the gas generation and adsorption studies, CO and H_2 were generated separately using formic acid/concentrated sulphuric acid and zinc/dilute hydrochloric acid, respectively. Prior to each experiment, nitrogen (N_2) gas was passed through the entire set-up to purge residual air and moisture and establish an inert atmosphere. The generated gases were dried using a calcium chloride ($CaCl_2$) column before being introduced into the adsorption chamber containing the AgNPs, where exposure took place under the experimental (controlled) pressure conditions at room temperature for 20, 40 and 60 min.

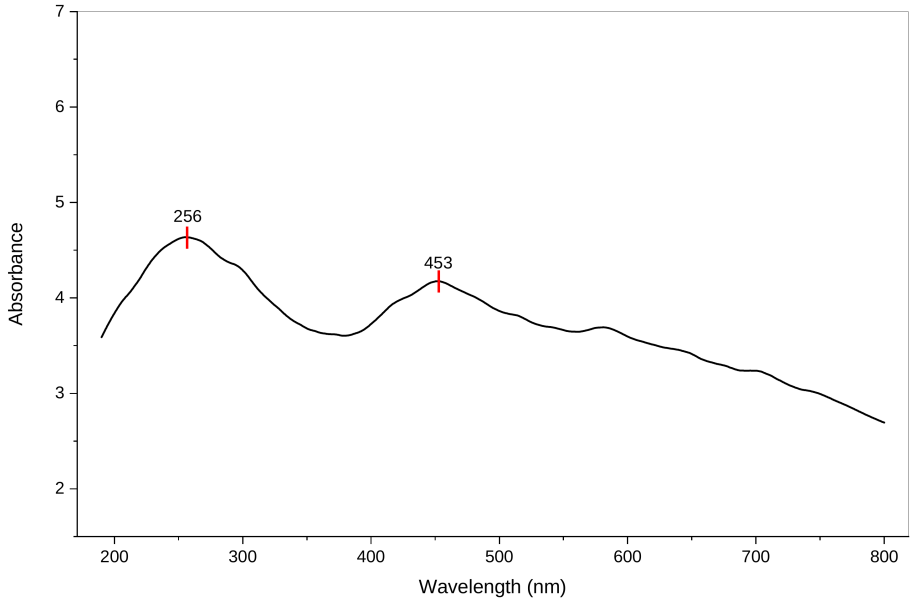
For characterisation and analysis, the synthesised AgNPs were examined by ultraviolet–visible (UV–Vis) spectroscopy (200–800 nm) and Fourier transform infrared (FTIR) spectroscopy to evaluate nanoparticle formation and surface functional groups. FTIR measurements were also performed after CO and H_2 exposure to investigate changes in the surface functional groups and gas–surface interactions.

Results and Discussion

The characterisation results confirmed the formation of AgNPs. Their formation was initially indicated by a colour change from pale yellow to reddish brown and was further supported by the characteristic surface plasmon resonance (SPR) band observed at approximately 430–460 nm in the UV–Vis spectrum (Figure 1). The broad absorption feature suggests the formation of AgNPs with some variation in particle size and possible aggregation.

Figure 1

UV–Visible Absorbance of the AgNP Solution



FTIR analysis of the synthesised AgNPs revealed characteristic absorption bands at 3404 cm^{-1} and 1603 cm^{-1}, corresponding to hydroxyl and carbonyl/amide functional groups, respectively. These observations indicate the presence of neem phytochemicals

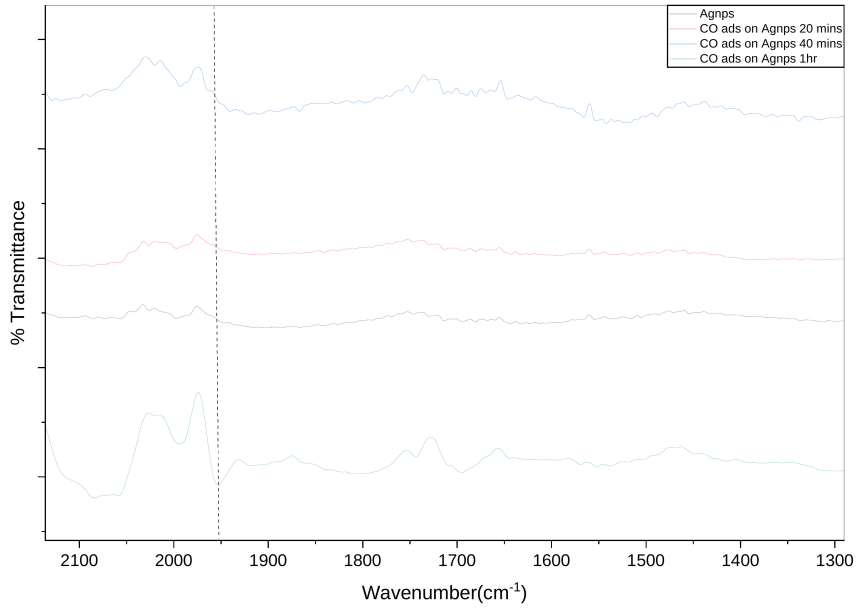
on the nanoparticle surface, suggesting their role as natural reducing and capping agents during the green synthesis of AgNPs. Particle size analysis revealed that the synthesised AgNPs had an average particle size of 44.1 nm, confirming the successful formation of nanoparticles within the nanoscale range.

FTIR analysis was then used to examine gas adsorption on the AgNPs. The FTIR spectra showed time-dependent changes following CO exposure (Figure 2). In particular, a band near 1953 cm^{-1} appeared after 60 min of CO exposure. This band is within the region previously associated with linearly adsorbed CO on silver surfaces, where CO-related bands have been reported in the 1970–2000 cm^{-1} region (Orozco et al., 1998). Therefore, the observed spectral change is consistent with a possible interaction between CO and the AgNP surface.

In comparison, H_2 exposure produced relatively minor spectral changes under the investigated conditions, suggesting a weaker interaction with the AgNP surface than that observed for CO. These results provide preliminary evidence of a preferential CO–AgNP interaction.

Figure 2

FTIR Spectra of Synthesised Silver Nanoparticles Before and After Carbon Monoxide Exposure for 20, 40 and 60 min



Further thermogravimetric analysis (TGA) supported the FTIR findings by indicating surface changes after CO exposure. However, additional TGA studies are required to distinguish CO adsorption from the decomposition of the phytochemical capping agents.

Conclusions and Implications

Green synthesis using *Azadirachta indica* leaf extract successfully produced AgNPs, as supported by UV–Vis and FTIR characterisation. FTIR analysis provided preliminary evidence of a stronger interaction of CO than of H_2 with the AgNP surface under the investigated conditions. The appearance of the FTIR band near 1953 cm^{-1} following CO exposure was consistent with a possible CO–Ag interaction. Further studies involving quantitative adsorption measurements, adsorption isotherms, selectivity analysis, regeneration studies, TGA and complementary surface characterisation are required to evaluate the potential of these green-synthesised AgNPs for future syngas separation applications.

***Keywords*:** Carbon monoxide adsorption, Fourier transform infrared spectroscopy, gas–surface interaction, silver nanoparticles, thermogravimetric analysis

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Digital Socialisation in Consumer Behaviour: A Systematic Literature Review of Theories, Measurements and Consumer Outcomes

Ranjith H.K.M.P.*, Hendeniya H.M.U.S. and Ranjith H.K.D.S.
Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: maduwanthapasidu03@gmail.com)

Introduction

The rapid expansion of digital technologies has profoundly reshaped the nature of human interaction, communication and social bonding. Digital socialisation theory examines the use of digital technologies to investigate how individuals connect and interact with others within social phenomena. According to its classic formulation, socialisation is a process influenced by cultural contexts, digital civilisation and traits shared among all people (Gebremariam et al., 2024). Digital socialisation encompasses the ways in which individuals are influenced by digital technologies in their everyday social interactions (Khatout et al., 2025). In contemporary society, digital socialisation plays a pivotal role in shaping identity development, peer interactions and engagement within digital spaces (Khalid et al., 2025). Consequently, a digital model of socialisation blends with the organic socialisation of a personality through life events, and digital socialisation should therefore be viewed as a characteristic of contemporary socialisation (Kiselev et al., 2022).

In Sri Lanka, there are 12.4 million individual internet users; 92% of internet users possess smartphones, 68% own laptops, 20% own desktop computers, 18% own smartwatches and 17% own tablets (Digital Outlook Sri Lanka, 2025). These tools offer valuable opportunities for maintaining a digital socialisation perspective. Generation Alpha, the future of digital consumerism and digital socialisation require more in-depth investigation in the Sri Lankan context; as the first generation born entirely in the digital age, Generation Alpha children, born from 2010 onwards, are redefining the digital landscape (Digital Outlook Sri Lanka, 2025). Facebook remains the dominant social media platform in Sri Lanka, with 83% of internet users actively engaging on the platform. YouTube follows closely with 77%, while Instagram and TikTok rank third and fourth, with 49% and 42%, respectively (Digital Outlook Sri Lanka, 2025). These platforms thus provide digital spaces in which users can maintain effective digital socialisation perspectives. The central problem that this paper seeks to address is to understand more deeply the digital socialisation phenomenon in terms of the applicable theories, measurements and consumer outcomes, which have not been explored in depth in Sri Lankan and global contexts, and to highlight opportunities for future research in consumer behaviour and digital marketing. Some scholars also point to a lack of work on the development of measures that can be used to assess the digital socialisation construct (Khalid et al., 2025).

Even though the literature on digital socialisation is growing, there is a pressing need for comprehensive tools that can precisely measure this multidimensional construct (Khalid et al., 2025). The originality of this study therefore lies in its design as a systematic literature review rather than an empirical investigation; its contribution lies in

synthesising fragmented knowledge on digital socialisation and identifying its key theoretical foundations, measurement approaches and consumer-related outcomes within a single integrated framework. Moreover, previous scholars emphasise that research on whether online socialisation affects the formation of online social identities remains limited (Avşar Arık & Şahin Kütük, 2022). Although digital platforms and social media have expanded rapidly in Sri Lanka, little empirical evidence exists on how the digital socialisation phenomenon actually functions in this context.

Several theories inform this phenomenon. Networked publics theory explains how individuals manage and display their identities and collaborate with others in an online environment through digital socialisation (Marwick & Boyd, 2014). Social learning theory emphasises that individuals learn behaviours, attitudes and norms through imitation, observation and modelling within the digital context. Social identity theory and social network theory also underscore how online platforms reconfigure patterns of influence, connectivity and social cohesion, allowing individuals to engage with both local and global communities. Investigating digital socialisation is therefore crucial for brands and businesses that adopt a digital-first mindset while ensuring ethical and responsible engagement, so that they are better positioned to connect with these target audiences. In 2026, the impact of digital technologies on digital shopping and consumer behaviour continues to expand, providing businesses with innovative ways to connect with their audiences; the investigation of digital socialisation is thus crucial for businesses and brands.

Methodology

This study is a systematic literature review conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Data were gathered from peer-reviewed journals and studies indexed in scholarly databases. Articles, reports and case studies published between 2015 and March 2026 were included in the review. Following the PRISMA guidelines, four main stages were adopted: identification, screening, eligibility and inclusion. The sources used to gather research articles were Web of Science, Google Scholar, ResearchGate, Emerald, Scopus, Sage, Elsevier and Taylor & Francis. Several search terms related to digital socialisation were used, including “new research avenues in digital socialisation”, “theories and models applicable in digital socialisation”, “challenges faced in digital socialisation”, “untouched areas of digital socialisation”, “digital socialisation in social networking”, “social identity formation in digital socialisation” and “digital socialisation and online community perspectives”. A total of 300 research articles were identified; these studies were critically examined to determine their relevance to the research questions and the inclusion criteria in line with the PRISMA guidelines. After screening, 20 papers were included in the systematic review.

Results and Discussion

This section presents a detailed analysis of the findings under different themes, such as the areas of digital socialisation, the key theoretical discussions and the distribution of

papers across journals. According to past studies, digital socialisation applies to various contexts and is aligned with various variables, such as social networking and adolescents' development (Khalid et al., 2025). Peer influence is another noteworthy factor in digital socialisation, and digital literacy and critical thinking are also aligned with it (Khalid et al., 2025). Digital socialisation can be discussed in relation to social influence, media literacy, digital ethics, digital empathy and spirituality (Khalid et al., 2025). Digital relatedness, which is aligned with digital socialisation, is defined as experiencing connection and care with others in the context of technology use (Latikka et al., 2024). Social capital, digital capital and social bonding constructs also align with the digital socialisation perspective (Moberg et al., 2019). The systematic literature review identified several major theories and models frequently applied to digital socialisation, including social learning theory, media richness theory, networked publics theory, social identity theory, self-determination theory, and uses and gratifications theory. The synthesis also indicates that digital socialisation can be treated as a multidimensional construct influencing communication patterns, identity formation, consumer behaviour and online social relationships.

Turning to the key theories, models and measurement dimensions, the literature reviewed identifies several theoretical perspectives and measurement approaches that contribute to understanding digital socialisation. Khalid et al. (2025) developed and psychometrically validated a 35-item digital socialisation scale, highlighting the importance of the systematic measurement of this construct. Their work addresses the need for a comprehensive measurement approach to examine digital socialisation and its multidimensional nature. Social learning theory provides an important theoretical foundation for understanding digital socialisation (Bandura, 1977); it explains that individuals acquire behaviours, attitudes and social norms through observation and imitation. Similarly, media richness theory, proposed by Daft and Lengel (1986), suggests that communication media differ in their capacity to convey rich information. This perspective provides a basis for understanding how different digital communication channels facilitate interpersonal communication and social interaction.

Furthermore, some scholars have used social cognitive theory and self-determination theory to examine the digital socialisation phenomenon (Niyazova et al., 2026). Eginli and Ozmelek Tas (2018) examined social media-based research through four theoretical perspectives: uses and gratifications theory, information processing theory, the social identity model and social cognitive theory. Network effect theory, discussed by Arroyo (2007), highlights that an increase in connections can provide individuals with greater social capital and other benefits while encouraging information-sharing behaviour. In addition, Makandar (2016) discussed sociological theory, emphasising the importance of interpersonal interactions in the development of self-concept and social identity. Social network theory further explains how online platforms reshape patterns of influence, connectivity and social cohesion, enabling individuals to engage with local and global communities.

Self-determination theory also contributes to understanding the social dimensions of digital socialisation. Ryan and Deci (2017) associated socialisation and relatedness with experiences of care, bonding and connection, identifying relatedness as one of the three basic psychological needs. Similarly, Peters et al. (2018) and Ryan and Deci (2019) discussed how basic psychological needs mediate the relationships between technological experiences and well-being, motivation and meaningful engagement. Zhang et al. (2010) highlighted the significance of social identity in understanding interactions within online communities and noted that online social identity is more common among young people. In terms of measurement, Genner and Süss (2017), Park et al. (2009), Spears et al. (2009) and Van Dijk (2012), following an extensive literature review, identified internet use, internet addiction and social media as three variables widely used to define online socialisation.

Conclusions and Implications

Digital socialisation has fundamentally transformed the nature of social relationships, reshaping how individuals interact, form identities and participate in their communities. Unlike traditional face-to-face socialisation, digital platforms provide unprecedented opportunities for connection across geographic, cultural and social boundaries. From a sociological perspective, digital socialisation does not replace traditional social structures but transforms them, creating hybrid spaces where offline and online interactions intersect. Understanding these dynamics is crucial for assessing the long-term implications of technology for social cohesion, identity formation and community life. Overall, the review indicates that digital socialisation not only transforms interpersonal communication but also creates new opportunities and challenges related to identity construction, social cohesion, digital ethics and consumer engagement in contemporary society.

This systematic literature review has several theoretical, methodological and practical implications. From a theoretical perspective, it demonstrates that digital socialisation is a multidimensional construct that cannot be adequately explained by a single framework; by drawing on theories such as social identity theory, uses and gratifications theory, social learning theory and networked publics theory, a more comprehensive explanation can be provided of how digital environments shape behaviour, identity and user engagement. Methodologically, the current literature shows variation in operational definitions and limited use of longitudinal, qualitative, experimental and mixed-method designs; future research should therefore focus on developing a more robust measurement framework that captures the complexity of digital socialisation across different platforms and user groups. From a practical perspective, the findings suggest that digital socialisation strongly influences consumer behaviour through peer interaction, social influence, electronic word of mouth and online community participation. Understanding their digital habits is essential for brands, educators and policymakers seeking to engage effectively with this emerging demographic (Emiroğlu, 2023). At the same time, ethical

considerations such as digital inequality, privacy concerns and online peer pressure should be addressed more systematically.

***Keywords*:** Digital civilisation, digital market spaces, digital socialisation, PRISMA model, social connections

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The Impact of Gamification on Brand Equity: The Mediating Role of Brand Engagement

Jayasingha J.M.P.M.* and Madhusanka J.D.T.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: paramimadhubhashini1@gmail.com)

Introduction

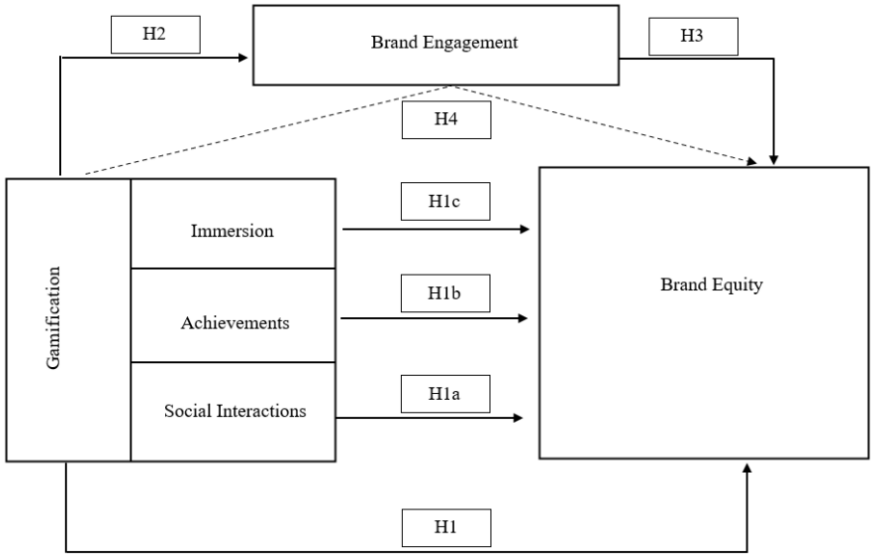
The rapid advancement of digital technologies has transformed online retailing, creating increasingly competitive environments in which retailers require innovative approaches to attract and engage consumers (Grewal & Roggeveen, 2020). Gamification, which integrates game-design elements such as rewards, challenges, achievement systems, and social interaction into non-game contexts, represents a technology-enabled marketing innovation that can enhance consumer participation and digital experiences (Deterding et al., 2011; Hamari et al., 2014). However, the effectiveness of gamification may vary according to the specific features through which consumers interact with online retailers.

This study is theoretically grounded in Self-Determination Theory (SDT) and the Stimulus–Organism–Response (S-O-R) model. SDT explains how gamified features can address consumers' psychological needs, while the S-O-R model explains how gamification stimuli may generate internal engagement and subsequent brand-related responses (Ebrahimi et al., 2024). Existing Sri Lankan research has examined gamification in digital service and e-tailing contexts, particularly regarding customer and brand engagement (Deterding et al., 2011). However, limited evidence has jointly examined the effects of immersion, achievement, and social interaction on brand equity while considering brand engagement as a mediating mechanism.

This study examines these relationships among online retail consumers in the Central Province of Sri Lanka, as set out in the conceptual framework (Figure 1). By identifying dimension-specific effects and the mediating role of brand engagement, the study provides context-specific evidence on how technological innovation can contribute to consumer engagement and brand-related outcomes.

Figure 1

Conceptual Framework



Methodology

A quantitative, deductive, cross-sectional survey design was adopted. The target population comprised online retail consumers in the Kandy, Matale, and Nuwara Eliya districts of the Central Province, Sri Lanka. As no complete sampling frame was available, convenience sampling was employed, and a sample of 384 respondents was determined following Bukhari (2021) for large populations. A total of 405 responses were obtained, of which 384 valid responses were retained. Data were collected during March–May 2026 through a Google Forms questionnaire distributed via WhatsApp and Facebook, with voluntary participation and screening questions confirming online retail experience. The questionnaire was adapted from established scales, including that of Xi and Hamari (2020), and contextualised to online retailing. It comprised 33 items, covering immersion (3), achievement (7), social interaction (3), cognitive engagement (4), emotional engagement (5), social engagement (5), brand awareness (5), and brand loyalty (4), measured on a five-point Likert scale. Cronbach's alpha coefficients ranged from .655 to .920, with most constructs exceeding .70. Kaiser–Meyer–Olkin (KMO) values ranged from .570 to .938, while the overall KMO was .959, and Bartlett's test was significant ($p < .001$). Pearson correlation and simple and multiple regression analyses were conducted using IBM SPSS, while Hayes' PROCESS macro was used to examine mediation through direct, indirect, and total effects using bootstrap confidence intervals.

Results and Discussion

The study analyses 384 valid responses from online retail consumers in the Central Province. The respondent profile indicated that 77.9% were female and 22.1% were male,

while the largest age group was 25–34 years (43.8%). Regarding education, 42.4% held a bachelor's degree. Respondents were distributed across Nuwara Eliya (36.5%), Matale (35.7%), and Kandy (27.9%). Descriptive results indicated generally positive perceptions, with mean values ranging from 3.91 to 4.37 across the study dimensions. Brand awareness recorded the highest mean (M = 4.37), followed by brand loyalty (M = 4.31), while achievement recorded the lowest gamification mean (M = 3.91).

Reliability analysis produced Cronbach's alpha values of .843 for immersion, .920 for achievement, .836 for social interaction, .884 for brand awareness, .853 for brand loyalty, .655 for cognitive engagement, .809 for emotional engagement, and .836 for social engagement. Although the value for cognitive engagement was below .70, the construct was retained in view of the study's exploratory context. Construct adequacy was supported by an overall KMO of .959 and a significant Bartlett's test, $\chi^2(630) = 9349.213$, $p < .001$.

Correlation analysis showed significant positive associations between gamification and brand equity (r = .730) and between gamification and brand engagement (r = .401). Regression results are reported using unstandardised B and standardised β separately: gamification significantly predicted brand equity (B = 0.585, β = .730, R^2 = .533, $p < .001$) and brand engagement (B = 0.260, β = .401, R^2 = .160, $p < .001$). Brand engagement also significantly predicted brand equity (B = 0.545, β = .442, R^2 = .195, $p < .001$). Table 1 summarises the results of hypothesis testing.

Table 1

Results of Hypothesis Testing

Hypothesis	Correlation		Regression			Result
	r	Sig.	*B*	β	Sig.	
H1	0.730	< .001	0.585	0.730	< .001	Supported
H1a	0.697	< .001	0.202	0.279	< .001	Supported
H1b	0.720	< .001	0.331	0.413	< .001	Supported
H1c	0.650	< .001	0.059	0.080	0.237	Not supported
H2	0.401	< .001	0.260	0.401	< .001	Supported
H3	0.442	< .001	0.545	0.442	< .001	Supported
H4	—	—	Indirect effect (0.057)	0.057	BootLLCI = 0.027; BootULCI = 0.093	Supported (partial mediation)

Conclusions and Implications

The findings indicate that gamification has a significant positive relationship with brand equity (β = .730, $p < .001$) and significantly predicts brand engagement (β = .401, $p < .001$). Brand engagement also significantly predicts brand equity (β = .442, $p < .001$). At the dimension level, achievement (B = 0.331, $p < .001$) and social interaction (B = 0.202, $p < .001$) significantly predicted brand equity, whereas immersion was not significant (B = 0.059, p = .237). Furthermore, brand engagement partially mediated the relationship between gamification and brand equity, with an indirect effect of .057 and a bootstrap confidence interval of [.027, .093].

The findings provide theoretical implications for SDT and the S-O-R model. The significant effects of achievement and social interaction suggest that gamified experiences that provide a sense of accomplishment and opportunities for social participation can be relevant to consumers' brand-related responses. The mediating role of brand engagement further supports the S-O-R perspective by indicating that consumers' engagement can function as an internal mechanism through which gamified stimuli are associated with brand equity.

From a practical perspective, online retail firms can emphasise achievement-oriented mechanisms, such as points, badges, rewards, and progress-based challenges, while incorporating social features such as reviews, ratings, referrals, and user-generated content. Since immersion was not statistically significant in this study, firms should interpret its role cautiously rather than assuming that more immersive features will automatically strengthen brand equity.

***Keywords*:** Brand engagement, brand equity, gamification, online retail industry

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Advertising Creativity and Footwear Purchase Intention: The Mediating Role of Attitude Toward Advertising

Perera W.L.A.L.* and Madhusanka J.D.T.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: walpolaliyanageperera@gmail.com)

Introduction

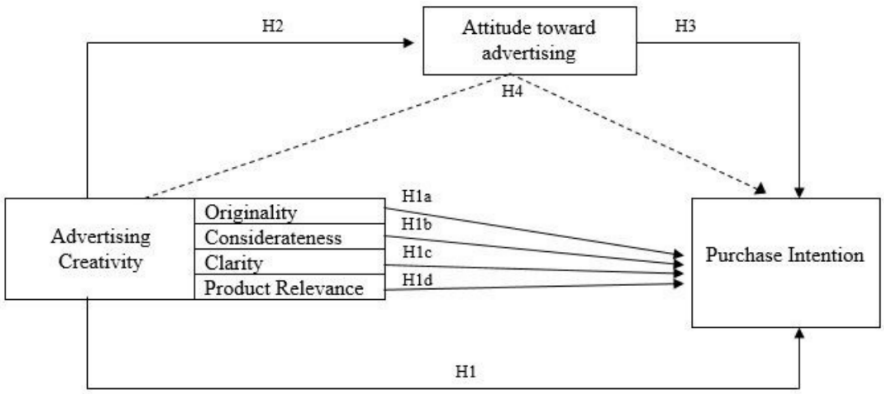
Advertising competes for attention in an increasingly cluttered and digitally mediated environment. Creativity is therefore important when advertisements are both distinctive and meaningful. The divergence–relevance perspective captures this balance, and Kim et al. (2010) operationalised advertising creativity through originality, considerateness, clarity and product relevance. As creative messages are increasingly delivered through digital and technology-enabled channels, the study also relates to contemporary marketing innovation.

Prior research reports positive relationships among advertising creativity, attitude toward advertising and purchase intention (Balroo, 2023; Sarılgan et al., 2022). Sri Lankan studies have examined social media advertising and purchase intention through factors such as informativeness, interactivity, entertainment and creativity (Seelanatha & Abeynayake, 2022; Shafnaz, 2021). However, little evidence jointly examines the four-dimensional advertising creativity construct, attitude toward advertising as a mediator, and purchase intention in the footwear context.

Integrating the divergence–relevance perspective with the stimulus–organism–response (S-O-R) model (Mehrabian & Russell, 1974), this study examines the association between advertising creativity and footwear purchase intention among consumers in Sri Lanka's North Central Province and tests the mediating role of attitude toward advertising. It also examines the separate associations of originality, considerateness, clarity and product relevance with purchase intention. Accordingly, positive associations are hypothesised between creativity and purchase intention (H1), between each of its four dimensions and purchase intention (H1a–H1d), between creativity and attitude (H2) and between attitude and purchase intention (H3), together with mediation through attitude (H4), as shown in the conceptual framework (Figure 1).

Figure 1

Conceptual Framework



Methodology

A quantitative, cross-sectional survey was conducted using a positivist, deductive approach. The target population comprised consumers in Sri Lanka's North Central Province who had recently been exposed to footwear advertising. A target of 384 usable responses was adopted with reference to Krejcie and Morgan (1970) as a benchmark for a large population. Because purposive non-probability sampling was used, the sample was intended to provide adequate data for analysis rather than population representativeness. Respondents were recruited through a Google Forms questionnaire distributed via social media and online networks, with screening questions confirming residence in Anuradhapura or Polonnaruwa District and recent exposure to footwear advertisements.

Advertising creativity was measured using 15 items covering originality (four items), considerateness (four), clarity (four) and product relevance (three), adapted from Kim et al. (2010). Attitude toward advertising and purchase intention were each measured using four items adapted from Balroo (2023). All items used a five-point Likert scale.

Data were analysed using IBM SPSS and PROCESS Model 4. Cronbach's alpha values ranged from .883 to .912. Factorability was supported by the Kaiser–Meyer–Olkin (KMO) measure (.963) and Bartlett's test, $\chi^2(253) = 7{,}013.808$, $p < .001$. Item-level skewness and kurtosis were examined for approximate normality, while tolerance (.429–.534) and variance inflation factor (VIF) values (1.872–2.328) indicated no evident multicollinearity. Pearson correlation, simple and multiple regression, and mediation analysis with 5,000 bootstrap samples and a 95% confidence interval (CI) were applied.

Results and Discussion

All constructs showed strong internal consistency (Cronbach's α = .883–.912). Factorability was supported by an overall KMO of .963 and Bartlett's test, $\chi^2(253) = 7{,}013.808$, $p < .001$; construct-level KMO values ranged from .746 to .855. The mean scores (*SD*s) were as follows: product relevance, 3.969 (.946); attitude toward advertising,

3.948 (.796); considerateness, 3.937 (.887); originality, 3.910 (.938); clarity, 3.907 (.932); and purchase intention, 3.839 (.935).

Pearson correlations were positive for advertising creativity with purchase intention (r = .771, p < .001) and with attitude (r = .757, p < .001), and for attitude with purchase intention (r = .631, p < .001). Each creativity dimension also correlated positively with purchase intention: originality (r = .644), considerateness (r = .688), clarity (r = .649) and product relevance (r = .641; all p < .001). Simple regressions showed that creativity predicted purchase intention (B = .916, β = .771, adjusted R^2 = .593), creativity predicted attitude (B = .765, β = .757, adjusted R^2 = .572) and attitude predicted purchase intention (B = .742, β = .631, adjusted R^2 = .397; all p < .001).

The four creativity dimensions jointly explained 59.5% of the adjusted variance in purchase intention (adjusted R^2 = .595, p < .001). All were significant positive predictors: originality (B = .151, β = .152, p = .002), considerateness (B = .329, β = .313, p < .001), clarity (B = .196, β = .196, p < .001) and product relevance (B = .246, β = .249, p < .001). Considerateness had the strongest unique standardised coefficient, although product relevance had the highest mean; mean ratings reflect overall perceptions, whereas β values compare relative contributions in the combined model.

In PROCESS Model 4, attitude remained positively associated with purchase intention after controlling for creativity (B = .132, p = .025), while the direct association of creativity remained significant (B = .815, p < .001). The indirect effect was .101 (BootSE = .063; 95% bootstrap CI [−.026, .224]); because the interval included zero, H4 was not supported. H1, H1a–H1d, H2 and H3 were supported. These findings are consistent with the divergence–relevance perspective but provide only partial support for the S-O-R pathway: the component associations were significant, but attitude was not established as a mediator. This differs from the mediation findings reported by Sarılgan et al. (2022) and Balroo (2023) and warrants further research in other contexts.

Conclusions and Implications

Advertising creativity was positively associated with footwear purchase intention among consumers in Sri Lanka's North Central Province. All four creativity dimensions were significant in the combined model, with considerateness showing the largest unique standardised association, followed by product relevance, clarity and originality. This supports the divergence–relevance perspective by indicating that effective creative advertising combines novelty with social appropriateness, clarity and meaningful product information.

Advertising creativity was also positively associated with attitude toward advertising, and attitude was positively associated with purchase intention. However, the indirect effect through attitude was not statistically significant; therefore, attitude toward advertising was not supported as a mediator. Accordingly, the findings provide partial support for the S-O-R framework.

In practice, footwear marketers should prioritise considerate and product-relevant advertising while maintaining clarity and originality, and should pre-test campaigns for appropriateness, sincerity, message clarity and product relevance. The findings should be interpreted cautiously because the study was cross-sectional, used purposive sampling, was limited to one province and relied on self-reported purchase intention. Future research should use broader probability samples, longitudinal or experimental designs, actual purchasing behaviour and alternative mediators.

***Keywords*:** Advertising attitude, advertising creativity, footwear industry, purchase intention, Sri Lanka

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Impact of AI Marketing on Purchase Intention: The Mediating Role of Perceived Value

Ududdumbara U.D.A.S.* and Madhusanka J.D.T.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: sewminiashani502@gmail.com)

Introduction

The rapid integration of artificial intelligence (AI) into online retail is a core driver of technological innovation and contemporary digital transformation, fundamentally reshaping consumer engagement with e-commerce platforms globally (Dwivedi et al., 2021; Huang & Rust, 2021). While the stimulus–organism–response (S-O-R) framework is widely applied to understand consumer behaviour in digital environments (Zhang & Benyoucef, 2016), a critical research gap persists: the multidimensional impact of specific AI marketing traits, namely interactivity, accuracy and insight, on perceived utilitarian and hedonic value remains underexplored in emerging South Asian markets (Arachchi & Samarasinghe, 2025; Wickramasinghe et al., 2025).

Unlike mature digital economies, Sri Lanka is an emerging market in which consumer trust in AI personalisation is still forming, digital infrastructure is evolving, and AI adoption patterns differ significantly from those in Western contexts. This study moves beyond mere geographical replication by elucidating the psychological mechanisms through which AI stimuli translate into behavioural responses within a resource-constrained digital ecosystem (Cara, 2023; Myat et al., 2025). Specifically, it investigates how distinct AI dimensions differentially drive value perceptions and, consequently, online purchase intention among Sri Lankan consumers. Therefore, this study aims to examine the impact of AI marketing technology experience on perceived value and online purchase intention, and to investigate the mediating role of perceived value in this relationship.

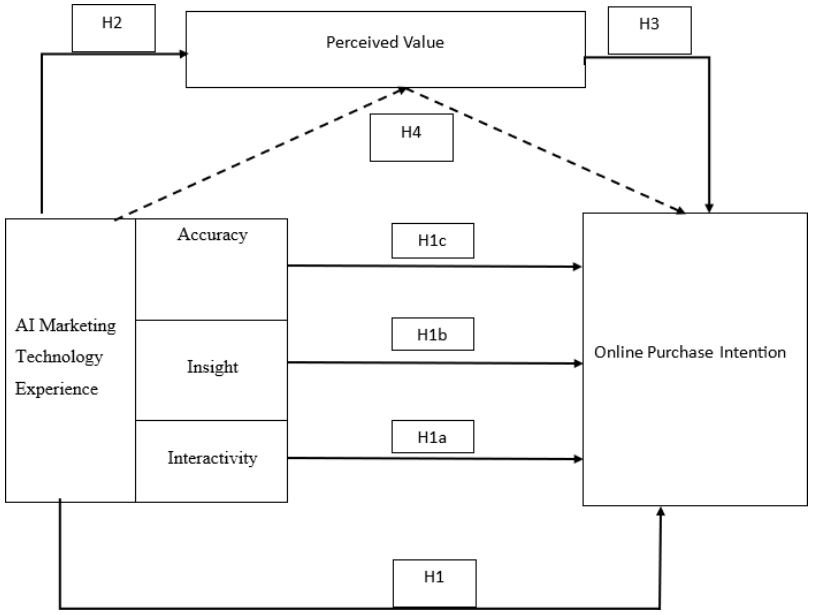
Methodology

This study employed a quantitative, cross-sectional research design based on the S-O-R theoretical framework. The target population consisted of online consumers in Sri Lanka's Western Province who had interacted with AI-enabled e-commerce platforms (e.g. personalised recommendations, chatbots and intelligent search features) within the preceding six months. As a comprehensive sampling frame for this specific consumer group was unavailable, a non-probability convenience sampling method was used. Assuming a 95% confidence level and a 5% margin of error, a sample size of 384 was determined using Cochran's formula for unknown population sizes; this also satisfies the minimum sample size requirement for robust regression-based mediation analysis using bootstrapping techniques (Zhao et al., 2010). Data were collected via a structured online questionnaire distributed through social media platforms and university networks. The inclusion criteria required participants to be (a) residents of the Western Province, (b) aged 18 years or older, (c) active online shoppers and (d) users of at least one AI-enabled e-commerce platform.

Scales measuring AI marketing technology experience (interactivity, accuracy and insight), perceived value (usefulness and enjoyment) and online purchase intention were developed from instruments validated in prior research (Cara, 2023; Yin & Qiu, 2021) and were measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The conceptual framework and the hypothesised relationships (H1–H4) are presented in Figure 1. Data analysis was performed using SPSS version 26 and comprised descriptive statistics, assessments of reliability and validity, and a regression-based mediation analysis using Hayes' PROCESS macro (Model 4).

Figure 1

Conceptual Framework



Results and Discussion

The final sample comprised 384 valid responses. Reliability analysis yielded Cronbach's alpha values ranging from .665 to .851. The insight dimension yielded an alpha of .665; although slightly below the conventional .70 threshold, this is deemed acceptable for exploratory research in emerging contexts, and the dimension was retained to preserve content validity (Taber, 2018). Construct validity was supported by a Kaiser–Meyer–Olkin (KMO) value of .954, a significant Bartlett's test of sphericity ($p < .001$) and factor loadings exceeding the 0.50 threshold for all items, confirming adequate convergent validity.

Regression analysis demonstrated that AI marketing technology experience significantly predicts both perceived value ($R^2 = .832$, $B = 0.901$, $p < .001$) and online purchase intention ($R^2 = .783$, $B = 0.989$, $p < .001$). Among the AI dimensions, interactivity

emerged as the strongest predictor of purchase intention ($B = 0.462$, $p < .001$), followed by insight ($B = 0.334$, $p < .001$) and accuracy ($B = 0.208$, $p < .001$). This aligns with recent findings that responsive AI interactions and positive online shopping experiences drive consumer purchase intention more effectively than search accuracy alone (Myat et al., 2025; Sipos, 2025).

The regression-based mediation analysis using Hayes' PROCESS macro (Model 4) confirmed mediation. The total effect of AI experience on purchase intention was significant ($B = 0.989$, $p < .001$). When perceived value was controlled for, the direct effect remained significant ($B = 0.551$, $p < .001$). Crucially, the indirect effect through perceived value was statistically significant (effect = 0.437, Boot *SE* = 0.078, 95% Boot CI [0.287, 0.590]). Because the confidence interval does not include zero, H4 is supported. These findings align with S-O-R theory, demonstrating that responsive AI interactions act as environmental stimuli that enhance cognitive and affective evaluations, thereby driving behavioural responses. The results of all hypothesis tests are summarised in Table 1.

Table 1

Test Results of Hypotheses

	Correlation			Regression		
Hypothesis	*r*	*p*	Decision	*B*	*p*	Decision
H1	0.885	< .001	Accepted	0.989	< .001	Accepted
H1a	0.771	< .001	Accepted	0.208	< .001	Accepted
H1b	0.815	< .001	Accepted	0.334	< .001	Accepted
H1c	0.844	< .001	Accepted	0.462	< .001	Accepted
H2	0.912	< .001	Accepted	0.901	< .001	Accepted
H3	0.879	< .001	Accepted	0.994	< .001	Accepted
H4	–	–	Accepted	0.437	< .001	Accepted

Note. All seven hypotheses were statistically supported at the $p < .001$ significance level. Regression and mediation analyses confirmed that AI marketing technology experience significantly predicts online purchase intention, with perceived value partially mediating this relationship. Interactivity emerged as the strongest predictor, supporting the proposed S-O-R theoretical framework within Sri Lanka's emerging e-commerce context.

Conclusions and Implications

This study concludes that AI marketing technology experiences significantly predict online purchase intention in Sri Lanka, operating both directly and indirectly through enhanced utilitarian and hedonic value perceptions. Theoretically, this research extends the S-O-R framework by validating the mediating mechanism of multidimensional perceived value in an emerging digital economy, thereby going beyond merely testing an existing model in a new geographical setting. Practically, e-commerce platforms operating in Sri Lanka should prioritise interactive AI features, such as responsive virtual assistants and personalised recommendations, to enhance consumer value perceptions and drive purchase behaviour.

A limitation of this study is its reliance on cross-sectional data and convenience sampling within the Western Province, which restricts causal inference and geographical generalisability. Future research should address this through methodological improvements such as probability sampling techniques, longitudinal designs and geographical expansion to other provinces, in order to establish causal relationships over time. Additionally, future studies should explore other psychological mediators, such as brand trust, perceived risk or technology anxiety, to provide a more comprehensive understanding of AI adoption in emerging markets.

***Keywords*:** AI marketing technology experience, online purchase intention, perceived value

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Impact of Brand Anthropomorphism and Brand Personality on Brand Loyalty among Fast-Food Consumers

Ranasinghe J.A.D.L.* and Madhusanka J.D.T.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: dinusharanasinghe224@gmail.com)

Introduction

The fast-food market has become increasingly competitive as consumers have access to a wide range of brands offering similar products, prices, and levels of convenience. In such an environment, retaining customers cannot depend only on functional attributes; brands also need to establish meaningful relationships with consumers. One approach that has received increasing attention in branding research is brand anthropomorphism, through which consumers attribute human-like characteristics, intentions, emotions, and behaviours to brands (Epley et al., 2007; Portal et al., 2018). When a brand is perceived as having human qualities, consumers may respond to it in ways similar to how they respond to people, creating opportunities for stronger emotional and relational connections.

Brand personality provides another important perspective for understanding these consumer–brand relationships. Aaker (1997) conceptualised brand personality as a set of human characteristics associated with a brand and identified five broad dimensions: sincerity, excitement, competence, sophistication, and ruggedness. A brand with a distinctive personality can become easier for consumers to recognise and relate to. This relational perspective is also consistent with self-brand congruity theory, which proposes that consumers tend to respond more favourably to brands whose images are compatible with their self-concepts (Sirgy, 1982). Thus, when anthropomorphic characteristics make a brand appear more human, these perceptions may contribute to the development of a recognisable brand personality and, subsequently, to stronger loyalty.

Although brand anthropomorphism, brand personality, and brand loyalty have each received attention in previous marketing research, the literature remains fragmented. Earlier studies have examined the consequences of anthropomorphism for consumer responses, while another stream of research has considered the role of brand personality in developing favourable consumer outcomes. However, comparatively limited attention has been given to the mechanism through which anthropomorphic perceptions may translate into brand loyalty through brand personality (Portal et al., 2018; Qamar-un-Nisa & Mehr-un-Nisa, 2023). This limitation is particularly relevant in the Sri Lankan context, where empirical evidence concerning these relationships remains limited. In addition, the fast-food sector provides an important setting for examining the issue because consumers frequently choose between competing brands with relatively similar functional offerings. Consequently, understanding the relational factors that encourage consumers to remain loyal is important both theoretically and managerially. Against this background, the present study examines the relationship between brand anthropomorphism and brand loyalty and investigates whether brand personality provides a mediating mechanism

between the two. The study addresses two research questions: (1) does brand anthropomorphism affect brand loyalty, and (2) does brand personality mediate the relationship between brand anthropomorphism and brand loyalty? The study therefore seeks to provide empirical evidence from fast-food consumers in the Western Province of Sri Lanka and to extend existing understanding of how human-like brand perceptions can contribute to consumer loyalty.

Methodology

A quantitative research approach was adopted within a positivist research philosophy, following deductive reasoning. A cross-sectional survey design was used because the study aimed to examine the relationships among brand anthropomorphism, brand personality, and brand loyalty using numerical data collected from consumers at a particular point in time. The unit of analysis was the individual fast-food consumer.

The target population consisted of consumers of fast-food brands in the Western Province of Sri Lanka. Convenience sampling, a non-probability sampling technique, was employed to reach respondents who had experience of purchasing fast-food products. Based on the Krejcie and Morgan approach, a sample of 384 respondents was used for the analysis. Primary data were gathered through a structured questionnaire containing closed-ended items measured on a five-point Likert scale ranging from strongly disagree to strongly agree. The measurement of brand anthropomorphism incorporated four aspects identified in the study: appearance, moral virtue, cognitive experience, and conscious emotionality. Brand personality was measured in terms of the dimensions proposed by Aaker (1997), while brand loyalty incorporated attitudinal and behavioural aspects.

The collected data were analysed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, reliability analysis, correlation analysis, and regression analysis were employed to assess the relationships among the study variables. The mediating role of brand personality was examined using Hayes' PROCESS macro (Model 4) with bootstrapping. This approach was appropriate because the main purpose of the study was not only to establish whether brand anthropomorphism is associated with brand loyalty but also to determine whether the relationship operates partly through consumers' perceptions of brand personality.

Results and Discussion

The measurement assessment indicated satisfactory reliability, with Cronbach's alpha values for all study constructs exceeding the commonly accepted threshold of .70. The Kaiser–Meyer–Olkin (KMO) value of .959 and the significant Bartlett's test ($p < .001$) further indicated that the data were suitable for the subsequent statistical analyses. The correlation analysis showed a strong positive association between brand anthropomorphism and brand loyalty ($r = .782$, $p < .01$). Brand personality also demonstrated a strong positive relationship with brand loyalty ($r = .789$, $p < .01$).

The regression analysis provided further evidence of the importance of brand anthropomorphism in explaining consumer loyalty. Brand anthropomorphism had a significant positive effect on brand loyalty (β = .782, $p < .001$), and the model explained 61.1% of the variance in brand loyalty ($R^2 = .611$). Therefore, the first research question is answered affirmatively: higher perceptions of human-like characteristics associated with a fast-food brand are accompanied by stronger consumer loyalty. This finding is consistent with previous research suggesting that anthropomorphic perceptions can strengthen consumer–brand relationships and encourage favourable behavioural responses (Portal et al., 2018; Qamar-un-Nisa & Mehr-un-Nisa, 2023).

The analysis also demonstrated a significant positive relationship between brand anthropomorphism and brand personality (β = .905, $p < .001$). In addition, brand personality had a significant positive effect on brand loyalty (β = .811, $p < .001$). These results suggest that human-like perceptions of a brand are not isolated perceptions; they can contribute to the way consumers characterise the brand and subsequently influence their willingness to maintain the relationship. This finding supports the logic of Aaker's (1997) Brand Personality Model, as human characteristics attributed to brands can provide a basis for forming meaningful personality perceptions. More importantly, the mediation analysis provided evidence for the second research question. The total effect of brand anthropomorphism on brand loyalty was significant ($B = 0.888$, $p < .001$, 95% confidence interval [CI] [0.817, 0.959]). After brand personality was introduced into the model, the direct effect remained significant ($B = 0.468$, $p < .001$, 95% CI [0.354, 0.581]). The indirect effect through brand personality was also significant ($B = 0.420$, BootSE = 0.090, 95% CI [0.250, 0.603]), as the confidence interval did not include zero. Hence, brand personality partially mediates the relationship between brand anthropomorphism and brand loyalty. This indicates that anthropomorphic perceptions influence loyalty through the development of favourable brand personality perceptions, while a portion of the influence remains direct.

The findings extend earlier work by showing that the connection between anthropomorphic branding and loyalty is not limited to a direct relationship. Instead, brand personality helps to explain how consumers move from perceiving a brand as human-like to developing a stronger relationship with that brand. This is consistent with the relational logic discussed by Fournier (1998) and with previous evidence that anthropomorphism can contribute to stronger emotional and relational responses towards brands (Rauschnabel & Ahuvia, 2014). The findings therefore provide context-specific evidence for an integrated relationship that has received comparatively limited attention in previous research.

Conclusions and Implications

The study concludes that brand anthropomorphism is an important factor associated with brand loyalty among fast-food consumers in the Western Province of Sri Lanka. The findings show that consumers who perceive greater human-like qualities in a brand are more likely to demonstrate stronger loyalty towards it. More importantly, the significant

indirect effect confirms that brand personality serves as a partial mechanism through which these anthropomorphic perceptions are translated into loyalty. Thus, the study provides empirical support for viewing anthropomorphism and brand personality as interconnected elements of consumer–brand relationship development rather than as completely separate branding concepts.

From a theoretical perspective, the study brings together brand anthropomorphism, brand personality, and brand loyalty within one explanatory framework. The finding that brand anthropomorphism contributes to brand personality perceptions is consistent with Aaker's (1997) view that brands can be understood through human personality characteristics. At the same time, the mediating relationship supports a relational interpretation of anthropomorphism, whereby humanising a brand can make it more personally meaningful and thereby strengthen consumer loyalty. In this sense, the study extends the application of the Brand Personality Model and the self-brand congruity perspective to an emerging-market fast-food context.

The findings also have practical value for fast-food brand managers. Rather than relying exclusively on price promotions or product-based communication, managers can use human-like brand elements to create more distinctive consumer experiences. Brand mascots, relatable narratives, conversational communication, emotionally meaningful messages, and consistent social media interactions are possible ways of making a brand appear more human and approachable. However, anthropomorphic communication should be supported by a clear and consistent brand personality. If consumers recognise the brand as having a distinctive personality, the human-like elements are more likely to contribute to a stronger and longer-term relationship with the brand. Therefore, fast-food marketers should consider anthropomorphism and brand personality as complementary elements when designing loyalty-oriented branding strategies.

The study should be interpreted in the light of its limitations. The use of convenience sampling and the geographical focus on the Western Province restrict the generalisability of the findings to other regions and consumer groups. In addition, the cross-sectional quantitative design provides a snapshot of consumer perceptions and does not capture how these relationships may change over time. Future research could examine other regions of Sri Lanka, employ probability-based or more diverse sampling approaches, and consider additional variables such as brand trust, brand love, or customer satisfaction.

***Keywords*:** Brand anthropomorphism, brand loyalty, brand personality, fast-food consumers, Sri Lanka

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The Impact of Brand Nostalgia on Brand Attachment: The Mediating Role of Consumer Emotions in Sri Lanka's Television Industry

Upeksha L.A.S.* and Adhikari A.M.S.I.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: sachiniupeksha46@gmail.com)

Introduction

Brand nostalgia refers to consumers' feelings and memories associated with meaningful experiences from the past and can influence consumer responses to marketing stimuli (Holak & Havlena, 1998). In the television industry, nostalgic experiences may arise from familiar programmes, presenters, advertisements, music and historical brand elements. Brand attachment refers to the emotional bond connecting consumers with a brand (Park et al., 2010), while consumer emotions represent affective responses that influence consumer attitudes and behaviour (Bagozzi et al., 1999).

Previous studies have established relationships between nostalgia and important consumer and brand outcomes. Banerjee and Shaikh (2022) examined brand nostalgia in relation to purchase intention towards brand extensions while considering brand attachment, and Wahab and Nagaty (2025) examined nostalgia in relation to brand trust, brand attachment and brand love. Srivastava et al. (2023) further identified nostalgia as an established area of consumer research. However, limited attention has been given to explaining the emotional mechanism through which brand nostalgia contributes to brand attachment. In addition, limited empirical evidence is available regarding this mechanism within the Sri Lankan television context.

Therefore, this study addresses a mechanism-based and contextual gap by examining consumer emotions as a mediator between brand nostalgia and brand attachment among television viewers in Colombo District, Sri Lanka. The main objective is to examine the impact of brand nostalgia on brand attachment and the mediating role of consumer emotions. Specifically, the study examines the effects of nostalgic advertising, memory recall, emotional evocation and brand heritage on brand attachment, together with the relationships among brand nostalgia, consumer emotions and brand attachment.

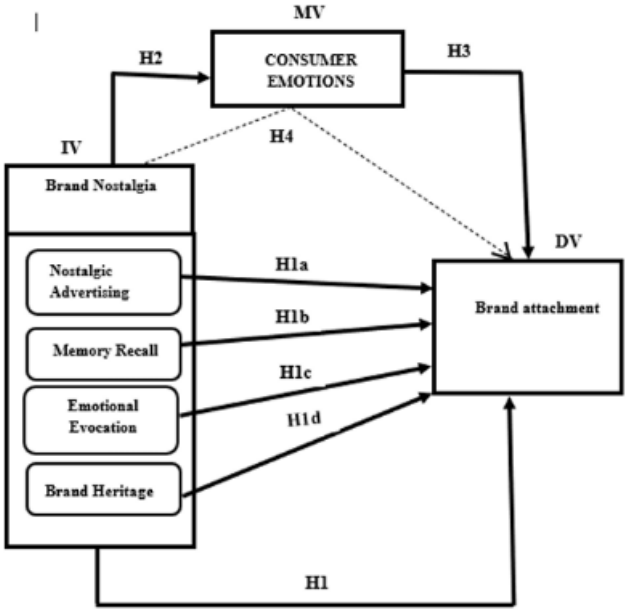
Methodology

A quantitative, deductive, cross-sectional survey design was adopted. The target population comprised television viewers in Colombo District, Sri Lanka. Convenience sampling was used because a comprehensive sampling frame was unavailable and eligible respondents had to be accessible and willing to participate. The required sample size of 384 was determined using the Krejcie and Morgan (1970) sample size table. Data were collected through a structured questionnaire distributed both online via Google Forms and in person, using a five-point Likert scale. Measurement items were adapted from established literature, including Muehling and Pascal (2011) for nostalgia, Bagozzi et al. (1999) for consumer emotions and Park et al. (2010) for brand attachment. Data were analysed using SPSS through descriptive statistics, reliability and validity assessment, Pearson correlation, regression and mediation analysis.

The conceptual framework (Figure 1) proposed direct and indirect relationships between brand nostalgia and brand attachment, with consumer emotions as the mediator. Brand nostalgia comprised nostalgic advertising, memory recall, emotional evocation and brand heritage. The hypotheses were as follows: H1, brand nostalgia positively affects brand attachment; H1a–H1d, its four dimensions positively affect brand attachment; H2, brand nostalgia positively affects consumer emotions; H3, consumer emotions positively affect brand attachment; and H4, consumer emotions mediate the relationship between brand nostalgia and brand attachment.

Figure 1

Conceptual Framework



Results and Discussion

The measurement scales demonstrated strong reliability, with Cronbach's alpha values of .861 for nostalgic advertising, .840 for memory recall, .830 for emotional evocation, .849 for brand heritage, .911 for consumer emotions and .917 for brand attachment. Overall reliability was .971. Kaiser–Meyer–Olkin (KMO) values were .892 for brand nostalgia, .898 for brand attachment and .923 for consumer emotions. The overall KMO was .767, and Bartlett's test of sphericity was significant (χ^2 = 1,114.451, $p < .001$), supporting further analysis.

Brand attachment recorded the highest mean (M = 3.9115, SD = 0.75721), followed by consumer emotions (M = 3.8980, SD = 0.72859). Among the nostalgia dimensions, brand heritage recorded the highest mean (M = 3.8837, SD = 0.78261). Pearson correlations were strong and positive between brand nostalgia and brand attachment (r = .830, $p <$ .001), between brand nostalgia and consumer emotions (r = .866, $p < .001$), and between consumer emotions and brand attachment (r = .874, $p < .001$).

Regression analysis showed that brand nostalgia significantly predicted brand attachment (β = .830, R^2 = .689, t = 29.096, p < .001), supporting H1. Brand nostalgia significantly predicted consumer emotions (β = .866, R^2 = .750, t = 33.869, p < .001), supporting H2, while consumer emotions significantly predicted brand attachment (β = .874, R^2 = .763, t = 35.106, p < .001), supporting H3. The four nostalgia dimensions significantly predicted brand attachment: nostalgic advertising (β = .649), memory recall (β = .725), emotional evocation (β = .801) and brand heritage (β = .816), all p < .001. Thus, H1a–H1d were supported, with brand heritage producing the strongest effect. The mediation analysis provided the main contribution. The total effect of brand nostalgia on brand attachment was 0.890 (p < .001), while the direct effect remained significant at 0.315 (SE = 0.051, t = 6.156, p < .001, 95% CI [0.214, 0.416]). The indirect effect through consumer emotions was 0.575, with a 95% bootstrap confidence interval of [0.417, 0.691]. As the confidence interval did not include zero and the direct effect remained significant, consumer emotions partially mediated the relationship, supporting H4.

The findings are consistent with previous research linking nostalgia with brand-related outcomes (Banerjee & Shaikh, 2022; Wahab & Nagaty, 2025). However, the study extends this literature by demonstrating that consumer emotions provide an important pathway through which nostalgia contributes to brand attachment. The strongest effect of brand heritage further indicates the importance of historical identity and continuity in the television broadcasting context.

Conclusions and Implications

The study concludes that brand nostalgia significantly influences brand attachment and consumer emotions, while consumer emotions also significantly influence brand attachment. Most importantly, consumer emotions partially mediate the relationship between brand nostalgia and brand attachment, with an indirect effect of 0.575 (95% bootstrap CI [0.417, 0.691]). Thus, nostalgic experiences strengthen consumer–brand attachment both directly and through emotional responses. Theoretically, the study extends consumer–brand relationship research by integrating brand nostalgia, consumer emotions and brand attachment within a mediation framework and by demonstrating the emotional mechanism underlying the nostalgia–attachment relationship. Practically, the television industry can use memorable programmes, presenters, music, historical elements and culturally meaningful content in nostalgic marketing. Because consumer emotions partially mediate the relationship, campaigns should stimulate memories while creating positive emotional experiences. The strongest effect of brand heritage (β = .816) highlights the importance of communicating brand history and continuity.

The study is limited by its focus on Colombo District, its use of convenience sampling and its cross-sectional design. These factors restrict generalisability and prevent examination of changes over time. Future studies should consider wider geographical coverage, probability sampling where feasible and longitudinal research.

Keywords**:** Brand attachment, brand heritage, brand nostalgia, consumer emotions, nostalgic marketing

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Visual and Informational Drivers of TikTok Concert Engagement in Sri Lanka

Suraweera S.P.W.G.D.* and Hendeniya H.M.U.S.
Department of Marketing Management, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: dukshanwarawaththa@gmail.com)

Introduction

In the live event sector, short-form platforms such as TikTok have transformed digital marketing (Sugito, 2025). In Sri Lanka, event organisers rely heavily on TikTok to promote music concerts through algorithmically driven visual content (Wang et al., 2026). However, a critical research problem persists: despite heavy promotional investment, event organisers lack empirical insight into how visual design choices and informational structures interact to convert initial social media attention into booking behaviour rather than purchase friction. While the global literature examines general e-commerce marketing, a contextual gap remains regarding localised, event-based promotion within developing South Asian digital ecosystems.

To bridge this gap, this study pursues three objectives: (1) to analyse the visual and informational elements of Sri Lankan TikTok concert promotions, (2) to evaluate how these elements drive audience engagement patterns, and (3) to establish a contextualised model of short-form video event marketing.

Theoretically, this study integrates Visual Hierarchy Theory and the Elaboration Likelihood Model (ELM) (Zhuang, 2022). Visual Hierarchy Theory explains how structural video design directs rapid visual attention (Ho, 2023), while the ELM clarifies how users move from peripheral sensory cues to the central evaluation of logistical details such as pricing and venues as purchase intention deepens (Rawangngam et al., 2025).

Methodology

This study adopted an interpretivist philosophy and an inductive qualitative approach, using netnography to analyse natural, public online interactions (Kozinets, 2015). A cross-sectional design captured audience responses within a defined period of the Sri Lankan TikTok concert ecosystem. Using purposive sampling based on predefined criteria of content relevance, visibility and audience engagement, 46 public TikTok concert promotional videos and 400–450 corresponding user comments were collected. NVivo was used to organise and manage the data. The data were analysed by identifying recurring patterns and systematically developing themes, following Braun and Clarke's (2006) six-phase thematic analysis framework (Clarke & Braun, 2017).

Results and Discussion

Thematic analysis of the netnographic data revealed five interrelated themes that illustrate users' dynamic transition from initial attention capture to action-oriented responses in the Sri Lankan TikTok concert promotional environment. These findings are synthesised into an Integrated Behavioural Flow Model (Table 1), which maps promotional content drivers to user response patterns and their interpreted processing shifts.

Table 1

Integrated Behavioural Flow Model of TikTok Concert Engagement

Stage and theme	Codes	Audience responses	Interpreted cognitive and behavioural processing
Stage 1: Sensory Curation and Aesthetic Authority	High saturation, warm tones, expert layouts	Praise for "magical vibes", unique visual design	Visual attention capture: directs visual attention and initial interest (Visual Hierarchy Theory)
Stage 2: Rhythmic Attention and Artist Credibility	Fast beat-synced cuts, instant artist hooks	Hype over raw vocals, artist talent validation	Initial persuasive engagement: builds perceived authenticity and immediate hype
Stage 3: Narrative Resonance and Emotional Drivers	Story-first marketing, behind-the-scenes content	Deep emotional connection, loyal fan expression	Affective resonance: fosters brand connection and community identity
Stage 4: Social Validation and Promotional FOMO	Crowd validation shots, scarcity cues	Tagging friends, countdown hype, ticket panic	Social proof activation: triggers peer interaction and perceived urgency
Stage 5: Information Transparency and Purchase Friction	Price lists, seating maps, clear CTAs	Inquiries on pricing, venue, payment methods	Deliberate information evaluation: lack of clarity causes purchase-related friction and hesitation

Note. FOMO = fear of missing out; CTA = call to action.

The findings demonstrate that audience engagement operates as a progressive continuum rather than as isolated interactions. Early engagement (Stages 1–2) can be interpreted through Visual Hierarchy Theory (Ho, 2023). High-saturation colour palettes, atmospheric branding and fast-paced editing synchronised to song beats function as primary "grabber" features that capture rapid visual focus. User responses at these early stages primarily reflect aesthetic praise (e.g. "magical vibe", "high-quality editing") and validation of artist talent through raw vocal hooks.

As users move into the intermediate stages (Stages 3–4), engagement evolves from passive visual processing to active social participation. Story-driven narratives and behind-the-scenes content foster emotional resonance and brand loyalty among mega fans. Simultaneously, crowd validation footage activates social proof, prompting peer-to-peer tagging, countdown excitement and expressions of fear of missing out (FOMO) or "ticket panic".

Finally, at Stage 5, engagement shifts towards more deliberate information evaluation, consistent with ELM principles (Rawangngam et al., 2025; Zhuang, 2022). At this stage, user comments increasingly move from emotional hype towards pragmatic inquiries concerning ticket pricing, seating arrangements, payment options and venue locations. Where videos provided explicit logistical information, comments showed stronger action-oriented responses; conversely, ambiguous information induced cognitive friction, purchase-related hesitation and logistical confusion among prospective attendees.

Conclusions and Implications

This study contributes to the digital marketing literature by proposing an Integrated Behavioural Flow Model, which illustrates a sequential pattern through which visual and sensory cues on short-form video platforms are associated with increasingly deliberate informational evaluation. Methodologically, it highlights the efficacy of combining netnography with thematic analysis to capture authentic, naturally occurring consumer interactions in event marketing contexts. In practical terms, Sri Lankan concert promoters must complement highly aesthetic video content with explicit logistical transparency (e.g. upfront pricing and venue details) to minimise purchase-related friction and facilitate action-related responses.

This study is limited by its qualitative cross-sectional design and its focus on public TikTok interactions within the Sri Lankan concert sector. Future research should employ quantitative experimental designs or eye-tracking methodologies across broader South Asian regional markets and alternative video platforms (e.g. YouTube) to test the relationships between stages empirically and to validate the generalisability of the Integrated Behavioural Flow Model.

Keywords**:** Action-related responses, audience engagement, Elaboration Likelihood Model, netnography, Visual Hierarchy Theory

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Advertising Avoidance and Customer Decision-Making on YouTube: The Mediating Role of Perceived Value

Siriwardhana S.S.S.* and Wasana K.M.L.K.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: sayurisiriwardhana2022@gmail.com)

Introduction

The advertising landscape has undergone a major transformation over the past two decades, moving from traditional print and television commercials to dynamic digital platforms. Among these, video streaming platforms such as YouTube have established themselves as dominant forces in global content consumption, capturing very large audiences through on-demand video services (Çelik et al., 2022). Despite this rapid growth, digital marketers face a substantial challenge in the form of advertising avoidance, which refers to any conscious or subconscious action taken by media users to reduce their exposure to promotional content (Çelik et al., 2022). Although YouTube offers a paid Premium tier that eliminates advertisements, market estimates indicate that over 85% of streaming users in developing markets such as Sri Lanka remain on the free platform because of sensitivity to subscription costs and restrictions on local payment gateways (Samarakoon et al., 2023). On the free version of YouTube, users frequently encounter non-skippable pre-roll and mid-roll advertisements that directly interrupt their primary viewing tasks, fostering feelings of goal impediment, forced exposure and intense frustration (Samarakoon et al., 2023). Empirical data indicate that approximately 36% of urban residents ignore online advertisements while 62% actively avoid them, creating a critical hurdle for brands striving to maintain message effectiveness (Samarakoon et al., 2023).

This widespread rejection of digital promotions has created significant practical and theoretical gaps. Theoretically, while the existing literature extensively documents the antecedents of avoidance, it frequently fails to examine how avoidance affects the downstream stages of consumer decision-making (Rege & Dimitrova, 2024). To address these gaps, the research problem investigated in this study is the unexamined direct and indirect influence of digital advertising avoidance on customer decision-making in streaming environments. The objectives of this study are to examine the direct impact of cognitive avoidance (intentional inattention), affective avoidance (negative emotional sentiment) and behavioural avoidance (active skipping or blocking) on customer decision-making; to assess the impact of advertising avoidance on perceived value; and to evaluate the mediating role of perceived value (utility and informational quality) in the relationship between advertising avoidance and decision-making. Theoretically, intrusive advertisements evoke affective aversion and selective inattention (H1), which reduce the perceived utility of the promotional content (H2), ultimately impairing the accuracy of product evaluation during decision-making (H3, H4).

Methodology

This study adopts a positivist research philosophy and a deductive quantitative approach, using a survey strategy with a cross-sectional time horizon. The individual free YouTube user in the Western Province of Sri Lanka is the unit of analysis, representing the target population. Owing to the absence of a centralised sampling frame of digital streaming users in the region, a non-probability convenience sampling technique was used to distribute a self-administered digital questionnaire across online platforms. A sample size of 384 respondents was determined using Krejcie and Morgan's (1970) table based on official population statistics (Department of Census and Statistics, Sri Lanka, 2026). Variables were operationalised using validated scales: cognitive, affective and behavioural avoidance were measured using the scales of Çelik et al. (2022); perceived value was operationalised through the multidimensional scale of Dastane et al. (2023), assessing functional and emotional utility; and customer decision-making was operationalised as evaluation efficiency and brand choice accuracy. The data were analysed in SPSS using descriptive statistics, Cronbach's alpha reliability tests, diagnostic assumption tests (normality, linearity and multicollinearity using variance inflation factors, VIF), Pearson correlation, multiple linear regression and formal mediation analysis using Hayes' PROCESS macro (Model 4).

Results and Discussion

The final sample consisted of 384 valid responses, balanced across gender (51.8% female, 48.2% male), with 64% of respondents aged between 18 and 30 years, reflecting the active demographic profile of digital consumers in Sri Lanka. Construct reliability was confirmed by Cronbach's alpha, with all scales exceeding the .70 threshold: cognitive avoidance (.847), affective avoidance (.909), behavioural avoidance (.903), perceived value (.789) and customer decision-making (.771). Diagnostic tests confirmed normal distribution, linear bivariate relationships and the absence of multicollinearity (all VIF values < 2.2).

Correlation, regression and mediation analyses supported all the proposed hypotheses. Advertising avoidance showed a significant negative relationship with customer decision-making ($r = -.506$, $p < .01$) and a significant direct negative effect ($B = -0.382$, $p < .001$), explaining 25.6% of its variance ($R^2 = .256$). All three dimensions had significant negative effects, with behavioural avoidance showing the strongest influence ($B = -0.186$, $p < .001$). These findings indicate that active avoidance tactics severely restrict consumer exposure to vital brand information, directly undermining decision-making performance.

Advertising avoidance also significantly reduced perceived value ($r = -.499$, $p < .01$; $B = 0.391$, $p < .001$, $R^2 = .249$). Conversely, perceived value strongly enhanced customer decision-making ($r = .690$, $p < .01$; $B = 0.665$, $p < .001$, $R^2 = .476$). Finally, mediation analysis using Hayes' PROCESS macro (Model 4) confirmed that perceived value partially mediates the relationship between advertising avoidance and customer decision-making (indirect effect $B = -0.260$, 95% CI [−0.322, −0.201]). Overall, advertising

avoidance undermines decision-making both directly and indirectly through reduced perceived value.

Conclusions and Implications

Based on the empirical findings, this study concludes that advertising avoidance, perceived value and customer decision-making are significantly interconnected among free YouTube users in the Western Province of Sri Lanka. The findings confirm that advertising avoidance, especially behavioural avoidance, directly hinders decision-making and also impairs it indirectly by reducing the perceived usefulness and value of promotional content.

The study makes important theoretical contributions by shifting the academic focus from the antecedents of advertising avoidance towards its downstream consequences for decision-making. It extends the application of the Theory of Planned Behavior (Ajzen et al., 2020) to digital streaming contexts in developing nations, proving that perceived value acts as a vital psychological buffer against exposure frustration. From a practical perspective, digital marketers must move away from intrusive non-skippable pre-roll formats that trigger instant skipping. Brands should prioritise permission-based native advertising, contextually targeted in-feed placements, and highly entertaining or informative storytelling that enhances perceived value and minimises goal impediment.

However, the study has several limitations: the cross-sectional design restricts causal inference, and non-probability convenience sampling within the Western Province limits generalisability to rural markets. Future research should employ longitudinal designs, compare behaviours between free and premium subscribers, and examine emerging platforms such as TikTok and Instagram Reels.

Keywords**:** Advertising avoidance, behavioural avoidance, customer decision-making, perceived value, YouTube

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The Impact of Information Overload on Consumers' Purchase Intention With Special Reference to the Online Fashion Industry in the Eastern Province, Sri Lanka

Penuja S.* and Wasana K.M.L.K.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: sinthu2357@gmail.com)

Introduction

The growth of e-commerce and social media platforms has increased the volume of fashion information that consumers can access on these platforms. Information can reduce uncertainty and support decision-making, but an excess of information beyond the consumer's cognitive capacity leads to information overload and complicates purchase intention. Most previous research on information overload has considered the phenomenon in general terms and has found negative impacts on consumer decision-making and purchasing behaviour. However, the impacts of different information conditions are not the same. In particular, information processing capacity, information quantity, information quality and available time may influence purchase intention in different ways. This study therefore extends the information overload literature by empirically examining these four dimensions simultaneously in the context of online fashion purchase intention. It focuses specifically on Generation Z (Gen Z) consumers aged 18–30 in the Eastern Province of Sri Lanka, a consumer group that is relevant to online fashion purchasing. The study aims to examine the relationships between information processing capacity, information quantity, information quality and available time, on the one hand, and consumers' purchase intention, on the other.

Methodology

A quantitative research design was adopted, based on a positivist philosophy and a deductive approach. The study employed a cross-sectional survey of Gen Z consumers aged 18–30 who reside in the Eastern Province of Sri Lanka and have experience of purchasing fashion products online. A structured questionnaire using a five-point Likert scale was administered through online platforms. Convenience sampling was used because the target population was accessed through online channels, and a sample of 384 respondents was obtained on the basis of the Krejcie and Morgan (1970) sample size guideline. The questionnaire consisted of 19 measurement items: six measuring information processing capacity, three measuring information quantity, five measuring information quality, two measuring available time and three measuring consumers' purchase intention. The measures were adapted from established literature. The data were analysed in SPSS using descriptive statistics, reliability analysis, validity analysis, Pearson correlation and multiple regression analysis. The validity analysis tested items measuring the internal consistency of the variables. The Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test were used to assess sampling adequacy and the suitability of the data for factor analysis, rather than being treated as standalone proof of construct validity.

Results and Discussion

The findings demonstrate that information-related conditions significantly influence consumers' purchase intention, but the direction of the relationships differs according to how information overload is experienced. Pearson correlation analysis showed significant negative relationships between information processing capacity and purchase intention ($r = -.780$, $p < .001$), between information quantity and purchase intention ($r = -.820$, $p < .001$) and between information quality and purchase intention ($r = -.798$, $p < .001$). In contrast, available time showed a significant positive relationship with purchase intention ($r = .780$, $p < .001$). Multiple regression analysis further confirmed that information processing capacity ($\beta = -.201$, $p < .001$), information quantity ($\beta = -.361$, $p < .001$) and information quality ($\beta = -.165$, $p = .008$) made significant negative contributions to purchase intention, whereas available time made a significant positive contribution ($\beta = .186$, $p = .001$). Information quantity was the strongest predictor among the four dimensions. The overall regression model was statistically significant ($F = 256.211$, $p < .001$), with $R^2 = .730$, indicating that the four dimensions collectively explained 73.0% of the variance in consumers' purchase intention.

These findings provide an important theoretical insight by showing that information overload should not be interpreted simply as "more information" or as a uniformly positive or negative condition. Rather, the consumer's experience of information difficulty, excessive information quantity, problematic information quality and the time available for processing can produce different consequences for purchase intention. The negative effects of information processing difficulty, information quantity and information quality are consistent with information overload theory, which suggests that excessive or difficult-to-process information can increase the cognitive burden and reduce decision effectiveness. The positive effect of available time suggests that sufficient time may enable consumers to evaluate and compare information more effectively, thereby reducing the negative consequences associated with information overload. Thus, the study contributes empirical evidence that the dimensions associated with information overload should be considered separately, rather than assuming that all information-related factors operate in the same direction.

Conclusions and Implications

The study concludes that conditions related to information overload are significantly associated with consumers' purchase intention in online fashion purchasing among Gen Z consumers aged 18–30 in the Eastern Province of Sri Lanka. The strongest negative predictor was information quantity, followed by information processing capacity and information quality, while available time showed a positive relationship with purchase intention. The findings suggest that online fashion retailers should avoid presenting excessive or difficult-to-process information and should instead organise essential product information clearly, accurately and efficiently, while allowing consumers sufficient opportunity to evaluate alternatives.

The study contributes to the information overload literature by providing a multidimensional examination of how different information conditions are associated with purchase intention, rather than treating information overload as a single undifferentiated construct. In practical terms, the findings can assist online fashion retailers in designing product pages and information strategies that reduce unnecessary cognitive burden while maintaining sufficient information for decision-making. However, because the study employed a cross-sectional design and convenience sampling, the findings indicate statistically significant relationships rather than definitive causal effects. The geographical and age-specific scope also limits generalisation beyond Gen Z online fashion consumers aged 18–30 in the Eastern Province. Future studies may therefore test the model using probability sampling, broader age groups, other regions of Sri Lanka and additional mediating or moderating variables.

Keywords**:** Available time, information overload, information processing capacity, information quality, information quantity

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The Impact of Electronic Word of Mouth (e-WOM) on Green Cosmetic Purchase Intention: Evidence From Consumers in the Western Province, Sri Lanka

Dissanayake D.M.T.D.[1,*], Gunarathne A.G.D.L.K.[2] and Jayasekara L.M.S.[1]
[1]*Department of Business Management, Wayamba University of Sri Lanka,* [2]*Department of Banking and Finance, Wayamba University of Sri Lanka*
*Corresponding author (email: tanyad@wyb.ac.lk)

Introduction

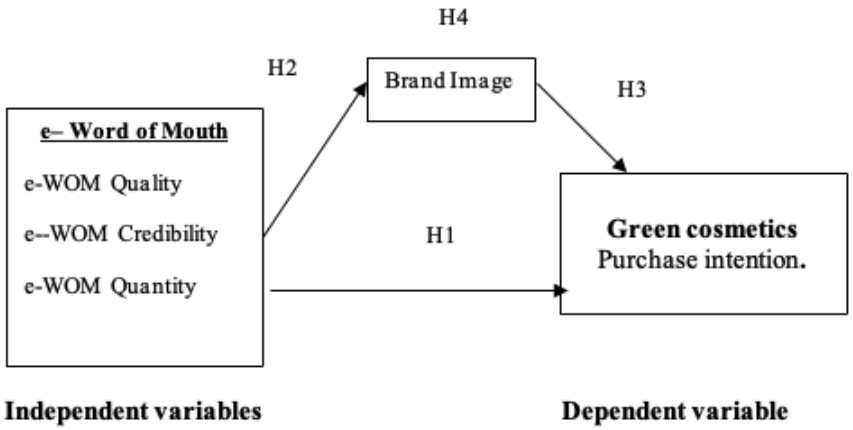
Digital communication has made electronic word of mouth (e-WOM) an important influence on green cosmetic purchasing, as consumers increasingly rely on online reviews and social media to evaluate products and build trust. However, the effects of e-WOM on green cosmetic purchase intention, particularly among women in Sri Lanka, remain underexplored, highlighting a gap between green preferences and actual purchasing behaviour. Previous research has separately established that e-WOM influences purchase intention (T. T. T. Nguyen et al., 2024) and that e-WOM shapes brand image (C. Nguyen et al., 2025), while Sri Lankan studies on green cosmetic purchase intention have so far centred on attitude and health-value-based predictors rather than on e-WOM (Ahsan & Ferdinando, 2023). However, an integrated model examining the three e-WOM dimensions of credibility, quality and quantity, together with brand image as a mediator, has not been tested specifically among female consumers of green cosmetics in Sri Lanka.

Conceptually, the study uses stimulus–organism–response (S-O-R) theory as its underpinning theory (Mehrabian & Russell, 1974), according to which environmental stimuli influence an individual's internal cognitive and affective states, which subsequently generate behavioural responses. In the present study, e-WOM characteristics, including e-WOM quality, credibility and quantity, serve as external stimuli. Exposure to such information can influence consumers' cognitive evaluations and perceptions of a green cosmetics brand, reflected in brand image. This internal evaluation subsequently contributes to consumers' behavioural response in the form of green cosmetics purchase intention. S-O-R theory therefore provides the principal theoretical foundation for explaining both the direct and the mediating relationships proposed in the conceptual framework.

Methodology

This study adopted a positivist philosophy and a deductive, quantitative approach with a cross-sectional survey design, guided by the conceptual framework shown in Figure 1. The target population was female consumers aged 20–50 years in the Western Province of Sri Lanka. The sample size was calculated using Cochran's formula, which gave an estimated total of 384. After screening, 293 valid responses were obtained, a response rate of 76.3%.

Figure 1
Conceptual Framework



Data were collected using a structured online questionnaire covering five constructs (e-WOM credibility, quality and quantity; brand image; and purchase intention) on a five-point Likert scale, with the e-WOM items adapted from Bataineh (2015). Convenience sampling was used. Data were analysed in SPSS using reliability and validity testing, descriptive statistics, Pearson correlation, regression and a four-step mediation analysis to test the mediating effect of brand image.

Results and Discussion

Reliability and validity were satisfactory, with no multicollinearity concerns (variance inflation factor, VIF = 2.495–3.043). All constructs recorded high mean scores (4.59–4.67). The variables were significantly and positively correlated ($p < .01$), with brand image showing the strongest relationship with purchase intention ($r = .770$).

e-WOM significantly predicts purchase intention ($R^2 = .679$, $p < .001$), supporting H1, and it also significantly predicts brand image ($R^2 = .587$, $p < .001$), supporting H2. Brand image significantly predicts purchase intention ($R^2 = .592$, $p < .001$), which supports H3 (Table 1).

Table 1
Regression Results for H1–H3

Path	*R*	R^2	β	*t*	*F*	*p*
e-WOM → purchase intention (H1)	.824	.679	.824	24.797	614.895	< .001
e-WOM → brand image (H2)	.766	.587	.766	20.343	413.856	< .001
Brand image → purchase intention (H3)	.770	.592	.770	20.562	422.810	< .001

Note. All paths significant at $p < .001$; H1, H2 and H3 supported.
Source: Survey data (2025)

A four-step mediation procedure was used to test whether brand image mediates the relationship between e-WOM and purchase intention (Table 2). When both e-WOM and brand image were entered as predictors of purchase intention, the combined model explained 72.5% of the variance ($R^2 = .725$, $F = 382.500$, $p < .001$), a slight rise from the 67.9% explained by e-WOM alone.

Table 2

Mediation Analysis Summary

Step	Path	Coefficient	*p*	Interpretation
1 (*c*)	Total effect: e-WOM → PI	0.958	< .001	Significant total effect
2 (*a*)	e-WOM → BI (mediator)	0.824	< .001	e-WOM significantly predicts BI
3 (*b*)	BI → PI (mediator effect)	0.363	< .001	BI significantly predicts PI
4 (*c′*)	Direct effect: e-WOM → PI (with BI)	0.660	< .001	Reduced but still significant

Note. PI = purchase intention; BI = brand image.

Since the effect of e-WOM on purchase intention remained significant but diminished once brand image was included (standardised β dropping from .824 to .660), brand image partially mediates the relationship between e-WOM and green cosmetic purchase intention, supporting H4. All four hypotheses were statistically supported at $p < .001$, confirming that e-WOM significantly and directly influences both brand image and purchase intention, that brand image itself significantly drives purchase intention, and that brand image partially mediates the overall relationship between e-WOM and purchase intention.

Consistent with prior e-WOM research (Erkan & Evans, 2016; T. T. T. Nguyen et al., 2024), e-WOM exerted a strong direct effect on purchase intention, explaining nearly two-thirds of its variance (H1). This supports the view that credible, high-quality and frequently encountered reviews reduce perceived risk and substitute for direct product experience when consumers evaluate unfamiliar green cosmetics (Cheung & Thadani, 2012). Brand image partially, rather than fully, mediated the relationship between e-WOM and purchase intention (H4): the standardised effect of e-WOM on purchase intention fell from .824 to .660 once brand image was included, but remained significant. This indicates that e-WOM operates through two complementary routes: directly, by supplying credible product-specific evidence, and indirectly, by shaping consumers' overall perception of the brand. A similar pattern was reported by C. Nguyen et al. (2025) for skin-care devices, where e-WOM credibility, quality and quantity fed into brand image en route to purchase intention, supporting the interpretation that brand image is one of several channels through which e-WOM persuades, rather than the sole mechanism.

The strong correlation between brand image and purchase intention ($r = .770$) and the substantial direct effect of brand image itself (H3) suggest that, for a credence good such as green cosmetics, whose sustainability claims consumers cannot easily verify through inspection, brand image functions as a heuristic that reduces the cognitive effort of assessing those claims. This is broadly consistent with Ahsan and Ferdinando (2023), who

found that Sri Lankan female consumers rely heavily on value-based cues when forming green cosmetic purchase intentions.

Conclusions and Implications

This study examined the impact of e-WOM on green cosmetic purchase intention among female consumers in the Western Province of Sri Lanka and the mediating role of brand image. e-WOM had a significant effect on both brand image and purchase intention, and brand image partially mediated the relationship between e-WOM and purchase intention. The results underscore the importance of review credibility, quality and quantity in shaping consumer behaviour in this market.

The study suggests that cosmetic brands should systematically encourage authentic customer reviews, engage micro-influencers and encourage user-generated content to establish trust and credibility. Brands can take a proactive approach to managing online conversations, responding to feedback and maintaining a consistent sustainability-oriented identity across digital platforms. In terms of marketing, the focus should be on the platforms most used by consumers, namely TikTok and Instagram. Policymakers should regulate digital spaces to promote transparency and to provide reliable information about green cosmetic products.

Keywords**:** Brand image, electronic word of mouth, green cosmetics, purchase intention, Sri Lanka

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Social Media Adoption and Its Effect on Sustainability Performance of SMEs in Kurunegala District

Gunathilaka M.D.S.V., Disanayaka H., Jayathilaka D*. and Mendis O.
Department of Accountancy, Wayamba University of Sri Lanka
*Corresponding author (email: jayathilakedilshan@gmail.com)

Introduction

Small and medium enterprises (SMEs) constitute approximately 80% of businesses in Sri Lanka, contributing 4.6% to gross domestic product (GDP) and employing 35% of the workforce (Central Bank of Sri Lanka, 2023). In Kurunegala District, SMEs face increasing competitive pressures while navigating limited resources and evolving sustainability expectations. The digital revolution has transformed business landscapes globally, with social media platforms emerging as powerful tools for organisational transformation. While an extensive literature exists on technology adoption models such as the Technology Acceptance Model (TAM) and the Technology–Organisation–Environment (TOE) framework, their application to understanding the nexus between social media adoption and sustainability outcomes in developing-country contexts remains underexplored. This study addresses this research gap by examining how social media adoption influences environmental, social and governance performance among SMEs in Kurunegala District. The research integrates technology adoption theories with sustainability performance frameworks, contributing to theoretical development at the intersection of digital transformation and sustainable business practices. The investigation provides evidence-based insights for SME owners, policymakers and researchers interested in understanding digital pathways to sustainability in emerging economies.

In line with Sahin (2006), the benefits that small and medium-sized businesses gain from using social media can be viewed analytically, namely in terms of identifying their relevant advantages. According to Parveen (2016), SME owners reported perceived benefits and found that the use of social media significantly improves the relationship between consumers and brands. Oliveira and Martins (2011) demonstrated that, in practice, the use of technology is important for consistency, that it facilitates the integration and refinement of business processes by reducing uncertainty, and that it has a positive effect through social practice. Rasheed (2022) found that cost-effectiveness has a significant positive effect on technology adoption among micro, small and medium-sized enterprises (MSMEs) in the Maldives. However, some scholars have observed an insignificant influence of cost on SMEs' technology adoption decisions (Maduku, 2015). Mou et al. (2017) demonstrated that trust reduces the perceived risks associated with social media use, thereby facilitating adoption decisions. Moreover, top management recognises the importance of social media in organisational processes and realises that it can be used to enhance business processes (Tajvidi & Karami, 2021). As an organisation matures technologically, it recognises that social media can be used to overcome existing challenges and expects to achieve benefits in the future (Scuotto, 2017). Similarly, competitive pressure provides an incentive for the organisation to focus on technology

(Zhu, 2006). Liang et al. (2007) showed that social media can be used to attract customers and secure market share and that, through this, an organisation can retain its attractiveness to customers. Chen (2024) also explained that social media can improve the relationship between the organisation and its stakeholders and maintain good communication. Accordingly, building on these findings of previous studies, this study develops a conceptual model for research in this area.

Methodology

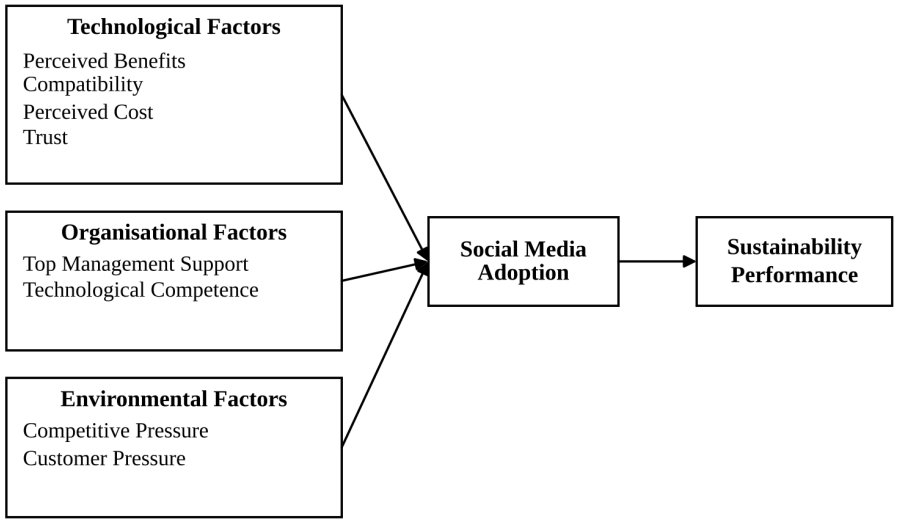
This study adopted a quantitative research approach using a cross-sectional survey design. A positivist research philosophy was employed to test theoretical relationships through empirical data collection and statistical analysis. The research followed a deductive approach, moving from established theoretical frameworks to specific empirical observations.

The target population consisted of SMEs operating in Kurunegala District. From approximately 4,794 registered SMEs in the district, a convenience sample of 82 enterprises was selected across diverse sectors, including retail, manufacturing, services, agriculture, textiles, logistics, construction, gems and jewellery, information technology, pharmaceuticals, tourism and clothing.

The study utilised the TOE framework developed by Arpaci (2012) as its primary theoretical foundation (Figure 1). The framework examines three contexts influencing organisational technology adoption: technological factors (perceived benefits, compatibility, perceived cost and trust), organisational factors (top management support and technological competence) and environmental factors (competitive pressure and customer pressure). Data analysis was conducted using SPSS version 28.0 for preliminary analysis and SmartPLS 4.0 for advanced structural equation modelling. Partial least squares structural equation modelling (PLS-SEM) was employed for hypothesis testing, chosen for its suitability for the sample size and the exploratory nature of the relationships. The analysis included assessment of measurement model quality, evaluation of structural relationships and hypothesis testing through bootstrapping procedures.

Figure 1

Conceptual Framework



Results and Discussion

The sample comprised businesses from diverse sectors, with retail enterprises constituting the largest segment (37.8%), followed by manufacturing and textiles (13.4% each). Respondents were distributed across age groups as follows: 18–28 years (45.1%), 29–44 years (39.0%) and 45–60 years (15.9%). The gender distribution was balanced, with 51.2% female and 48.8% male respondents. Most enterprises (70.7%) employed 1–10 people, qualifying as small enterprises under Sri Lankan definitions.

This study examined the factors influencing social media adoption by SMEs and its impact on sustainability performance using structural equation modelling. The results strongly supported all nine hypotheses (Table 1). Among technological factors, perceived benefits showed the strongest influence on adoption ($\beta = .436$, $p < .001$), followed by compatibility ($\beta = .348$, $p < .001$), while trust ($\beta = .210$, $p < .001$) and perceived cost ($\beta = .074$, $p < .001$) also demonstrated significant positive effects. Organisational factors proved highly influential, with both top management support ($\beta = .512$, $p < .001$) and technological competence ($\beta = .509$, $p < .001$) showing strong positive relationships with adoption. Among environmental factors, competitive pressure significantly drives adoption ($\beta = .528$, $p < .001$), while customer pressure influences adoption indirectly through environmental pathways ($\beta = .534$, $p < .001$). Most significantly, the study confirmed that social media adoption substantially enhances SME sustainability performance ($\beta = .800$, $p < .001$), providing robust empirical evidence for the strategic value of social media in achieving sustainable competitive advantage. These findings demonstrate that successful social media adoption by SMEs requires the alignment of technological capabilities, organisational readiness and environmental pressures to maximise sustainability outcomes.

Table 1

Hypothesis Testing Results

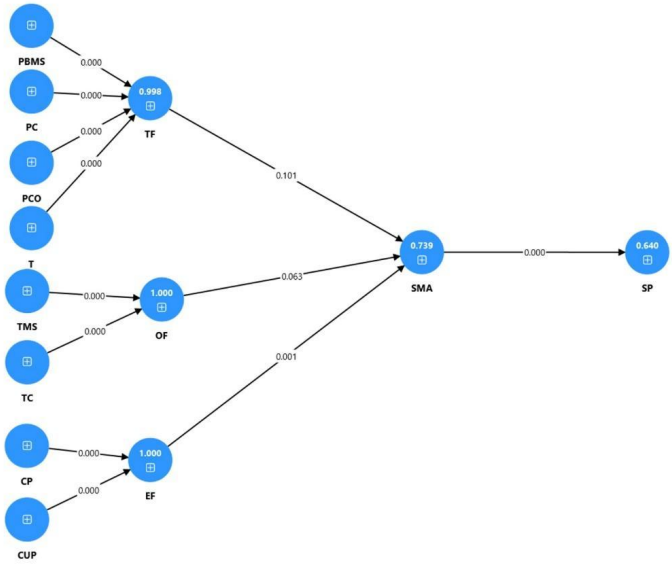
Hypothesis	Relationship	β	*t*	*p*	Significant
H1	Perceived Benefits → SMA	.436	22.295	< .001	Yes
H2	Compatibility → SMA	.348	15.276	< .001	Yes
H3	Perceived Cost → SMA	.074	3.559	< .001	Yes
H4	Trust → SMA	.210	8.926	< .001	Yes
H5	Top Management Support → SMA	.512	31.396	< .001	Yes
H6	Technological Competence → SMA	.509	32.894	< .001	Yes
H7	Competitive Pressure → SMA	.528	16.961	< .001	Yes
H8	Customer Pressure → SMA	.534	13.390	< .001	Yes
H9	Social Media Adoption → SP	.800	11.100	< .001	Yes

Note. SMA = social media adoption; SP = sustainability performance.

Social media adoption demonstrated substantial explanatory power (R^2 = .739), with environmental factors showing the strongest direct influence (β = .433, t = 3.378, p = .001) (Figure 2). The central finding revealed a powerful relationship between social media adoption and sustainability performance (β = .800, t = 11.100, p < .001), with social media adoption explaining 64% of the variance in sustainability outcomes (R^2 = .640).

Figure 2

Structural Model: Path Analysis



Conclusions and Implications

This research successfully demonstrates that social media adoption significantly enhances sustainability performance among SMEs in Kurunegala District. The study validates social media platforms as comprehensive mechanisms for sustainable business transformation rather than merely as marketing tools. The findings provide evidence-

based guidance for SME managers and policymakers regarding strategic social media adoption for enhanced sustainability outcomes. Future research should explore longitudinal relationships and cross-regional comparisons to strengthen generalisability.

***Keywords*:** Digital transformation, small and medium enterprises, social media adoption, sustainability performance, technology–organisation–environment framework

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Impact of Short-Form Video Consumption on Cognitive Functions of Sri Lankan Undergraduates

De Jayathunga A.*, Subasinghe G.P. and Senarath T.U.S.
Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: akeshdulanjana@gmail.com)

Introduction

Short-form video (SFV) platforms such as TikTok, Instagram Reels, YouTube Shorts, and Facebook Reels have rapidly transformed digital media consumption among university students. These platforms deliver algorithmically curated clips that capture attention through rapid scene changes, dopamine-enhancing feedback loops, and continuous novelty. Sri Lanka has over 8.2 million active social media users, with 10.5% of the population aged 18–24, the exact age range of undergraduates, which raises urgent questions about how habitual SFV consumption may be reshaping learning-related cognition (DataReportal, 2025). The Working Memory Model (Baddeley, 2000), Cognitive Load Theory (Sweller, 1988), and the Levels of Processing Theory (Craik & Lockhart, 1972) explain why working memory, memory retention, reading comprehension, and decision-making are especially vulnerable to the fast, fragmented, audio-visual stimulation characteristic of SFVs. Prior international studies have linked SFV exposure to reduced prospective memory, weaker visual short-term memory, and shortened attention spans (Chiossi et al., 2023). However, most of this evidence originates from Western or Gulf contexts, whereas Sri Lankan undergraduates operate within a distinct digital ecosystem shaped by uneven digital literacy, infrastructural constraints, and growing concern over data privacy and security, factors that may alter the strength of these relationships.

Although SFVs have proliferated globally, their cognitive influence on Sri Lankan undergraduates remains empirically unexamined. Senarath and Ratnayake (2021) reported negative correlations ($r = -.62$ to $-.68$) between broad social media use and cognitive performance among Sri Lankan undergraduates but did not isolate SFV consumption as a distinct predictor or test privacy and security concerns as a moderator. This reveals three gaps. First, empirically, no study has examined the unique cognitive architecture of SFVs (rapid context-switching and algorithmic personalisation) across all four core cognitive domains simultaneously. Second, methodologically, prior research relies on broad social media metrics rather than SFV-specific exposure measures or validated privacy and security scales. Third, contextually, no localised evidence exists to guide digital-wellness interventions for Sri Lanka's social media users.

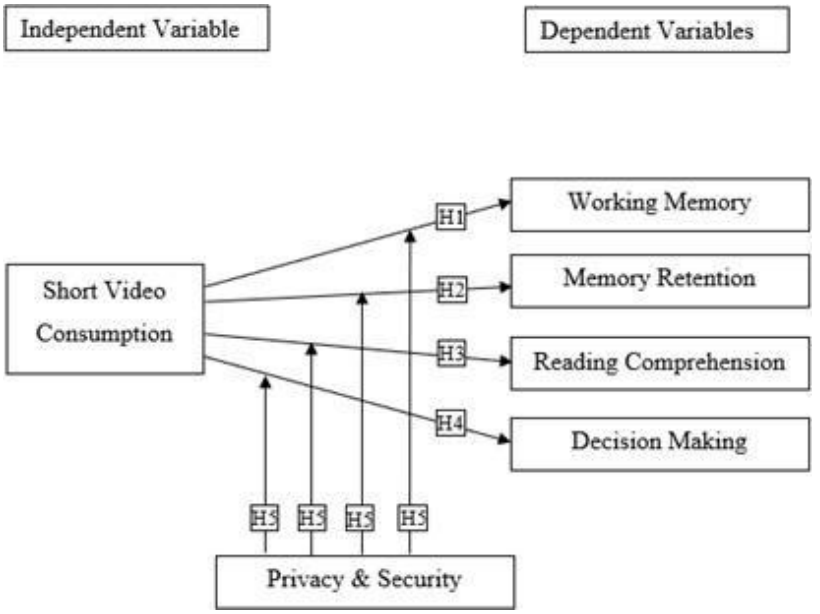
To address these gaps, the general objective of the study was to identify the impact of short-form video consumption on the cognitive functions of undergraduates in Sri Lankan state universities. The specific objectives were to identify the impact of SFV consumption on (1) working memory, (2) memory retention, (3) reading comprehension, and (4) decision-making, and (5) to identify the moderating effect of privacy and security concerns on the relationship between SFV consumption and the four cognitive functions.

Methodology

Guided by the Working Memory Model, Cognitive Load Theory, and Privacy Calculus Theory (Dinev & Hart, 2006), the study proposes an integrated conceptual framework adapted from Senarath and Ratnayake (2021) (Figure 1), in which SFV consumption is the independent variable directly influencing four cognitive functions, while privacy and security concerns moderate each relationship. Five hypotheses were formulated. Hypotheses H1–H4 state that SFV consumption has a significant impact on working memory (H1), memory retention (H2), reading comprehension (H3), and decision-making (H4), respectively; H5 states that privacy and security concerns significantly moderate the relationship between SFV consumption and the four cognitive functions.

Figure 1

Conceptual Framework



Note. H1–H4 = direct effects; H5 = moderating effect of privacy and security concerns.
Source: Adapted from Senarath and Ratnayake (2021)

A quantitative, explanatory, cross-sectional design with a deductive approach grounded in established cognitive theories was adopted. The target population comprised undergraduates enrolled in Sri Lankan state universities (DataReportal, 2025). A sample size of 384 was determined using Krejcie and Morgan's (1970) sampling table at a 95% confidence level and a 5% margin of error, and was proportionally allocated across 17 state universities on the basis of University Grants Commission (2025) enrolment figures. As no centralised student database exists and campus access was restricted, snowball sampling was employed (Etikan et al., 2016) through personal networks and university-affiliated social media communities. Respondents were required to be aged 18–26,

currently enrolled in a Sri Lankan state university, and using SFVs for at least 30 minutes daily.

Primary data were collected through a structured online questionnaire (Google Forms) between March and May 2026. All constructs were measured on a five-point Likert scale using items adapted from validated instruments: cognitive functioning from Senarath and Ratnayake (2021), privacy and security from Koohang et al. (2021), and SFV consumption from Chiossi et al. (2023) and Asif and Kazi (2024). Informed consent was obtained, and confidentiality and anonymity were assured. Data were analysed using SPSS version 27.0. Descriptive statistics summarised the sample characteristics, Cronbach's alpha assessed reliability, and the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity confirmed construct validity. Multiple linear regression tested the direct relationships (H1–H4), and moderation analysis using Hayes' PROCESS macro (Model 1) tested the moderating role of privacy and security concerns (H5).

Results and Discussion

All constructs demonstrated strong internal consistency (Cronbach's alpha from .806 to .959) and excellent construct validity (KMO > .80; Bartlett's test, $p < .001$), confirming that the instrument was reliable and suitable for regression and moderation analysis. Mean levels of SFV consumption ($M = 3.88$) and privacy and security concern ($M = 4.25$) were high, while the four cognitive domains scored comparatively low (M = 2.14 to 2.22) (Table 1).

Table 1

Reliability, Validity, and Descriptive Statistics of Study Variables (N = 384)

Variable	Mean (*SD*)	Items	Cronbach's α	KMO
Short-form video consumption	3.88 (1.31)	4	.922	.859
Working memory	2.20 (1.34)	6	.951	.934
Memory retention	2.17 (1.30)	6	.943	.929
Reading comprehension	2.22 (1.37)	6	.959	.929
Decision-making	2.14 (1.34)	6	.957	.937
Privacy and security	4.25 (0.81)	4	.806	.800
Overall	–	32	.923	.980

Note. *SD* = standard deviation; KMO = Kaiser–Meyer–Olkin measure; all Bartlett's test results were significant at $p < .001$.

Source: Survey data (2026)

Regression analysis revealed that SFV consumption had a strong, statistically significant negative impact on all four cognitive functions, supporting H1–H4. Working memory showed the strongest effect, followed by decision-making, memory retention, and reading comprehension (Table 2). Moderation analysis further showed that privacy and security concerns significantly strengthened these negative relationships across all four domains, supporting H5, with the largest interaction effect observed for reading comprehension. Including the moderator raised explanatory power; for example, the R^2 for working memory rose from .862 to .880.

Table 2

Regression and Moderation Results for SFV Consumption and Cognitive Functions

Cognitive function	β (direct)	*p*	Interaction *B*	*p*
Working memory (H1, H5)	−.929	< .001	−0.162	< .001
Memory retention (H2, H5)	−.901	< .001	−0.159	< .001
Reading comprehension (H3, H5)	−.894	< .001	−0.212	< .001
Decision-making (H4, H5)	−.908	< .001	−0.158	< .001

Note. β = standardised regression coefficient (direct effect); *B* = unstandardised interaction coefficient (moderator: privacy and security concerns).

Source: Survey data (2026)

These findings are consistent with the Working Memory Model and Cognitive Load Theory, which suggest that the rapid audio-visual shifts inherent in SFV content overload limited cognitive resources, while the significant moderation effect of privacy and security concerns aligns with Privacy Calculus Theory. Notably, respondents reported both high SFV consumption and high privacy concern simultaneously, a pattern consistent with the privacy paradox, whereby awareness of privacy risk does not translate into reduced platform engagement.

Conclusions and Implications

This study confirms that SFV consumption exerts a significant negative impact on working memory, memory retention, reading comprehension, and decision-making among Sri Lankan undergraduates, and that privacy and security concerns significantly intensify these effects. All five hypotheses were supported, and all five research objectives were achieved. In terms of theoretical implications, the study extends Cognitive Load Theory and Privacy Calculus Theory to a South Asian higher-education context that is under-represented in the literature, and shows that privacy and security concerns function as a genuine amplifying moderator rather than merely a parallel stressor. In terms of practical implications, mindful SFV use and screen-time regulation by students, particularly during study periods, may help protect cognitive performance. For educators and universities, the findings support digital-wellness workshops within student counselling and orientation programmes. For policymakers, since awareness of privacy risk alone appears insufficient to curb usage (the privacy paradox), digital-wellness programmes should pair privacy-literacy initiatives with behavioural change strategies.

As the study relies on self-reported, cross-sectional data from state university students only, causal inference and generalisability are limited. Future research should adopt longitudinal designs, add moderators such as sleep quality and self-regulation, and examine platform-specific effects.

***Keywords*:** Cognitive functions, decision-making, privacy and security concerns, short-form video consumption, working memory

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Siddha *Dinacharya* and Health Promotion: Integrating Traditional Wisdom With Modern Science

Karunya S.[1,*], Saruja N.[2], Sivagajendran S.[1] and Sathiyaseelan V.[2]
[1]*Branava Health Care, Jaffna, Sri Lanka,* [2]*Faculty of Siddha Medicine, University of Jaffna, Sri Lanka*
*Corresponding author (email: srikaru030@gmail.com)

Introduction

Health is defined as a state of complete physical, mental, and social well-being rather than merely the absence of disease. Non-communicable diseases continue to be a major health concern worldwide despite breakthroughs in modern medicine, primarily because of poor lifestyles. Siddha medicine places a strong emphasis on keeping the three humours (*Vali*, *Azhal*, and *Iyyam*) in balance in order to prevent illness.

Dinacharya (daily routine), which encompasses regulated routines including hygiene, exercise, food, sleep, and mental discipline, is a crucial preventive concept. These practices are intended to improve general health and to align human biological rhythms with natural cycles. Therefore, this narrative review aimed to identify and critically examine the key principles of Siddha *Dinacharya* and to explore their relevance to contemporary health promotion and disease prevention by comparing traditional Siddha concepts with evidence from modern biomedical research.

Methodology

This study is a narrative review of contemporary biomedical research and Siddha medical literature. Classical Siddha texts and secondary sources were analysed to identify the core principles of *Dinacharya*. These principles were subsequently compared with findings from contemporary scientific disciplines. A literature search was conducted using PubMed, Google Scholar, Scopus, and ScienceDirect for studies published from 2000 to 2025. The search used combinations of the keywords “Siddha medicine”, “Dinacharya”, “daily routine”, “health promotion”, “disease prevention”, “circadian rhythm”, “sleep”, “physical activity”, “oral hygiene”, “oil bath”, “meditation”, “yoga”, “nutrition”, and “meal timing”. Relevant classical Siddha texts, peer-reviewed articles, review papers, and authoritative health resources were considered on the basis of their relevance to the principles of *Dinacharya* and contemporary health promotion. The identified literature was qualitatively synthesised to examine conceptual and practical parallels between Siddha preventive practices and evidence-based contemporary medicine.

Results and Discussion

The findings of this review indicate that the principles of *Dinacharya* in Siddha medicine show considerable alignment with the contemporary scientific understanding of health promotion and disease prevention. Although these traditions have roots going back hundreds of years, many of their fundamental principles align with recent findings in public health, lifestyle medicine, nutrition science, chronobiology, and sleep research. This convergence implies that Siddha *Dinacharya* offers a comprehensive framework for preserving health and reducing the risk of lifestyle-related diseases. The qualitative

synthesis identified recurring themes related to circadian regulation, elimination, oral hygiene, physical activity, stress management, dietary regulation, and sleep, which were subsequently compared with findings from contemporary health and biomedical research; each theme is discussed in turn below.

The first theme concerns early morning awakening and circadian rhythm. A key characteristic of Siddha *Dinacharya* is rising early in the morning at *Brahma Muhurtham*, approximately 1.5 hours before sunrise. According to Siddha medicine, this time is ideal for fostering mental clarity, emotional equilibrium, physical energy, and spiritual well-being (Durairasan, 1951). Because of the peaceful and pleasant atmosphere, traditional texts advise using this time for breathing exercises, yoga, meditation, and prayer. These traditions are supported by contemporary circadian rhythm research, which demonstrates that regular sleep–wake cycles in synchrony with natural light enhance immunity, hormonal balance, metabolic function, and cognitive function. Additionally, exposure to morning sunlight increases alertness, improves sleep quality, and helps regulate the secretion of melatonin and cortisol (Hall, 2021; Taheri & Arabameri, 2023). The Siddha advice to awaken during *Brahma Muhurtham* is therefore in line with current scientific knowledge regarding circadian health and general well-being.

The proper evacuation of urine and faeces is another crucial component of Siddha daily routines. Siddha philosophy states that incomplete or delayed elimination may disturb the equilibrium of the three humours and hasten the onset of disease (Durairasan, 1951). Contemporary medical science also acknowledges the significance of normal bowel function for gastrointestinal health: adequate dietary fibre, water, and physical activity support regular bowel movements and help prevent constipation and related diseases (Mahan & Raymond, 2023).

Siddha medicine also emphasises oral hygiene practices, such as brushing the teeth and cleaning the tongue. Neem and other medicinal plant sticks were traditionally used to strengthen the gums and clean the teeth, and tongue cleansing was advised to promote digestion and remove coatings (Durairasan, 1951). According to modern dentistry, regular oral hygiene reduces dental plaque, periodontal disease, and oral infections. Additionally, studies have shown links between poor oral health and systemic conditions such as diabetes and cardiovascular disease (Mahan & Raymond, 2023).

The oil bath is a characteristic of Siddha preventive care. This practice, which entails applying oil to the scalp and body before bathing, is thought to lessen fatigue, enhance circulation, ease tension, and preserve physiological equilibrium (Durairasan, 1951). Current research on topical oil application and massage therapy has shown positive effects on circulation, relaxation, muscle healing, and mental health. The available evidence indicates that traditional oil bath techniques may help with stress reduction and musculoskeletal health, but further clinical research is needed to assess these practices specifically (Sharma & Clark, 2021).

Siddha *Dinacharya* places a strong emphasis on physical exercise. The Siddhas emphasised that excessive exercise could be detrimental and advised moderate exercise

based on an individual's age and physical condition (Durairasan, 1951). According to the World Health Organization (2024), physical inactivity is a significant risk factor for non-communicable diseases, and regular exercise is advised to preserve mental, metabolic, and cardiovascular health. Exercise has been demonstrated to lower blood pressure, reduce obesity, increase psychological well-being, and improve insulin sensitivity (Reddy, 2023).

With regard to yoga, meditation, and breathing practices, *Dinacharya* employs yoga, breathing techniques, meditation, and self-control to develop emotional stability and mental relaxation. The Siddhas understood that emotional disorders could play a role in the emergence of disease (Durairasan, 1951). According to current scientific research, chronic stress is linked to hypertension, cardiovascular disease, anxiety, depression, and weakened immunity, and yoga and meditation have been shown to lower stress, enhance emotional regulation, improve sleep quality, and boost resilience (Patwardhan, 2022).

Diet regulation is one of the main pillars of Siddha *Dinacharya*. To preserve physiological equilibrium, Siddha treatment places a strong emphasis on moderation, consistent meal scheduling, and the incorporation of all six tastes (*Arusuvai*) (Durairasan, 1951). These ideas are supported by contemporary nutrition science, which demonstrates that regular meal schedules and balanced diets enhance metabolic health and lower the risk of obesity and cardiovascular disease (Mentzelou et al., 2024; National Institute of Nutrition, 2023).

Sleep regulation is another key component of Siddha health promotion. Siddha medicine discourages excessive daytime rest and advises sufficient sleep at night (Durairasan, 1951). According to recent studies, insufficient or irregular sleep raises the risk of obesity, diabetes, high blood pressure, and cognitive impairment (Taheri & Arabameri, 2023). Siddha sleep advice is therefore in line with the most recent research on sleep health.

Overall, the reviewed evidence indicates that Siddha *Dinacharya* serves as a comprehensive preventive healthcare approach that simultaneously addresses several health variables. Physical, mental, and social well-being are influenced by a variety of factors, including early rising, appropriate elimination, oral hygiene, oil bathing, physical activity, balanced eating, sleep management, and mental discipline.

Conclusions and Implications

Siddha *Dinacharya* provides a holistic preventive framework encompassing sleep, hygiene, physical activity, mental well-being, and dietary regulation. The reviewed evidence shows alignment between several *Dinacharya* principles and contemporary health-promotion approaches, particularly in circadian health, exercise, stress management, nutrition, and sleep. These findings suggest that selected *Dinacharya* practices may have potential for integration into culturally appropriate health-promotion and lifestyle-intervention strategies. However, evidence for some traditional practices, particularly oil bathing, remains limited and requires further well-designed clinical and community-based research to establish their effectiveness, safety, and applicability in modern public health settings.

Keywords**:** *Dinacharya*, health, modern science, Siddha medicine

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Levels and Patterns of Smokeless Tobacco Use Among Manual Cleaning Workers in a Workplace Setting in Sri Lanka

Meewaddana L.W.R.M.R.[1,*], Warnasekara Y.P.J.N.[2] and Senarathna L.[1]
[1]*Department of Health Promotion, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Department of Community Medicine, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Saliyapura, Sri Lanka*
*Corresponding author (email: rashmimalshani22@gmail.com)

Introduction

There are two major forms of tobacco use: smoking and smokeless tobacco (SLT) use. SLT is tobacco that is consumed without smoking or burning (Dhanapriyanka et al., 2022; National Institutes of Health, 2025), and it can be chewed or inhaled. SLT remains comparatively under-recognised in tobacco control, although, like smoking, it increases the risk of cancers of the oral cavity, lips and pharynx and of other tobacco-related problems (National Cancer Institute, 2025). Sri Lanka is among the ten countries with the highest prevalence of SLT use (Dhanapriyanka et al., 2022). However, most studies on tobacco use have focused on smoking rather than on SLT use (Thilakarathne et al., 2025).

Different types of SLT products are available, among which betel chewing with tobacco is the most prominent in rural Sri Lanka, particularly among low-income occupational groups (Mahees et al., 2021; Somatunga et al., 2012). Among these groups, manual cleaning workers are particularly susceptible to SLT use, mainly because of their workplace culture, and this use adversely affects not only their health but also the economy. Understanding SLT use patterns and related factors in these groups is important for planning prevention. Hence, this study aimed to assess the levels and patterns of SLT use among manual cleaning workers at Rajarata University of Sri Lanka.

Methodology

A survey was conducted as part of a quasi-experimental study among manual cleaning workers at Rajarata University of Sri Lanka to determine the levels and patterns of SLT use among participants. The distribution of SLT use status and the patterns, contexts and behaviour related to SLT use were identified. Cleaning workers who were expected to be available for the entire study period were included in the sample. Data were collected anonymously using a pre-tested interviewer-administered questionnaire. The data were analysed using descriptive statistics and reported as frequencies and proportions.

Results and Discussion

Ninety-three manual cleaning workers aged 21 to 70 years participated in the study. The largest proportion of participants were aged 40–49 years (40.9%), and most were female (81.8%). Overall, 67.7% of participants reported being current SLT users, 14% reported that they had never used SLT, and 16.1% preferred not to disclose their SLT use status. Only 2.2% were former users who had quit the habit. Among current users, 74.6% used SLT daily, with 29.7% using it once or twice, 23.4% three or four times and 46.9% five or more times per day.

Betel quid with tobacco was the form of SLT most commonly used by participants, and the use of betel quid with tobacco only was more prevalent among males (75.0%) than among females (23.5%). In contrast, the use of betel quid without tobacco only was more prevalent among females (92.2%) than among males (41.7%). Moreover, only 6.3% of all users reported chewing tobacco leaves alone. Even though betel quid without tobacco is not classified as an SLT product, its use may indicate a potential risk of future use of betel quid containing tobacco.

The workplace was the most commonly reported setting for SLT use, with 90.5% of users consuming SLT at work and 34.9% bringing SLT to the workplace. Other commonly reported settings were social gatherings, including funerals (52.4%). Only 41.3% reported using SLT at home. Social influence appeared to play a significant role in SLT use: 74.6% reported using SLT when they observed others using it (*'Dutu vita'*), while 61.9% used SLT when offered it by someone else (*'Dun Vita'*). Furthermore, 34.9% reported using SLT when experiencing an unpleasant taste in the mouth or after a meal.

Conclusions and Implications

This study indicates that SLT use is highly prevalent among manual cleaning workers at Rajarata University of Sri Lanka, with betel quid with tobacco being the predominant form of SLT use. The high rate of daily use in workplace settings and the strong influence of social interactions suggest that SLT use is deeply embedded within the occupational and social culture of this group. Consequently, the findings are most applicable to similar workplace groups, and their generalisability to other occupational groups or communities is limited. Overall, the findings highlight the need for workplace-based, socially informed interventions that address peer influence, cultural normalisation and habitual triggers of SLT use among manual cleaning workers.

***Keywords*:** Betel quid, manual cleaning workers, smokeless tobacco, workplace setting

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Prevalence and Patterns of Body Image Concern Among School Adolescents: Findings From a School-Based Study

Thennakoon T.M.G.H.[1,*], Senadheera S.[2] and Fernando M.[1]
[1]*Department of Health Promotion, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Department of Biochemistry, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Saliyapura, Sri Lanka*
*Corresponding author (email: harshanithennakoon28@gmail.com)

Introduction

Body image encompasses an individual's subjective perceptions, feelings, and thoughts regarding their body shape and size (Bodega et al., 2024). A positive body image is associated with self-acceptance and well-being, whereas a negative body image is linked to low self-esteem, depression, disordered eating, reduced academic performance, and reduced quality of life (Goonapienuwala et al., 2019).

Globally, body image concern (BIC) has emerged as a critical public health issue, particularly among adolescents. Pubertal transitions, exposure to social media, peer influences, family expectations, and societal beauty standards may contribute to body dissatisfaction and concerns regarding appearance (Croll, 2005; Goonapienuwala et al., 2017, 2019).

Although the global literature extensively documents BIC, most findings originate from high-income countries, limiting their direct application to South Asian contexts (Goonapienuwala et al., 2017). In Sri Lanka, existing research remains sparse and yields contradictory patterns. While regional Asian data typically report higher dissatisfaction among females, Sri Lankan studies across urban and rural settings present conflicting trends regarding whether males or females experience greater dissatisfaction (Goonapienuwala et al., 2019; Liyanage et al., 2021). Crucially, a knowledge gap exists regarding domain-specific body satisfaction and body discrepancy patterns in North Central Sri Lanka. To address this gap, this study aimed to determine the prevalence of BIC and to examine its specific patterns among Grade 11 students at a national school in Anuradhapura.

Methodology

A school-based cross-sectional study was conducted among Grade 11 students at Central College, Anuradhapura. From a population of 456 schoolchildren, a sample of 90 students from two classes was selected by convenience sampling owing to administrative constraints. This non-probability sampling method is acknowledged as a methodological limitation restricting generalisability to the population. A pre-tested, self-administered questionnaire in the Sinhala language was used to collect the data.

Body satisfaction was assessed by analysing participants' overall satisfaction with their body image as well as their satisfaction with specific body parts. Responses of individuals who were either satisfied or very satisfied were combined into a single category labelled "body satisfaction", whereas neutral, dissatisfied, and very dissatisfied responses were grouped together as "not satisfied" with body image.

The body discrepancy score (BDS) was obtained from the Stunkard Figure Rating Scale. Only two questions were asked using the silhouettes: "select the figure which best represents your current body size" (perceived current body size, PCBS) and "select the figure which best represents your ideal body size" (ideal body size, IBS). The discrepancy between the two scores (PCBS minus IBS) was calculated to obtain the BDS.

An exploratory, study-specific composite Body Satisfaction Score (BSS; range 0–50) was computed by summing the domain items: overall satisfaction, weight satisfaction, height satisfaction, mirror-image comfort, skin tone perception, specific body parts, and BDS. Scores were divided into low (0–16), moderate (17–33), and high (34–50) categories based on equal score divisions. As this composite score lacks external psychometric validation, it was used solely as an exploratory descriptive index.

Patterns of body image concern were examined descriptively by comparing the prevalence of dissatisfaction across sex, family income, and self-reported perception of body weight category. Categorical variables across gender, family income, and self-reported weight were compared using Pearson's chi-square tests, and a p value < .05 was considered statistically significant. All analyses were conducted using IBM SPSS (Version 27). Ethical approval was obtained from the Ethics Review Committee of the Faculty of Applied Sciences, Rajarata University of Sri Lanka (ERC/2026/05), and informed assent/consent was obtained from participants and guardians.

Results and Discussion

The response rate was 90% (N = 81). Reasons for exclusion were refusal to participate, missing data, and incomplete questionnaires. All participants were 15 years old, of Sinhala ethnicity, and predominantly Buddhist (95.1%). Females comprised 53.1% (n = 43) of the sample, and 51.9% reported a monthly family income exceeding LKR 100,000 (Sri Lankan rupees). More than half of the participants reported dissatisfaction with their body image (60.5%), reflecting the high prevalence of body image concern among adolescents reported in previous local and international studies (Goonapienuwala et al., 2019; Liyanage et al., 2021).

Female participants demonstrated slightly higher dissatisfaction than males. However, the association between gender and body satisfaction was not statistically significant, $\chi^2(1, N = 81) = 0.202$, $p > .05$, indicating that body dissatisfaction appears widespread regardless of gender. Moreover, there was no statistically significant association between weight range and body satisfaction, $\chi^2(2, N = 81) = 4.2$, $p > .05$, or between monthly family income and body satisfaction, $\chi^2(1, N = 81) = 1.104$, $p > .05$.

Among females (n = 43), the highest satisfaction was reported for the waist (55.8%), skin (53.5%), and hair (53.5%), while lower satisfaction was seen for the chest/breasts (34.9%), thighs (37.2%), and stomach (37.2%). In contrast, males (n = 38) showed relatively higher satisfaction with the hair (68.4%) and skin (55.3%), but lower satisfaction with the arms (26.3%), thighs (23.7%), and chest (15.8%).

Results on body discrepancy showed that 70.4% of adolescents perceived a discrepancy between how they viewed their own bodies and their ideal body images. The association between gender and the BDS demonstrated clear gender differences in body discrepancy score patterns among adolescents. A higher proportion of female students desired to be thinner (42.9% vs 28.9%), while a higher proportion of male students desired to be fatter (47.4% vs 20.9%). This suggests that females may experience greater pressure towards achieving a thin body ideal, whereas males may be more concerned with increasing body size or muscularity. These findings are consistent with previous studies reporting that more boys than girls wanted to have a larger body size (Goonapienuwala et al., 2019). Similarly, Bibiloni et al. (2013) explained that the ideal male body is often associated with muscularity and strength, whereas girls are more likely to prefer slim body shapes.

Based on the body satisfaction score derived from various domain-specific items, most participants demonstrated a moderate level of body satisfaction (74.1%). Additionally, 21.0% of students reported high body satisfaction, while only 4.9% reported low body satisfaction. This approach offers a more comprehensive evaluation of body satisfaction than a single overall impression item.

Conclusions and Implications

While overall body dissatisfaction was not significantly associated with gender, income, or weight status, divergent body shape preferences were observed, with females leaning towards thinness and males towards larger body sizes. Given the high prevalence of body image concern (60.5%), school-based health promotion initiatives may consider integrating body image awareness tailored to these distinct gender preferences. Methodological limitations, including convenience sampling at a single institution, the small sample size, and the use of an unvalidated composite score, constrain statistical power and generalisability to the population. Future research should use representative sampling across diverse school types to validate these domain-specific measures and establish generalisable findings.

Keywords**:** Adolescents, body image concerns, body satisfaction

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Determinants of Processed Food Consumption Among Grade Nine Adolescents in a Selected School, Anuradhapura, Sri Lanka

Subhashini D.T.A.K.* and Parween Reyal H.
Department of Health Promotion, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: subhashinikaushalya98@gmail.com)

Introduction

Adolescence is a critical period for establishing lifelong dietary habits (World Health Organization [WHO], 2009). The consumption of processed foods among adolescents has become a significant public health concern in Sri Lanka (WHO, 2018). The 2024 Global School-based Student Health Survey reported that 75% of Sri Lankan adolescents consume processed foods or street-vended snacks weekly (WHO, 2024). These foods contribute to rising rates of overweight, obesity and diet-related non-communicable diseases (WHO, 2025).

Existing school-based interventions have focused primarily on raising general nutrition awareness without addressing the underlying determinants of dietary habits (Samad et al., 2024). Evidence on the determinants of processed food consumption among adolescents in Anuradhapura District is lacking. This district represents a rapidly changing food environment in which urbanisation is progressively displacing traditional dietary habits. Understanding these determinants is essential for designing effective health promotion interventions. Hence, this study aimed to identify the key determinants of processed food consumption among school-going adolescents in a selected school in Anuradhapura, Sri Lanka.

Methodology

A qualitative study was conducted with Grade 9 students at a selected school in Anuradhapura. Data were collected through focus group discussions (FGDs) using a semi-structured discussion guide (Shannon & Avery, 2025). In total, four FGDs were conducted with 25 students. The FGDs were audio-recorded, transcribed verbatim and translated from Sinhala into English. Data were analysed using an inductive thematic analysis approach. To ensure the validity of the findings, the identification of misconceptions was based on the researchers' analysis of the FGD transcripts, which was then cross-validated and refined in consultation with a subject expert in health promotion.

Ethical approval for this study was obtained from the Ethics Review Committee of the Faculty of Applied Sciences, Rajarata University of Sri Lanka. Informed parental consent and student assent were obtained before data collection.

Results and Discussion

Inductive thematic analysis identified three major themes, each representing key determinants of processed food consumption among school-going adolescents. The key determinants were limited knowledge about processed foods and food misconceptions, physical availability, and peer influence, media and marketing strategies. The themes were

the knowledge–behaviour gap and food misconceptions; environmental convenience and physical availability; and peer influence, media and marketing strategies.

The knowledge–behaviour gap and food misconceptions referred to the disconnect between what adolescents know about processed food and how they behave, shaped by inaccurate beliefs about what constitutes a healthy product. Adolescents demonstrated partial awareness of processed foods, identifying them primarily by their packaging and manufacturing origin. However, a persistent misconception emerged: products containing familiar wholesome ingredients, such as milk in flavoured yoghurt or chocolate, were widely perceived as healthy despite being heavily processed. Students also expressed disbelief towards health warnings and acknowledged continued consumption of foods they recognised as unhealthy. These findings reflect a disconnect between factual nutritional knowledge and actual dietary behaviour, further compounded by inaccurate beliefs about product composition.

Environmental convenience and physical availability refer to the physical and situational factors within and around the school setting that make processed foods the easiest and most accessible choice for adolescents. The school canteen and nearby food vendors were the primary sources of processed food for students, making these foods the most readily accessible options. Time constraints associated with early-morning schedules, tuition commitments and limited meal preparation time reinforced reliance on ready-made, convenient snacks. Allowances received for daily expenses, often repurposed from transport or tuition fees, enabled regular purchases of processed foods. Peer-sharing behaviours further sustained access to processed foods even when self-funding was limited, embedding processed foods within the everyday school routine.

Peer influence, media and marketing strategies refer to the social and commercial forces that shaped adolescent food preferences and normalised processed food consumption beyond individual nutritional awareness. Social norms around eating strongly shaped adolescent dietary habits. Peer consumption served as a powerful behavioural trigger, with group eating occasions, including birthday celebrations, normalising processed food within the school social context. Media marketing, particularly television advertisements featuring favourite characters such as athletes, reinforced the desirability of processed food products. These social and media influences operated independently of nutritional knowledge, underscoring their significance as behavioural determinants.

These findings align with other evidence showing that adolescent dietary habits are shaped more by social and environmental factors than by individual knowledge alone (Chavez-Ugalde et al., 2024; Harris & Graff, 2012). Similar patterns have been observed in other South Asian settings, where rapid urbanisation and changes in food systems have created unhealthy food environments that increase the risk of overweight and obesity among school-aged children (Chagas et al., 2022). This study extends these findings to a mixed rural–urban setting in Sri Lanka, where the food environment is changing rapidly.

Conclusions and Implications

This study identified key determinants of processed food consumption among Grade 9 school-going adolescents in Anuradhapura. The determinants were food-related misconceptions, convenience, availability, peer influence, targeted media and marketing.

These determinants are modifiable through health promotion interventions. School-based interventions should move beyond general nutrition awareness to include practical label-reading skills, peer resistance strategies and media literacy training. At the policy level, restricting processed-food marketing directed at adolescents, regulating food offerings in school canteens and improving the affordability of healthy food options are recommended to create supportive food environments (UNICEF, 2019). However, this study focused on a single school setting, and future research should explore determinants across diverse school types.

***Keywords*:** Adolescents, determinants, diet, processed food

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Digital Health Literacy and Socio-Demographic Correlates Among Elderly Patients in a Rural Tertiary Hospital

Dasanayaka D.R.G.V.[1,*], Chinthaka A.K.A.U.[1], Dasanayaka D.M.R.T.[1], Dasanayaka D.M.W.G.J.K.[1], Dissanayaka P.P.P.[1], Dissanayake D.M.N.K.[1] and Abeyrathne D.M.P.L.K.[2]

[1]*Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka,* [2]*Department of Family Medicine, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Sri Lanka*

*Corresponding author (email:)

Introduction

Sri Lanka's rapidly ageing population has increased the demand for healthcare and for the continuous management of non-communicable diseases (NCDs), placing significant financial and logistical burdens on elderly patients in rural areas. Digital health literacy (DHL) is crucial for navigating modern digital platforms and is therefore essential for equitable access to healthcare and for continuous NCD self-management (Cai et al., 2024; Norman & Skinner, 2006; Wu et al., 2022). However, physical and cognitive limitations, together with socio-demographic barriers such as visual impairments, leave older adults highly susceptible to poor DHL, widening the "grey digital divide" (Hepburn et al., 2025; Vaportzis et al., 2017; World Health Organization, 2022). This study therefore aims to assess the level of DHL and to identify its associated socio-demographic factors among older adults with NCDs in the North Central Province of Sri Lanka.

Methodology

A descriptive cross-sectional study was conducted among patients aged 60 years and older attending NCD clinics at the Teaching Hospital Anuradhapura to determine the association between DHL and socio-demographic factors. Participants were selected by cluster sampling and provided informed written consent; individuals with severe cognitive impairment or life-threatening conditions were excluded. The final sample size of 273 was calculated using the standard prevalence-based formula ($n = Z^2P(1 - P)/E^2$), with a 95% confidence level, an estimated population proportion of 20%, a 5% margin of error and a 10% allowance for non-response. Data were collected using an interviewer-administered questionnaire covering socio-demographic characteristics, digital device use, healthcare utilisation and the validated eight-item Sinhala eHealth Literacy Scale (Si-eHEALS). As no standard categorical cut-off is available, the total DHL score was treated as a continuous measure obtained by summing the eight items (each scored from 1 to 5; total range 8–40), with higher values indicating greater perceived DHL. Finally, the data were entered into Microsoft Excel and analysed in SPSS using descriptive and inferential statistics ($p < .05$) to evaluate associations with variables including age, educational level, living arrangement and income.

Results and Discussion

With regard to the participants' highest educational qualification, the largest proportion, 84 participants (30.8%), had passed the General Certificate of Education Ordinary Level (G.C.E. O/L) examination. With regard to the ability to understand English, the largest group of participants, 106 (38.8%), reported a very poor ability (Table 1).

Table 1

Descriptive Analysis of Categorical Variables From the Total Population (N = 273)

Variable	Subcategory	*n* (%)
Gender	Male	156 (57.1%)
	Female	117 (42.9%)
Highest education	No formal education	16 (5.9%)
	Grade 1–5 (primary)	44 (16.1%)
	Grade 6–10 (junior secondary)	71 (26%)
	G.C.E. O/L passed	84 (30.8%)
	G.C.E. A/L passed	39 (14.3%)
	Diploma/degree or higher	19 (7%)
Ability to understand English	Very poor	106 (38.8%)
	Poor	70 (25.6%)
	Fair	75 (27.5%)
	Good	17 (6.2%)
	Very good	5 (1.8%)
Area of residence	Urban	70 (25.6%)
	Rural	203 (74.4%)
Ethnicity	Sinhalese	261 (96.6%)
	Sri Lankan Tamils	2 (0.7%)
	Sri Lankan Moors	10 (3.7%)
Monthly household income	< LKR 17,000	84 (30.8%)
	LKR 17,000–27,000	54 (19.8%)
	LKR 27,000–56,000	92 (33.7%)
	LKR 56,000–196,000	39 (14.3%)
	> LKR 196,000	4 (1.5%)
I own or have access to a mobile phone	Yes, a touchscreen phone (smartphone)	94 (34.4%)
	Yes, a button phone (non-touchscreen)	143 (52.4%)
	No	36 (13.2%)

Note. Values are the number and percentage of participants in each subcategory (N = 273). G.C.E. O/L = General Certificate of Education Ordinary Level; G.C.E. A/L = General Certificate of Education Advanced Level.

Turning to the association between socio-demographic characteristics and DHL, highest educational attainment, ability to understand English, area of residence and monthly household income were significantly associated with DHL (p < .001; Table 2).

Table 2

Non-Parametric Analysis of Digital Health Literacy and Socio-Demographic Characteristics

Category	Subcategory	Median	IQR	*p*
Gender	Male	16	8, 20	.413
	Female	10	8, 23	
Highest education	No formal education	8	8, 9.5	< .001
	Grade 1–5 (primary)	10	8, 16	
	Grade 6–10 (junior secondary)	10	8, 17	
	G.C.E. O/L passed	10	8, 17	
	G.C.E. A/L passed	24	10, 30	
	Diploma/degree or higher	29	19, 32	
Ability to understand English	Very poor	8	8, 10.25	< .001
	Poor	10	8, 16	

Category	Subcategory	Median	IQR	*p*
	Fair	22	11, 30	
	Good	29	21, 31.5	
	Very good	32	20.5, 39	
Area of residence	Urban	17	10, 28	< .001
	Rural	10	8, 17	
Ethnicity	Sinhalese	10	8, 21	.277
	Sri Lankan Tamils	18.5	17, –	
	Sri Lankan Moors	17	10, 31.25	
Monthly household income	< LKR 17,000	8	8, 14.75	< .001
	LKR 17,000–27,000	10	8, 17	
	LKR 27,000–56,000	16	8.25, 24	
	LKR 56,000–196,000	25	10, 32	
	> LKR 196,000	13.5	10, 27.5	

Note. IQR = interquartile range. Significance was set at $p < .05$.

These findings are consistent with a study conducted in Telangana, India (Patel et al., 2024), which also identified education as an important determinant of eHealth literacy and found no significant association with gender, although the present study demonstrated a significant urban–rural difference. The findings are also supported by a systematic review of older Chinese adults (Shi et al., 2023), which identified education, socio-economic status, language and social factors as important influences on eHealth literacy. Overall, education, ability to understand English, area of residence and household income were associated with eHealth literacy, while the widespread use of mobile phones suggests potential for simple mobile-based approaches to improve digital health engagement among older adults.

Conclusions and Implications

Digital health literacy was significantly associated with education, ability to understand English, area of residence and household income, highlighting important educational and socio-economic disparities among older adults. Targeted digital literacy training, multilingual platforms, improved access to smartphones and connectivity, and family-supported health communication are recommended, while further multicentre longitudinal studies are needed to confirm these findings.

***Keywords*:** Digital health literacy, non-communicable diseases, Sinhala eHealth Literacy Scale

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Impact of Tube Type and Delayed Analysis on Serum C-Reactive Protein (CRP)

Koggalage D.N.[1], Lakshini K.G.T.[2], Nethmini M.K.G.M.M., Vidanapathirana D.M.[*], Ranasinghe R.D.S. and Majitha S.I.

[1]*University of Sri Jayewardenepura, Gangodawila, Nugegoda, Sri Lanka,* [2]*Lady Ridgeway Hospital for Children, Colombo, Sri Lanka*

*Corresponding author (email: maduri@sjp.ac.lk)

Introduction

C-reactive protein (CRP) is an acute-phase protein synthesised by the liver in response to inflammation, infection, tissue injury and various pathological conditions. Owing to the rapid rise and decline in its concentration during inflammatory processes, CRP is widely used in clinical practice as a sensitive biomarker for the diagnosis, monitoring and prognosis of inflammatory diseases (Pepys & Hirschfield, 2003). Accurate measurement of CRP is therefore essential for appropriate clinical interpretation and patient management. However, several pre-analytical factors may influence laboratory results before the analytical phase begins. Among these factors, blood collection tube type, delays in serum separation and delays in sample analysis are particularly important, as they may alter the biochemical composition of samples and consequently affect test accuracy (Hedayati et al., 2020).

In routine laboratory practice, samples are frequently subject to transportation delays, storage before analysis or variations in sample handling procedures due to workload and logistical limitations. In tropical countries such as Sri Lanka, high environmental temperatures may further accelerate cellular metabolism and biochemical reactions in unseparated blood samples, potentially affecting analyte stability. Although serum separator gel tubes and plain tubes are commonly used for CRP estimation, evidence regarding their comparative performance and the influence of delayed processing remains limited. Therefore, this study aimed to evaluate the impact of tube type and delayed analysis on serum CRP levels by comparing CRP concentrations obtained from gel and plain tubes, assessing the effects of delayed serum analysis under different storage conditions and determining the influence of delayed serum separation on CRP measurements.

Methodology

This study was designed as a controlled laboratory experiment to evaluate the effects of blood collection tube type and delayed sample processing on serum CRP measurements. The study population consisted of 36 healthy volunteers (12 men and 24 women) aged between 20 and 26 years, recruited from the Department of Medical Laboratory Sciences, University of Sri Jayewardenepura. Participants with conditions or exposures that could influence immune responses or metabolic activity, such as recent vaccination, medication use, acute illness, smoking, pregnancy, blood transfusion, hospitalisation, surgery, trauma or hormonal therapy, were excluded to minimise confounding and to ensure a relatively homogeneous study population. A total of 36 participants were recruited to account for possible sample loss and to ensure adequate statistical power for repeated measurements

performed at multiple time intervals. Ethical approval was obtained from the Research Ethics Review Committee, Faculty of Allied Health Sciences, University of Sri Jayewardenepura (REC/AHS/25/101), prior to the commencement of the study. All participants provided written informed consent, and confidentiality was maintained throughout the study by not collecting personal identifiers.

From each participant, 5 mL of venous blood was collected and distributed equally into one serum separator gel tube (G1) and three plain tubes with clot activator (P1, P2 and P3). CRP analysis was performed using the Dimension Clinical Chemistry System with the Siemens Healthcare Diagnostics CRP assay, based on the particle-enhanced turbidimetric immunoassay (PETIA) principle, in which CRP molecules react with antibody-coated particles to produce aggregation and increased turbidity proportional to the CRP concentration (Wei et al., 2000).

For the first objective, G1 and P1 were centrifuged immediately after clot formation; serum from G1 was transferred into one Eppendorf tube, while serum from P1 was aliquoted into three Eppendorf tubes (Pa, Pb and Pc), each containing 100 µL of serum. CRP measurements obtained from G1 and Pa were analysed within two hours to compare CRP levels between gel and plain tubes. For the second objective, the separated serum aliquots from P1 were analysed under different storage conditions to evaluate the effect of delayed serum analysis: Pa was analysed within two hours, Pb was stored at room temperature for six hours before analysis, and Pc was stored at 2–8 °C for 24 hours before analysis. For the third objective, the remaining plain tubes (P2 and P3) were stored as unseparated whole blood samples at room temperature for two and six hours, respectively, before centrifugation. Following centrifugation, serum was transferred into Eppendorf tubes labelled P2h and P6h and analysed to determine the effect of delayed serum separation on CRP stability. In total, six CRP measurements were obtained from each participant, generating 216 test values. The limit of detection (LOD) of the assay is 0.5 mg/L.

Data were entered into Microsoft Excel and analysed using the Statistical Package for the Social Sciences (SPSS), version 25. Boxplot analysis was performed to identify outliers, resulting in the exclusion of five samples and a final analytical sample of 31 participants. Data normality was assessed using the Shapiro–Wilk test. On the basis of the distribution of the data, the Wilcoxon signed-rank test, repeated-measures analysis of variance (ANOVA) and the paired *t*-test were applied for objectives one, two and three, respectively.

Results and Discussion

Serum CRP concentrations measured in serum separator tubes and plain tubes differed significantly (p = .002), indicating that tube type affected CRP measurements. CRP concentrations were generally higher in serum separator tubes (0.88 ± 0.264 mg/L) than in plain tubes (0.76 ± 0.268 mg/L). This finding implies that blood collection tube selection should be standardised to ensure accurate CRP measurement and interpretation.

Delayed serum analysis after serum separation did not produce a statistically significant difference in CRP concentrations (p = .449). The mean concentrations were 0.7645 ± 0.26777 mg/L for immediate analysis, 0.8226 ± 0.31592 mg/L after 6 hours at room temperature and 0.7258 ± 0.31830 mg/L after 24 hours of refrigerated storage, indicating that CRP remains relatively stable after serum separation under the conditions studied.

Conversely, serum CRP concentrations were significantly affected by delayed serum separation (p = .004). Higher CRP concentrations were found in samples that were in contact with blood cells for 6 hours prior to centrifugation (0.87 ± 0.269 mg/L) than in samples separated after 2 hours (0.73 ± 0.316 mg/L), indicating that delayed processing may compromise analytical accuracy. The findings regarding the effect of tube type on serum CRP levels and of delayed analysis after serum separation were consistent with previous studies (Chang et al., 2003; Hedayati et al., 2020). In contrast, the findings related to delayed serum separation differed from those reported in previous studies conducted in non-tropical countries (Tanner et al., 2008). This disparity may reflect differences in environmental conditions, such as the tropical climate.

Conclusions and Implications

CRP levels measured in gel tubes differed significantly from those measured in plain tubes. Delayed analysis after serum separation did not significantly affect CRP levels within the time intervals studied. However, delayed serum separation significantly influenced CRP measurements, emphasising the importance of timely centrifugation and serum separation. The findings underline the importance of standardised pre-analytical procedures, including the use of consistent blood collection tube types and timely serum separation, to ensure reliable CRP measurements. They also support the development of standardised specimen handling protocols and provide evidence for optimising laboratory practices in tropical settings. Larger studies incorporating replicate measurements, participants with a wider range of CRP concentrations, different analytical platforms and the assessment of potential confounding factors such as body mass index (BMI) are required to confirm these findings.

Keywords**:** C-reactive protein, delayed serum analysis, delayed serum separation, plain tube, serum separator tube

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Prevalence of Anaemia among Adolescents in Jaffna District

Sivakaran M.[1,*], Arasaratnam V.[2] and Surenthirakumaran R.[3]
[1]*Unit of Home Economics, Faculty of Arts, University of Jaffna, Sri Lanka,* [2]*Department of Biochemistry, Faculty of Medicine, University of Jaffna, Sri Lanka,* [3]*Department of Family and Community Medicine, Faculty of Medicine, University of Jaffna, Sri Lanka*
*Corresponding author (email: jmenakaj@yahoo.com)

Introduction

Adolescence is a critical period of rapid growth and development. The increased nutritional requirements of this stage can heighten vulnerability to nutritional anaemia. Iron deficiency is an important cause of anaemia and may adversely affect growth, cognitive function and well-being. A previous study in the Tellipalai Medical Officer of Health (MOH) area of Jaffna reported a high prevalence of anaemia among adolescent students (Kandeepan et al., 2016). However, updated evidence on anaemia and iron deficiency anaemia among adolescents across Jaffna District is limited. Therefore, this study aimed to assess the prevalence of anaemia and iron deficiency anaemia and to examine their associations with selected sociodemographic and dietary factors among adolescents aged 17–19 years in Jaffna District.

Methodology

A descriptive cross-sectional study was conducted among adolescents aged 17–19 years in Jaffna District over a one-year period from June 2024 to May 2025. Ethical approval was obtained from the Ethics Review Committee, Faculty of Medicine, University of Jaffna. A total of 752 adolescents were included in the analysis. Sociodemographic information was collected using an interviewer-administered questionnaire. Following written informed consent, 5 mL of venous blood was collected from each participant. Haemoglobin (Hb), serum ferritin and C-reactive protein (CRP) were measured. Dietary information was collected using a food diary and a food-frequency questionnaire. Anaemia severity was classified according to the sex-specific Hb criteria used in the study. Iron deficiency anaemia was identified using a serum ferritin concentration of < 15 µg/L among participants without inflammation (CRP < 5 mg/L) and of < 30 µg/L among those with elevated CRP (CRP ≥ 5 mg/L).

Results and Discussion

Of the 752 adolescents, 51.1% were male and 48.9% were female. The mean age was 18.04 (±0.80) years, with mean ages of 18.01 (±0.04) years among males and 18.07 (±0.04) years among females. The mean Hb concentration was 13.2 (±1.2) g/dL. Mild anaemia was the most prevalent category (20.2%), followed by moderate anaemia (11.9%), while severe anaemia was uncommon (0.7%). Female adolescents had a higher burden of mild and moderate anaemia than males. This finding is consistent with national evidence showing a higher prevalence of anaemia and poorer iron status among female Sri Lankan secondary-school students, with female sex identified as an important risk factor for iron deficiency (Allen et al., 2017). The higher burden among females may be related to increased iron requirements and menstrual iron losses during adolescence.

Iron deficiency anaemia was identified in 82 adolescents (11.8%), demonstrating that iron deficiency constitutes an important component of the anaemia burden in this population. This prevalence is higher than the 3.9% iron deficiency anaemia estimated in a large national survey of Sri Lankan secondary-school students, although differences in study population, age distribution, sampling and laboratory indicators should be considered when making comparisons (Allen et al., 2017). The earlier Tellipalai study also reported a substantial burden of anaemia among adolescents in Jaffna, supporting the continued importance of adolescent anaemia in the district (Kandeepan et al., 2016). A statistically significant difference in anaemia prevalence was observed across Divisional Secretariat divisions (p = .01), indicating geographical variation within Jaffna District. In addition, anaemia was significantly associated with milk consumption (p = .04), while iron deficiency anaemia was significantly associated with fish consumption (p = .01) and egg consumption (p = .03). These findings indicate that dietary practices may be relevant to adolescent iron status. However, because the study was cross-sectional, the observed associations should not be interpreted as causal relationships. Further studies incorporating detailed dietary nutrient intake and other determinants of anaemia would help to clarify these relationships.

Conclusions and Implications

Anaemia and iron deficiency anaemia remain important nutritional concerns among adolescents aged 17–19 years in Jaffna District, with a greater burden of mild and moderate anaemia among females. Significant geographical variation and associations with selected dietary factors highlight the need for context-specific nutrition interventions. Strengthening nutrition education, promoting dietary diversity and the consumption of iron-rich foods, and implementing regular screening may contribute to reducing adolescent anaemia.

Keywords**:** Adolescents, haemoglobin, iron deficiency anaemia, Jaffna, serum ferritin

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Users' Perceptions and Experiences of Jogging Paths: A Case Study of Madiwela Jogging Path

Weerakoon W.M.T.S.* and Rajapaksha R.M.S.P.
Faculty of Indigenous Social Sciences and Management Studies, Gampaha Wickramarachchi University of Indigenous Medicine, Sri Lanka
*Corresponding author (email: thiwanthisweerakoon@gmail.com)

Introduction

Urban green spaces such as jogging paths play an important role in supporting physical health, psychological well-being, social interaction and community engagement. Previous research has shown that environmental qualities, such as greenery, accessibility, safety, aesthetics and social conditions, influence how people use and experience urban recreational spaces (Gao & Fang, 2025; Huang et al., 2024). Existing studies have primarily examined stress reduction, infrastructure, environmental characteristics and perceptions of walking avenues, while providing limited insight into users' personal motivations, emotional experiences, social relationships and the meanings attached to jogging path use (Fernando, 2021; Wickramaarachchi et al., 2021). Therefore, this study explores users' perceptions and experiences of the Madiwela Jogging Path, an accessible urban recreational space used by diverse groups at different times of the day. The study aimed to examine users' perceptions of the path's physical, social and environmental characteristics; to identify the main reasons and motivations for its use; to explore how demographic and user characteristics shape experiences; and to generate practical insights for inclusive and user-responsive urban recreational planning.

Methodology

The study adopted an interpretivist philosophy and a qualitative case study design to explore users' meanings, experiences, motivations and perceptions of the Madiwela Jogging Path in the Western Province of Sri Lanka. Purposive sampling was used to recruit 40 users, comprising 10 males and 30 females from different age groups and usage patterns, including morning, evening and night-time users. Data were collected over four weeks through semi-structured interviews and non-participant observations. Interviews were conducted in Sinhala, recorded with consent, and transcribed and translated where necessary. They explored users' motivations, perceptions, emotional experiences, social interactions, facility use, safety concerns and suggestions for improvement. Observations conducted during morning, evening and night-time periods examined user behaviour, activity patterns, social interactions, facility use and environmental conditions, complementing the interview findings.

Data were analysed using thematic analysis following Braun and Clarke (2006), involving familiarisation, coding, theme development and review, and interpretation. Five interconnected themes were identified: time-based patterns of use; physical and mental well-being; social and community engagement; creative and intellectual uses of the jogging path; and environmental, safety and accessibility concerns. Credibility was enhanced by triangulating interview and observation data.

Results and Discussion

The findings demonstrate that the Madiwela Jogging Path functions as a multifunctional urban recreational space rather than merely a place for physical exercise. Users attached different meanings and purposes to the space according to their age, daily routines, interests and time of use. The results are presented below under the five themes.

With regard to time-based patterns of use, three distinct patterns emerged across morning, evening and night-time use. Morning users, particularly older and health-conscious participants, valued the cool weather, fresh air, exercise, safety and social interaction. Observations showed group exercises, conversations, community activities, cleaning initiatives, charity activities and other collective events, indicating that regular use can encourage community participation and collective care. This reflects Place Attachment Theory, as repeated use and meaningful social experiences can strengthen emotional connections with the jogging path. Evening users, particularly working adults and parents, mainly used the path for stress relief, exercise, relaxation and family time. Night-time users valued the quieter environment for solitude, reflection, music and emotional relaxation. However, inadequate lighting and limited security created safety concerns, particularly among female users in less crowded areas.

In terms of physical and mental well-being, physical health was an important motivation, with participants describing walking and exercise as ways to maintain fitness, manage health concerns and support healthy lifestyles. Beyond the physical benefits, greenery, fresh air, ponds and calm surroundings helped users to reduce stress, relax, improve their mood and recover mentally from daily pressures. These experiences are consistent with Stress Recovery Theory (Ulrich, 1983), suggesting that the natural environment supports psychological recovery and emotional restoration.

Regarding social and community engagement, the jogging path provided opportunities to meet friends, participate in group exercise, spend time with family and engage in community activities. Morning users demonstrated particularly strong community engagement through group exercises, cleaning activities, charity programmes, celebrations and other social events. These activities transformed the jogging path into a shared community space and contributed to users' sense of belonging and place attachment.

Creative and intellectual uses of the path constituted a distinctive finding, as users engaged in activities beyond exercise. Younger users participated in painting, craft making, photography and listening to music, while older adults used the space for reading, meditation and quiet reflection. These findings indicate that urban recreational spaces can support creative expression, intellectual relaxation, emotional comfort and healthy ageing in addition to physical activity.

Finally, concerning environmental, safety and accessibility issues, participants valued the greenery, natural scenery, fresh air and accessibility of the jogging path but identified concerns regarding inadequate lighting and safety, waste management, insufficient seating, the lack of toilets, maintenance and limited accessibility for people with

disabilities. These findings highlight the importance of both natural qualities and inclusive physical infrastructure in maximising the benefits of the jogging path.

Conclusions and Implications

The central finding of this study is that the Madiwela Jogging Path is experienced as a multifunctional urban recreational space in which physical activity, psychological recovery, social connection, creative expression and everyday leisure are interconnected. Natural and social qualities, including greenery, fresh air, calm surroundings, physical activity and social interaction, contribute to users' well-being and connection with the place. However, safety and accessibility remain important concerns, particularly for night-time users and people with disabilities.

The findings have practical implications for urban planners, local authorities and policymakers. Improving lighting and security, accessible toilets, seating, waste management, maintenance and wheelchair-friendly pathways could enhance comfort and inclusivity. Protecting greenery, planting trees and providing spaces for reading, reflection and meditation could further strengthen the recreational and psychological value of the space. Community-based activities and volunteer initiatives could also strengthen users' sense of ownership and collective responsibility. As a qualitative case study of one jogging path involving 40 participants, the findings are context-specific and cannot be generalised to all urban recreational spaces in Sri Lanka. Future research could compare jogging paths in different urban settings and examine differences in user experiences across age, gender and other characteristics.

Keywords**:** Community engagement, Madiwela Jogging Path, mental well-being, urban green spaces, users' perceptions

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Burnout Among School Counsellors: A Narrative Review of Theoretical Perspectives, Antecedents, Consequences, and Prevention Strategies

Liyadipita H.[1,*] and Herath S.[2]
[1]*University of Vocational Technology, Sri Lanka,* [2]*Lincoln University College*
*Corresponding author (email: hansaniliyadipita@12gmail.com)

Introduction

The issue of school counsellor burnout extends beyond individual occupational well-being and has implications for the sustainability of counselling services in educational settings. School counsellors have various professional responsibilities and duties that contribute to the academic, career, social and emotional development of learners (American School Counselor Association [ASCA], 2012; Borders, 2002; Dahir & Stone, 2009). As these responsibilities continue to increase, school counsellors face growing occupational demands, including heavy workloads, ambiguous role expectations, clerical responsibilities and the need to address complex student issues. When these difficulties persist over time without adequate administrative support, they lead to burnout, which has become one of the most important occupational challenges in the school counselling profession (McCarthy et al., 2010; Murray, 2010; Wilkerson & Bellini, 2006).

Although burnout among school counsellors has received considerable academic attention, the evidence remains fragmented across theoretical perspectives, antecedents, consequences and prevention. Furthermore, the majority of studies examine isolated predictors and relationships rather than providing an integrated understanding of burnout as a complex occupational phenomenon. The current narrative review aims to address this gap by synthesising the existing literature on theoretical perspectives, antecedents, consequences and prevention strategies related to burnout among school counsellors. It integrates theoretical and empirical evidence to examine the conceptual foundations of burnout, major theoretical perspectives, antecedents, consequences and protective factors, and to highlight the importance of future research. The review thus aims to provide an understanding of the concept of burnout while identifying recommendations for educational policy, counselling practice and future scholarly investigation. It contributes to the existing literature by bringing together theoretical explanations, antecedents, consequences and prevention strategies related specifically to burnout among school counsellors within a single narrative synthesis. Rather than considering burnout only as an individual psychological outcome, the review considers the interaction between individual, professional, organisational and contextual factors that may influence counsellor well-being.

Methodology

The study used a narrative review methodology. Electronic databases, namely Scopus, Web of Science, PsycINFO, ERIC, Education Source, PubMed and Google Scholar, were searched to identify relevant published literature. Additional publications were identified through backward citation searching of seminal studies and major review articles. The search used combinations of keywords and Boolean operators related to the central

concepts of the review, including "school counsellor/school counselor", "burnout", "professional wellbeing", "emotional exhaustion", "counselling", "school counselling" and "burnout prevention". Seminal works by Maslach, Bandura and the American School Counselor Association were included together with recent studies to capture both the historical development and the current understanding of burnout. The data gathered were synthesised thematically. The main themes across the literature were the concept of burnout, theoretical explanations of burnout, the developing role of school counsellors, the antecedents of burnout, the significance of burnout, prevention strategies, and gaps in the research and future directions in the area.

Results and Discussion

The synthesis of the reviewed literature identified several interconnected themes associated with burnout among school counsellors. These themes were organised into four broad areas: the antecedents of burnout, the consequences of burnout, factors influencing professional well-being, and prevention and intervention strategies.

With regard to the nature of burnout, the reviewed literature indicates that school counsellor burnout is associated with a combination of individual, occupational and organisational factors. Burnout is a common consequence of continuing occupational tension, especially among professionals. Maslach et al. (2001) explained that burnout comprises three significant dimensions: emotional exhaustion, depersonalisation and reduced personal accomplishment, that is, feeling less effective in the job (Maslach & Jackson, 1981, 1996; Maslach et al., 2001). Emotional exhaustion is the fundamental component of burnout, reflecting counsellors' feelings of being emotionally drained after continued exposure to challenging interactions. Depersonalisation is emotional distancing from pupils and colleagues, frequently manifesting as reduced empathy or the discontinuation of professional relationships. Reduced personal accomplishment reflects declining confidence in one's professional effectiveness despite continuous effort. Although Maslach's model is considered the principal framework for understanding burnout, recent literature presents burnout as a multidimensional phenomenon interconnected with individual, institutional and environmental factors (Maslach & Leiter, 2008). Across the reviewed literature, burnout appeared to be influenced by multiple interacting factors rather than by a single cause. The findings therefore support an understanding of school counsellor burnout as a multidimensional occupational and organisational issue requiring responses at the individual, professional, organisational and systemic levels.

In terms of theoretical perspectives, the theoretical foundation for explaining the concept of burnout is Maslach's multidimensional theory, whereas Bandura's theory explains individual differences in the experience of burnout. According to Bandura (1977, 1993, 2006), counsellors with strong self-efficacy are better able to overcome workplace obstacles and stress. Accordingly, higher self-efficacy consistently acts as a protective mechanism against burnout (Bodenhorn & Skaggs, 2005; Gündüz, 2012). The stress–strain–coping framework holds that burnout results from continuous occupational stress

unless this stress is effectively managed through adaptive coping strategies (Wilkerson, 2009). Similarly, the job demands–resources (JD-R) model proposes that burnout arises when workplace demands exceed the available organisational support.

Turning to antecedents, the existing literature highlights that burnout among school counsellors is not attributable to a single factor but develops through the interaction of individual, organisational and environmental factors. At the individual level, self-efficacy is the most important factor to be considered in managing burnout among counsellors, as it reduces emotional fatigue and improves counsellors' professional achievement (Bandura, 1977, 1993, 2006; Bodenhorn & Skaggs, 2005; Bodenhorn et al., 2010; Gündüz, 2012). Similarly, flexibility, emotional aptitude, adaptive management strategies and professional capability promote counsellor well-being, while maladaptive coping, perfectionism, low professional self-confidence and poor emotional regulation increase the risk of burnout. However, the literature indicates that the effectiveness of these individual resources depends heavily on supportive institutional contexts.

The review identified organisational (institutional) factors as the most important contributors to burnout among school counsellors. Heavy workloads, high counsellor-to-student ratios, role ambiguity, administrative responsibilities, limited professional autonomy, inadequate supervision and insufficient organisational support consistently increased emotional exhaustion and professional disengagement (Kolodinsky et al., 2009; McCarthy et al., 2010; Wilkerson & Bellini, 2006). Conversely, supportive leadership, collaborative work environments, effective supervision, professional recognition and manageable workloads were found to reduce burnout among counsellors.

The literature further indicates that environmental factors intensify burnout. Increasing student mental health needs, changes in educational accountability, socio-economic difficulties and community expectations have made the school counsellor's role more demanding. However, schools with cooperative cultures, active leadership and comprehensive counselling programmes were able to mitigate the adverse impacts of these environmental stressors. The review also found that the significance of burnout extends beyond individual counsellors. Burnout contributes to emotional fatigue, anxiety, distress, reduced job satisfaction, compassion fatigue, a weakened professional identity and increased intentions to leave the profession (Lawson & Myers, 2011; Lee et al., 2010; Lent & Schwartz, 2012). It also reduces counsellors' capacity to provide effective student support, lowers the effectiveness of counselling programmes, increases staff turnover and ultimately affects students' well-being and educational performance. Furthermore, the literature highlights that burnout is preventable through comprehensive, multi-level interventions. Individual protective factors such as resilience, self-efficacy, emotional intelligence, adaptive coping and self-care support counsellor well-being. Administrative measures such as supportive leadership, qualified supervision, manageable workloads, increased autonomy and adequate counselling resources were recognised as the most effective protective mechanisms. At the policy level, establishing suitable counsellor-to-student ratios, developing school mental health infrastructure, and developing general

counselling standards and codes are crucial for the sustainable prevention of counsellor burnout.

Conclusions and Implications

This review identifies significant gaps in the literature and corresponding recommendations. Existing studies rely mainly on cross-sectional designs and self-report measures, which limits understanding of the causal mechanisms and long-term development of burnout. Future studies are therefore recommended to use longitudinal and mixed-methods designs to gain a thorough understanding of burnout over time, and future research needs to adopt wider theoretical perspectives.

The findings indicate that effective burnout prevention should extend beyond individual coping and self-care. Sustainable responses require supportive organisational environments, manageable workloads, clear professional roles, access to supervision and professional development, adequate resources, and mechanisms that promote counsellor well-being. Strengthening these conditions is important not only for protecting school counsellors but also for maintaining the long-term capacity of schools to provide effective psychosocial and emotional support to students. Future empirical research should examine school counsellor burnout across diverse educational contexts and investigate the effectiveness of organisational and systemic interventions. Greater attention to counsellor well-being as a component of sustainable school support systems may contribute to more resilient counselling services and improved continuity of student support.

Keywords**:** Burnout, counselling, professional well-being, school counsellors, sustainability

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Digital Transformation in Museum Management: Challenges and Opportunities in Sri Lanka

Priyangana T.D.S.G.*
School of Cultural Industries, Nanjing University of the Arts, China
*Corresponding author (email: sureshpriyangana1986@gmail.com)

Introduction

The current era has brought a significant shift towards the application of technologies within institutions, known as digital transformation. This process can be understood as an organisational transformation that creates added value through the use of digitally enabled systems (Han, 2026). Museums are changing from solely collection-based institutions into visitor-based ones that embrace the concepts of access, participation, and collaboration (Nikolaou, 2024). In the digital era, museums can maintain, manage, and distribute cultural heritage using digital technologies such as databases, artificial intelligence (AI), augmented reality (AR), and virtual reality (VR) (Li et al., 2024).

Sri Lankan museums have started to engage with digital technologies as part of the modernisation of cultural institutions. Several government interventions and initiatives have been reported, including digital libraries and a digital encyclopaedia of archaeology (Ministry of Cultural Affairs, 2025). However, limitations related to funding, infrastructure, trained personnel, and organisational capacity remain barriers to the full implementation and sustainability of digital initiatives. Therefore, this study investigates the opportunities and challenges of digital transformation in Sri Lankan museums. It examines current digital practices and proposes practical measures to support sustainable digital transformation and the preservation of cultural heritage.

Accordingly, the study addresses four research questions: what opportunities digital technologies provide for museum management and cultural heritage preservation; what challenges affect their adoption; what digital technologies are currently used in Sri Lankan museums; and what measures can support sustainable digital transformation. The study provides empirical insight into the current stage of digital transformation in Sri Lankan museums, showing that practices focus on basic digital documentation and collection management, while the use of advanced technologies such as three-dimensional (3D) scanning is limited.

Methodology

A qualitative research approach was used to examine the opportunities, challenges, and current practices of digital transformation in Sri Lankan museums. This approach was appropriate because the study aimed to understand the experiences and perspectives of professionals involved in museum management, heritage, archaeology, and digital technology. Primary data were collected through recorded semi-structured interviews with 10 participants: one museum director, two museum superintendents, two museum officers, two archaeologists, two information technology (IT) officers, and one academic. The participants were selected on the basis of their professional knowledge and their involvement in museum, heritage, archaeological, or digital activities in Sri Lanka. The

interviews focused on four areas: opportunities offered by digital technologies, challenges and barriers, current digital practices, and recommendations for sustainable digital transformation. Secondary data were obtained from academic literature, museum reports, government reports, and policy documents. The interview and documentary data were analysed thematically by coding and grouping the findings into themes on current practices, opportunities, challenges, and future directions.

Results and Discussion

With regard to current practices, the interview findings indicate that digital transformation in the Sri Lankan museums examined currently focuses on digital documentation, collection management, conservation monitoring, visitor engagement, and security. Information on museum collections is entered into digital databases, and objects are documented through high-resolution photography. Digital images and related information are stored and managed through digital systems and cloud storage, supporting efficient documentation, management, and retrieval. However, 3D scanning has not yet been implemented, although 3D modelling and other advanced technologies are recognised as potential future applications. Digital environmental monitoring, including data loggers, records temperature, relative humidity, and light levels for preventive conservation. Automatic or plug-switch controls support environmental and lighting management. Digital screens and audio guides engage visitors, and closed-circuit television (CCTV) supports museum security. An online ticketing system is being developed, while participants identified quick response (QR) codes and barcodes as potential future tools for object identification and access to information.

Turning to opportunities, the findings reveal important prospects for digital transformation in Sri Lankan museums. Digitalisation can improve collection management by enabling digital catalogues and databases to record, store, retrieve, and manage collection information more systematically than traditional paper-based systems (Li et al., 2024). High-resolution photography provides detailed visual documentation for research, management, and preservation, and cloud storage can support the management of digital collection information.

Digitalisation can also expand public access through websites, digital archives, online exhibitions, and other platforms. The digitisation of the National Museum Herbarium, Sri Lanka, provides an example of improved access to, and management of, information related to a research collection (Ministry of Cultural Affairs, 2025). Websites, social media, virtual exhibitions, QR codes, and digital archives can further strengthen museum communication, audience development, and awareness of Sri Lankan cultural heritage.

Digital monitoring technologies offer opportunities for preventive conservation by enabling museum professionals to monitor temperature, relative humidity, and light levels. Digital screens and audio guides can enhance visitor engagement, and QR codes and barcodes provide convenient access to information about individual objects. AI, VR, and AR represent potential future applications: AI can support image identification and

museum guidance, while AR and VR can provide interactive experiences and support the reconstruction of historical environments and cultural events (Li et al., 2024).

Regarding challenges and barriers, the findings identified several significant challenges affecting digital transformation. Financial limitations are a major barrier because digitisation requires investment in equipment, software, high-resolution photography, digital storage, network infrastructure, cybersecurity, and maintenance. Limited resources may restrict long-term digital programmes.

The scarcity of trained personnel is a major concern. Participants highlighted the need for expertise in digital documentation, databases, digital preservation, information and communication technology (ICT) infrastructure, and emerging technologies. The Museum Department lacks a specialised digital or ICT team, and expertise in ICT infrastructure and digital museum technologies is limited within the relevant government institutions.

Infrastructure limitations, such as inadequate technological equipment, internet connectivity, storage capacity, and technical support, can affect implementation. Sustainability is a further concern because digital systems require continuous upgrading and maintenance, and rapid technological change can cause obsolescence and additional costs. Participants also highlighted the need for institutional coordination and common standards for digitisation, documentation, storage, and digital preservation.

Ethical, copyright, and intellectual property issues require attention as museums increase digital access to cultural heritage. Questions about the ownership, copyright, access, and appropriate use of digital representations need to be addressed, and Sri Lanka lacks a national standard or policy framework to guide digital museum and heritage work. Sustainable digital transformation therefore requires not only the acquisition of technology but also adequate funding, skilled personnel, appropriate infrastructure, long-term maintenance, institutional coordination, ethical frameworks, and supportive national policies.

Conclusions and Implications

Digital transformation offers significant opportunities for Sri Lankan museums in collection management, cultural heritage preservation, preventive conservation, visitor engagement, communication, and security. The museums examined use digital collection databases, high-resolution photography, cloud storage, data loggers, environmental monitoring systems, digital screens, audio guides, and CCTV. However, 3D scanning has not yet been implemented.

The findings suggest that sustainable transformation should strengthen existing digital foundations such as collection databases, digital documentation, storage, environmental monitoring, and visitor-oriented technologies. Websites, social media, virtual exhibitions, QR codes, and digital archives can improve public access to, and awareness of, Sri Lankan cultural heritage, and online ticketing can enhance museum services.

Strengthening human-resource capacity is essential. The Museum Department should develop specialised digital and ICT expertise and provide training in digital documentation, databases, digital preservation, and ICT infrastructure. Engagement with external consultants and technical service providers should also be strengthened. National standards and policy guidance are needed to support consistent practices in digital documentation, preservation, data management, copyright, and intellectual property.

With these foundations in place, museums can explore 3D scanning, 3D modelling, AR, VR, and AI. Sustainable digital transformation requires appropriate technology, skilled personnel, infrastructure, funding, policy support, and professional collaboration.

Keywords**:** Cultural heritage preservation, digital transformation, museum management, Sri Lanka, visitor engagement

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Labour Market Conditions and Graduate Human Capital Utilisation: Evidence From Sri Lankan Commercial Banks

Lankathilaka L.S.P.*
Career Guidance Unit, University of Peradeniya, Sri Lanka
*Corresponding author (email: sumulanka7@gmail.com)

Introduction

Education plays a prominent role in shaping the socio-economic dimensions of countries; this applies particularly to higher education, which equips young people with the qualifications needed to pursue diverse job opportunities (Tavares et al., 2023). Sri Lanka produces a considerable number of graduates each year through public universities, private higher education institutions and specialised education providers; according to the University Grants Commission (2023), 33,306 students graduated from state universities in 2023. However, labour market expansion has not matched the increase in graduate output, resulting in unemployment, underemployment, skill mismatches and limited career development opportunities (Amarasinghe, 1996; Senarath & Patabadige, 2014), and unemployment has been rising among young, educated people (Wongnaa & Seyram, 2014). Returns on investment in education are a widely investigated area, as such returns are not always realised, especially in the case of university education, which is not provided free of charge in most developed and developing countries (Aysha & Sulaiha Beevi, 2022).

Human capital is a major factor in the development of individuals, organisations and countries (Weligamage, 2023). In today's business world, human capital is a competitive tool considered by every organisation (Rahman & Akhter, 2021), and human capital utilisation refers to the effective application of employees' education, knowledge, skills and competencies to enhance organisational productivity and performance (Becker, 1964; Schultz, 1961). In knowledge-intensive industries, organisations depend heavily on the effective utilisation of employees' capacities to maintain effectiveness and sustainability.

The banking sector plays a vital role in the Sri Lankan economy, and commercial banks play a major role within that sector (Kobika, 2018). The commercial banking sector employs a considerable number of graduates in finance, management, information technology, human resources and customer relationship management. Nevertheless, concerns remain as to whether graduate employees are able to utilise their competences fully, owing to role uncertainty, workload pressures, limited opportunities for professional growth, and mismatches between academic qualifications and job responsibilities. In reality, qualifications alone are not sufficient to secure a job because of the mismatch between demand and supply in the job market. Consequently, some graduates must take up unrelated jobs, mostly at low salaries, while others remain unemployed and wait for long periods, often until the government provides opportunities (Aysha & Sulaiha Beevi, 2022). Previous Sri Lankan studies have focused mostly on graduate unemployment, employability and skill mismatch, while limited empirical evidence exists on the relationship between labour market conditions and human capital utilisation in the

banking sector. Therefore, this study aims to examine whether labour market conditions significantly influence human capital utilisation among graduate employees in Sri Lankan commercial banks.

Methodology

This study adopted a quantitative, cross-sectional survey design to examine the relationship between labour market conditions and human capital utilisation among graduate employees in the Sri Lankan commercial banking sector. The sample comprised 156 graduate employees working in Sri Lankan commercial banks. Primary data were collected through a structured, self-administered questionnaire. Labour market conditions were conceptualised as the independent variable and operationalised through two dimensions: perceived underemployment and unemployment perception. Perceived underemployment was measured using nine items adapted from the Scale of Perceived Overqualification developed by Maynard et al. (2006), and unemployment perception was measured using five items adapted from Bhat et al. (2023). Human capital utilisation was the dependent variable and was operationalised through three dimensions: education (five items), knowledge (four items) and skills (six items). The measurement framework was informed by the human capital investment perspective, which emphasises education, knowledge and skills as key components of human capital. All items were measured on a five-point Likert scale, based on this framework and the Human Capital Investment Model (Rahman & Akhter, 2021). Reliability was assessed using Cronbach's alpha, and all constructs recorded values above .70, indicating acceptable internal consistency. The data were analysed using descriptive statistics, Pearson correlation analysis and multiple regression analysis.

Results and Discussion

The descriptive statistics indicated a moderate level of labour market constraints among the respondents (n = 156). The mean value was 2.94 for underemployment and 3.01 for unemployment perception, and the overall labour market conditions score was 2.97. In contrast, human capital utilisation recorded a relatively high mean value of 3.75, suggesting that employees generally perceived their education, knowledge and skills to be effectively utilised within their organisations.

Pearson correlation analysis revealed very weak associations between labour market conditions and human capital utilisation. The overall relationship between labour market conditions and human capital utilisation was negligible (r = −.004). Underemployment showed a negligible negative relationship with human capital utilisation (r = −.056), while unemployment perception showed a negligible positive relationship (r = .086).

The multiple regression analysis indicated that neither underemployment (β = −.078, p > .05) nor unemployment perception (β = .090, p > .05) had a statistically significant effect on human capital utilisation. The model explained only 1.6% of the variance in human capital utilisation (R^2 = .016), indicating that labour market conditions have limited explanatory power in predicting the effective utilisation of graduate employees' capabilities.

Conclusions and Implications

The study finds that labour market conditions, including underemployment and unemployment perception, have a limited direct impact on human capital utilisation among graduate employees in Sri Lankan commercial banks. Although the statistical relationships were weak, the positive coefficient observed for unemployment perception suggests that graduates who are more aware of labour market competition may make greater efforts to utilise and develop their skills in the workplace. Despite moderate labour market challenges, employees reported relatively high levels of utilisation of their education, knowledge and skills.

The results indicate that organisational factors, including well-defined job responsibilities, employee preparation and development programmes, performance management systems and supportive workplace structures, play a more significant role in improving human capital utilisation than external labour market conditions. Accordingly, banking institutions should adopt organisational strategies that align employees' qualifications and competencies with job requirements in order to increase the utilisation of graduate human capital.

Keywords**:** Banking sector, human capital utilisation, labour market conditions, underemployment, unemployment perception

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Anuradhapura Beyond Pilgrimage: Branding a Sacred Heritage City Through Stakeholder Perspective

Weerawansa S.R.S.D.K.[1,*] and Hewage T.U.[2]
[1]*Department of Economics, University of Colombo, Sri Lanka,* [2]*Department of Mathematics, University of Colombo, Sri Lanka*
*Corresponding author (email: shashi@econ.cmb.ac.lk)

Introduction

City branding has become a strategic tool through which urban destinations communicate their unique characteristics, shape external perceptions, and build long-term competitiveness (Anholt, 2006; Kavaratzis, 2004; Kavaratzis & Ashworth, 2006). Much of the city branding literature has focused on large metropolitan centres, commercial hubs, and leisure destinations, particularly in Europe and North America. Comparatively less scholarly attention has been given to sacred heritage cities in the Global South, where branding must balance tourism development with cultural authenticity, religious significance, and heritage conservation. As one of Sri Lanka's ancient capitals and a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage city, Anuradhapura represents the cradle of Sri Lankan Buddhist civilisation and one of South Asia's most important sacred urban landscapes. The city is home to monumental archaeological remains, sacred stupas, monasteries, and the revered Sri Maha Bodhi, which is widely regarded as the oldest historically documented tree in the world. Beyond its religious importance, Anuradhapura also embodies an advanced ancient hydraulic civilisation characterised by irrigation systems, reservoirs, and ecological urban planning.

This study investigates how Anuradhapura can be strategically branded as a tourist destination while preserving its sacred identity and heritage integrity. Specifically, it explores stakeholder perceptions of the city's current image, key brand assets, tourism opportunities, branding challenges, and strategic pathways for sustainable destination development.

Methodology

This study adopted a qualitative research design to explore stakeholder perceptions of Anuradhapura's branding potential as a tourist destination. Qualitative inquiry was appropriate because the study sought to understand perceptions, meanings, experiences, and expert interpretations that cannot be captured fully through quantitative methods (Braun & Clarke, 2006; Hsieh & Shannon, 2005). Primary data were collected through semi-structured interviews with key stakeholders involved in tourism development, destination management, heritage conservation, urban planning, and related sectors. Purposive sampling was used to select respondents with direct knowledge of tourism development, destination management, heritage conservation, and urban planning. Secondary data included relevant documents such as heritage registers, tourism plans, infrastructure development plans, visitor statistics, and media reports. The study also

conducted field observations at religious sites, heritage buildings, transport nodes, and designated UNESCO sites.

Data were analysed using thematic content analysis. Content analysis is a rigorous and widely accepted research method used to identify, categorise, and interpret patterns, themes, meanings, and relationships within textual data (Krippendorff, 2018). The analysis followed a thematic approach in which meaningful units of text were categorised into broader themes derived both from the literature on city branding and from insights emerging directly from the data. This enabled categories to be developed both inductively from the data and deductively from existing theory (Braun & Clarke, 2006; Hsieh & Shannon, 2005). The findings were organised into themes such as the existing image of Anuradhapura, stakeholder branding ideologies, unique brand assets, tourism development opportunities, challenges and constraints, and strategic pathways for implementation.

Results and Discussion

Stakeholders generally viewed Anuradhapura as a city with a distinctive identity rooted in sacred Buddhist heritage, archaeological significance, and national historical importance. However, respondents also felt that the city is currently perceived mainly as a pilgrimage destination rather than as a multidimensional heritage and learning destination. The thematic analysis of the stakeholder interviews, supported by secondary literature, revealed six major themes relating to the branding potential of Anuradhapura as a tourist destination. This worldview is articulated through five branding ideologies, each shaped by distinct stakeholder concerns and constituencies. In this sense, the challenge is not identity creation but identity articulation (Anholt, 2006; Kavaratzis, 2004).

Monumental Buddhist architecture, archaeological significance, sacred pilgrimage value, the Sri Maha Bodhi, and the city's ancient hydraulic civilisation emerged as the main brand assets. Stakeholders observed that Sri Lanka has not fully developed spiritual tourism despite possessing exceptional Buddhist heritage. According to this perspective, tourists frequently visit temples and dagobas but rarely engage with the deeper spiritual meaning of Buddhism, suggesting significant potential for developing tourism experiences centred on meditation, monastic traditions, religious learning, and spiritual reflection. The findings suggest that Anuradhapura's competitive advantage lies in its layered identity as a sacred, historical, ecological, and educational landscape. The strategic task is to clarify and communicate what already exists (Anholt, 2006).

Stakeholders also stressed that branding must support, rather than compromise, heritage protection. Their concerns included the physical degradation of monuments, insensitive infrastructure development, visual pollution around sacred areas, and the commercialisation of sacred landscapes. While conservation-oriented stakeholders focused on preservation, those representing the hospitality sector, tourism businesses, and small and medium-sized enterprises (SMEs) shifted the framing towards tourism as a driver of economic development. Although Anuradhapura receives large numbers of

pilgrims and visitors, many stay only briefly and generate limited economic spillover (Sri Lanka Tourism Development Authority, n.d.). Consequently, this perspective supports branding strategies aimed at increasing the length of stay, diversifying tourism products, increasing visitor expenditure, and supporting local enterprise (Timothy & Olsen, 2006).

Key concerns included the uneven distribution of tourism benefits, the displacement of local residents, cultural commodification, and unsustainable tourism growth. This ideology therefore supports community-centred branding approaches that prioritise local participation and equitable benefits (Garanti et al., 2024). The study also highlights that city branding in sacred destinations must be stakeholder-led. Heritage authorities, Buddhist institutions, local communities, businesses, and tourism agencies all shape brand credibility, and without coordination, branding efforts risk becoming fragmented or commercially shallow (Kavaratzis & Ashworth, 2006; Rainisto, 2003).

Conclusions and Implications

This study demonstrates that Anuradhapura possesses one of the strongest intrinsic place identities among Sri Lankan cities, grounded in its sacred Buddhist heritage, monumental archaeological landscape, UNESCO-recognised heritage assets, and sophisticated ancient ecological knowledge. Anuradhapura's principal challenge lies in communicating and managing its existing identity more strategically while safeguarding the authenticity that underpins its cultural significance. Stakeholder perceptions indicate that the city's tourism potential extends well beyond its established role as a pilgrimage destination. Participants consistently emphasised opportunities to broaden the destination's appeal through spiritual tourism, heritage interpretation, educational tourism, and experiential products that connect visitors with the city's living cultural landscape. At the same time, stakeholders identified several challenges that must be addressed if branding is to support sustainable tourism development, including limited product diversification, fragmented institutional coordination, weak destination marketing, and concerns regarding over-commercialisation.

Taken together, these findings suggest that Anuradhapura's greatest competitive advantage lies in positioning itself as a living civilisational landscape where sacred heritage, spiritual experience, agricultural intelligence, and ancient ecological wisdom converge. Realising this vision, however, requires a strategic approach that integrates destination management, heritage conservation, stakeholder collaboration, and experience design. Based on the findings, five strategic implications emerge.

Keywords**:** Anuradhapura, city branding, heritage tourism, sacred tourism, stakeholder perceptions

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Perceived Usefulness and Trust in AI-Supported Learning: Evidence From Sri Lankan Undergraduates

Wasalthilake W.T.P.* and Munasinghe P.G.
Department of Information Systems, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: prabodhatarini@gmail.com)

Introduction

Generative artificial intelligence tools (GAIT), such as ChatGPT and Google Gemini, are rapidly transforming higher education by reshaping how students access information, complete academic tasks and engage with learning activities (Kasneci et al., 2023). These tools support content generation, conceptual clarification, writing assistance and real-time feedback, thereby enhancing interactive and personalised learning experiences. In developing countries such as Sri Lanka, GAIT have become increasingly important where learning resources are limited and access to academic resources is restricted (Thilakarathna & Godage, 2024). However, concerns remain regarding reliability, ethical use, academic integrity and overdependence on content generated by artificial intelligence (AI) (Kasneci et al., 2023; Weerasinghe & Abeysinghe, 2024).

Students' perceptions of the usefulness and trustworthiness of AI tools significantly influence technology acceptance and learning outcomes (Davis, 1989; Nazaretsky et al., 2025). These perceptions are conceptualised in the Technology Acceptance Model (TAM; Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003), which anchor this study. Trust is a human factor in the integration of AI-based educational technology (Nazaretsky et al., 2022). However, limited empirical evidence exists within the Sri Lankan higher education context regarding how these perceptions shape undergraduate learning experiences. Previous studies have examined AI use (Weerasinghe & Abeysinghe, 2024) and UTAUT-based behavioural intention (Gunasekara & De Silva, 2025), but few have tested usefulness, trust and the willingness to use AI within state universities.

This study aims to examine the impact of perceived usefulness, perceived trust and the willingness to use AI on the learning experiences of Sri Lankan undergraduates using GAIT. Providing evidence from 16 state universities, it extends the usefulness-based logic of TAM by testing trust and willingness together. Testing four hypotheses revealed that each variable positively impacts the learning experience (H1–H3) and that, together, they explain a significant proportion of its variance (H4).

Methodology

This study adopted a quantitative, explanatory, cross-sectional research design to investigate the relationships between the variables, a design suited to testing relationships among Likert-scale perceptions. The population comprised 167,087 state university undergraduates, excluding the Open University of Sri Lanka (University Grants Commission, 2024). The universities were treated as strata, and sample sizes were allocated approximately in proportion to enrolment. Respondents within each stratum

were purposively selected on the basis of their exposure to AI tools (stratified purposive sampling, a non-probability method). The selected sample size of 394 slightly exceeds the 384 given by Cochran's formula (95% confidence level, 5% margin of error), which was used as a reference only.

Data were gathered through a structured, self-administered online questionnaire distributed through Google Forms, using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). The survey began with an information statement explaining that participation was voluntary and that all responses would remain confidential. Items for perceived usefulness (8) and perceived trust (4) were adapted from Davis (1989) and Nazaretsky et al. (2022); items for willingness (6) were adapted from Davis (1989) and Venkatesh et al. (2003); and items for learning experience (6) were developed from the literature on cognitive and emotional engagement (Fredricks et al., 2004) and from expert opinion. Of the 400 questionnaires distributed, all were returned complete (response rate 100%), and six surplus responses were excluded, leaving 394. Respondents were mainly in their second (35.0%), third (30.5%) and fourth (26.9%) years; all used AI tools at least occasionally (71.6% frequently).

The reliability and validity of the measurement scales were assessed using Cronbach's alpha, the Kaiser–Meyer–Olkin (KMO) statistic, Bartlett's test of sphericity, average variance extracted (AVE) and discriminant validity using the Fornell–Larcker criterion. Pearson correlation and multiple regression analyses were conducted, with multicollinearity checked through variance inflation factors (VIF) and autocorrelation through the Durbin–Watson statistic.

Results and Discussion

Reliability analysis confirmed acceptable to high internal consistency, with Cronbach's alpha values ranging from .786 (willingness) to .894 (learning experience). Sampling adequacy (KMO = .820–.910; Bartlett's test $p < .001$) and convergent validity (AVE = .500–.721) were satisfactory (Table 1). The square roots of the AVEs (.71–.85) exceeded all correlations between constructs (maximum .46), supporting discriminant validity.

Table 1

Reliability, Validity, Descriptive Statistics, Correlations and Regression Results

Variable (items)	α	AVE	*M*	*SD*	*r*	β	VIF
Perceived usefulness (8)	.885	.578	4.20	0.50	.462**	.446***	1.002
Perceived trust (4)	.871	.721	4.52	0.54	.434**	.425***	1.000
Willingness to use AI (6)	.786	.500	4.16	0.39	.298**	.272***	1.002
Learning experience (6)	.894	.651	4.48	0.37	–	–	–

Note. $N = 394$. α = Cronbach's alpha; AVE = average variance extracted; *M* = mean; *SD* = standard deviation; *r* = Pearson correlation with learning experience; β = standardised coefficient; VIF = variance inflation factor. $R^2 = .471$, adjusted $R^2 = .467$, $F(3, 390) = 115.98$, $p < .001$; Durbin–Watson = 1.919. $^{**}p < .01$. $^{***}p < .001$.

Descriptive statistics revealed strongly positive perceptions. The distributions were negatively skewed (−1.10 to −1.78), so ceiling effects or social desirability bias cannot be

ruled out. Perceived usefulness, perceived trust and willingness correlated positively with learning experience, whereas the three variables were virtually uncorrelated with one another (r = .010–.043). Multiple regression showed that perceived usefulness, perceived trust and willingness significantly predicted learning experience, $F(3, 390) = 115.98$, $p <$ .001, explaining 47.1% of the variance (R^2 = .471; adjusted R^2 = .467). VIF values (1.000–1.002) and a Durbin–Watson statistic of 1.919 indicated no multicollinearity or autocorrelation problems, and H1–H4 were supported.

Students who find AI tools beneficial and reliable, and who are willing to use them, tend to report greater engagement, confidence and learning efficiency; as the design is cross-sectional, these are associations rather than causal effects. Usefulness and trust were of comparable strength, whereas willingness was weaker. The importance of usefulness agrees with a UTAUT-based Sri Lankan study in which performance expectancy predicted behavioural intention (Gunasekara & De Silva, 2025). Nazaretsky et al. (2025) found that trust increased perceived usefulness, whereas here the two were almost uncorrelated, so they acted as separate correlates of learning experience.

Conclusions and Implications

This study concludes that perceived usefulness, perceived trust and the willingness to use AI significantly and positively influence the learning experiences of Sri Lankan undergraduate students using GAIT. The findings demonstrate that AI-supported learning can enhance academic engagement, efficiency and confidence when students perceive AI technologies as trustworthy and academically beneficial and are willing to use them.

From a practical perspective, universities should focus on improving AI literacy and promoting responsible AI use through structured training programmes and institutional guidelines. Educators could be supported in using AI in teaching while maintaining academic integrity, and policymakers and institutions should collaborate to ensure ethical, accessible and student-centred AI adoption. Whether and how AI should be integrated into assessment requires further study, as these data do not address it. The study is limited by non-probability sampling, a cross-sectional design, self-reported data with high and skewed ratings, the absence of a formal test of common method bias, a sample of AI users only, and the lack of data on faculty or discipline. Future research should incorporate AI readiness, digital literacy and ethical awareness and extend to private universities and to longitudinal or experimental designs.

***Keywords*:** Artificial intelligence, higher education, learning experience, perceived trust, perceived usefulness

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An Explainable Multi-Agent System for Agricultural Decision Support in Rice Yield Prediction

Udayangani H.K.N.[1,*], Ekanayake E.M.U.W.J.B.[1], Suriyagoda B.M.L.D.B.[2] and Bandara R.M.U.S.[3]
[1]*Department of Computer Science and Informatics, Faculty of Applied Sciences, Uva Wellassa University of Sri Lanka, Sri Lanka,* [2]*Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka,* [3]*Rice Research and Development Institute, Bathalagoda, Sri Lanka*
*Corresponding author (email: niroshimaudayangani@gmail.com)

Introduction

Machine learning models are widely used for crop yield prediction. However, a major limitation of these models is that they often act as "black boxes", providing predictions without explaining how the results are obtained. This lack of transparency makes it difficult for agricultural practitioners to trust and use these models in decision-making (Barredo Arrieta et al., 2020).

Existing studies have shown that machine learning can improve prediction accuracy in agriculture, but they often do not clearly explain how different factors influence yield (Van Klompenburg et al., 2020). As a result, there is a gap between model performance and practical usability in real-world farming systems, where understanding the reasons behind yield changes is important.

The objective of this study is to develop an explainable decision-support system using a multi-agent system (MAS) combined with a machine learning model. By representing key agricultural factors as interacting agents, the proposed approach aims to improve transparency while maintaining reasonable prediction performance, focusing specifically on the BG 300 rice variety in Bathalagoda, Sri Lanka.

Methodology

The proposed system combines a MAS with a random forest coordinator, hereafter referred to as the MAS-RF model, to provide explainable rice yield prediction. Five agents represent the main yield-related domains: climate, soil, pest, growth (representing maturity and lodging conditions) and management. Each agent processes its inputs using rule-based logic and produces a score that reflects its condition, while also interacting with other agents to capture key agricultural relationships such as climate–pest and soil–lodging interactions. The agent outputs are then used as features for the random forest model, which was selected because it can model nonlinear relationships among the agent-derived features (Breiman, 2001).

For data collection, the study used long-term agronomic records from the Rice Research and Development Institute (RRDI), Bathalagoda, together with climate data from the Department of Meteorology. The dataset included yield; soil parameters (pH, electrical conductivity (EC) and potassium (K)); pest and disease parameters, including brown planthopper (BPH), bacterial leaf blight (BLB), rice blast and rice gall midge (RGM); maturity and lodging parameters; and management data for BG 300, along with rainfall, temperature and sunshine duration. The original dataset covered 40 cultivation seasons,

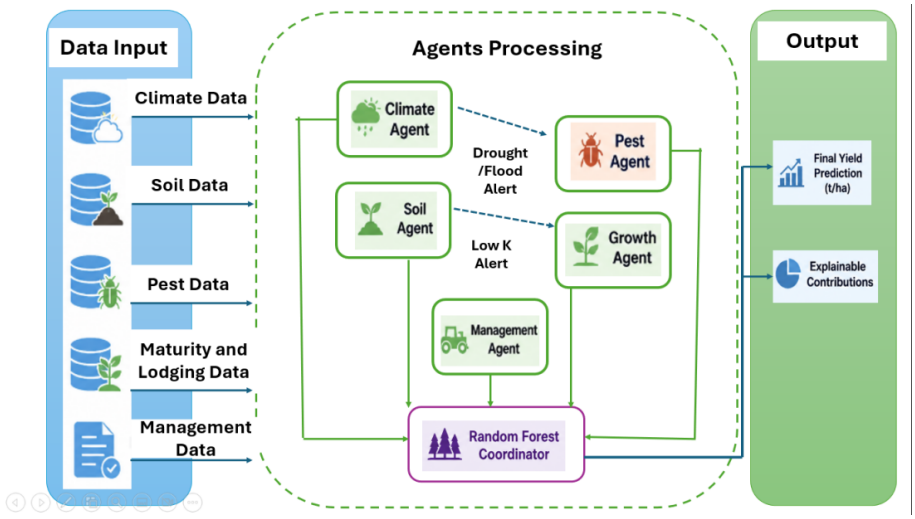
and after cleaning and removal of incomplete observations, 30 complete seasons were retained for analysis.

The raw records were organised season-wise according to the Yala and Maha cultivation periods, and monthly climate values were aligned with the relevant season before being aggregated into seasonal values. Rainfall and sunshine duration were summed; temperature variables were averaged; pest and disease categories were converted into numerical risk scores; lodging severity recorded at different stages was combined into a single seasonal lodging-risk feature; and missing values were handled during preprocessing to maintain consistency in the final dataset.

The logical flow through which these agricultural factors are processed by the agents before the final prediction is illustrated in Figure 1.

Figure 1

Workflow of the Explainable Multi-Agent System With Random Forest Coordinator



Note. This figure illustrates how the raw environmental and biological factors are processed by individual agents before the final prediction.

The proposed model was evaluated against three baselines: a limiting-factor baseline based on Liebig's Law, multiple linear regression and a standalone random forest model. This comparison was used to assess both prediction accuracy and the added explanatory value of the proposed framework.

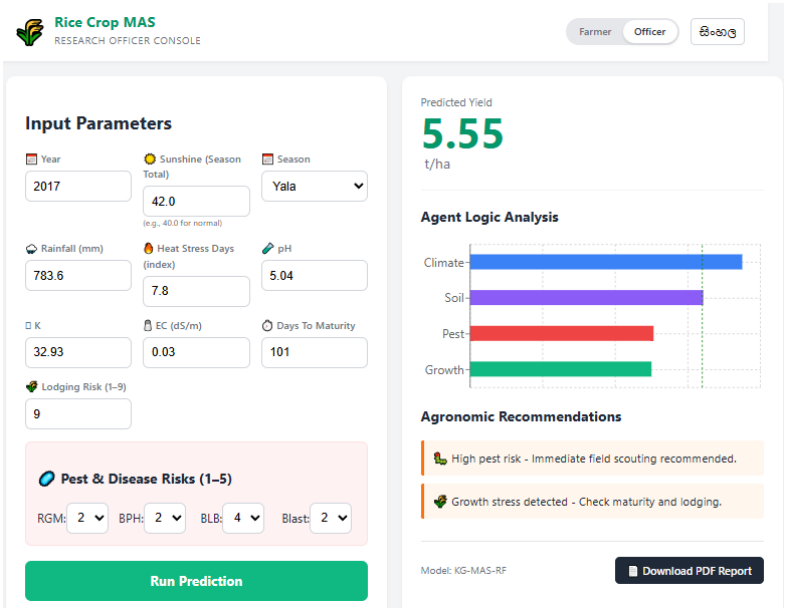
Results and Discussion

The proposed MAS-RF model achieved an in-sample root mean square error (RMSE) of 0.4952 t/ha, whereas cross-validation produced higher RMSE values of 1.1291 t/ha for 5-fold validation and 1.1795 t/ha for leave-one-season-out cross-validation, indicating limited generalisation owing to the small seasonal dataset. Compared with the limiting-factor baseline based on Liebig's Law (RMSE = 1.1333 t/ha) and multiple linear regression (RMSE = 0.7136 t/ha), the proposed framework showed better performance.

Although the standalone random forest achieved the lowest in-sample RMSE (0.4374 t/ha), it provided less agronomic interpretability. Overall, the proposed framework offers a balance between predictive performance and agent-level agronomic interpretation. Figure 2 presents the officer-view dashboard, which displays the predicted yield and agent-level suitability scores to support agricultural decision-making.

Figure 2

Officer-View Dashboard Displaying Predicted Yield and Agent-Level Suitability Scores



Note. This interface displays the prediction results alongside key agricultural risk factors to support informed decision-making.

Conclusions and Implications

This study presents an explainable approach to agricultural decision support that combines a multi-agent system with a machine learning model. The system improves interpretability by presenting the conditions represented by individual agents alongside the final yield prediction, rather than providing only a final numerical value.

Although the model is limited by the size of the dataset, the overall framework can be extended with additional data and applied to other crop varieties and regions in the future. The proposed approach demonstrates that combining agent-based modelling with machine learning can support both prediction and explanation, showing its potential for practical decision-support applications in agriculture.

***Keywords*:** Agricultural decision support, explainability, machine learning, multi-agent systems, rice yield prediction

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Ensemble Deep Learning Approach for Categorising Synthetic and Original Gems

Kularathne A.M.R.M.[1,*], Kumara B.T.G.S.[2], Wanniarachchi D.N.S.[3] and Dilshan B.T.[4]
[1]*Department of Computing and Information Systems, Faculty of Computing, Sabaragamuwa University of Sri Lanka, Sri Lanka,* [2]*Department of Data Science, Faculty of Computing, Sabaragamuwa University of Sri Lanka, Sri Lanka,* [3]*Department of Natural Resources, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, Sri Lanka,* [4]*Faculty of Graduate Studies, Sabaragamuwa University of Sri Lanka, Sri Lanka*
*Corresponding author (email: ruwinikularathne2000@gmail.com)

Introduction

The gemstone industry is one of the major pillars of the Sri Lankan economy. However, the emergence of synthetic gemstones has become a threat to the gemstone market. Manual microscopic inspection, which is currently widely used for gemstone identification, requires significant expertise and is prone to human fatigue. Authenticating gems is a "fine-grained" classification problem in which the subtle internal features of a gem must be identified (Judixon & Shivaraman, 2023). Existing research has mainly focused on gemstone-type classification using traditional machine learning models, convolutional neural networks (CNNs), transfer learning and hybrid deep learning approaches (Nadimpalli et al., 2024). Multi-feature and ensemble-style classification strategies have also been reported to perform better than basic CNN models (Huang & Cui, 2022). While prior studies have successfully used microscopic images to classify synthetic and natural sapphires (Thadsha et al., 2025), few studies have attempted to apply deep ensemble CNN architectures to generalise this fine-grained authentication across multiple gemstone types. This study proposes a Triple CNN ensemble model for the classification of natural and synthetic gemstones from microscopic images.

Methodology

With regard to data acquisition and preprocessing, a set of 740 high-resolution microscopic images was collected by photographing both natural and synthetic gemstones at the Earth Resource Laboratory of the Department of Natural Resources, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka. A 70/15/15 split was applied during preprocessing to ensure scientific rigour and avoid data leakage. Class imbalance was addressed by selecting 400 images from the natural class and applying data augmentation (90° rotation and horizontal shifting) to the training set to achieve a balanced 1:1 class distribution (560 training images).

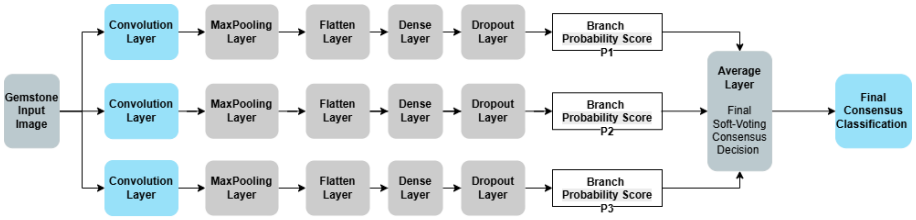
In terms of architecture design, a Triple CNN model was selected because this structure allows individual CNNs to learn different local image representations of fine-grained textures. Three identical branches with different initialisations enable each network to learn different visual features from the same image (Figure 1). Each branch consists of a five-layer pipeline. First, convolutional layers with 32 to 128 filters learn fine-grained textures. Second, max-pooling layers down-sample the spatial dimensions while retaining essential inclusion data. Third, batch normalisation stabilises the learning process and speeds up convergence. Fourth, fully connected (dense) layers perform high-level

reasoning on the extracted features. Fifth, dropout prevents overfitting by randomly deactivating neurones during training.

For the final classification, predictions are aggregated by soft voting, in which the posterior class probabilities are averaged. Soft voting was selected over hard voting because it incorporates the prediction confidence of each branch; it therefore allows a high-confidence prediction from one branch to compensate for borderline ambiguity in another.

Figure 1

Conceptual Data Flow of the Triple CNN Model



Results and Discussion

The model was trained for 12 epochs using the Adam optimiser with a learning rate of 0.0001. Table 1 compares the performance of the successive model iterations.

Table 1

Comparative Performance Analysis of Iterative Models

Iteration	Model architecture	Optimiser	Key strategy	Training accuracy	Testing accuracy
1	Basic CNN	Adam (0.0005)	3-layer sequential	74.50%	58.00%
2	CNN + Dropout	Adam (0.0005)	Added 0.5 dropout	78.20%	64.10%
3	Triple CNN (v1)	Adam (0.0001)	Soft voting (no augmentation)	82.15%	69.00%
4	VGG-16 (pre-trained)	Adam (0.0001)	Transfer learning	83.30%	70.20%
5	Triple CNN + Batch Norm	RMSprop	Layer normalisation	83.40%	71.30%
6	Weighted Triple CNN	Adam (0.0001)	Synthetic class bias (1.2)	89.10%	76.50%
7	Triple CNN + Augmented	Adam (0.0001)	Data augmentation	94.20%	82.40%
8	Final Triple CNN Ensemble	Adam (0.0001)	Optimised weights + augmentation	97.32%	87.38%

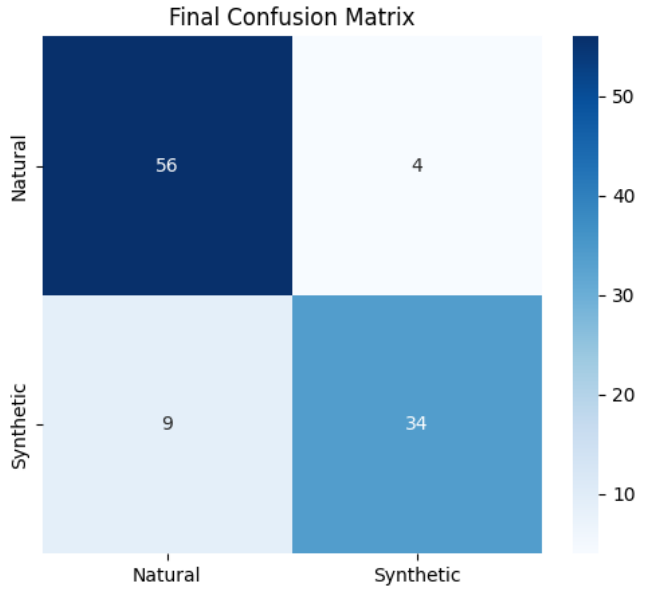
Note. The ensemble approach outperformed transfer learning (VGG-16) by 17.18 percentage points in testing accuracy.

The final model achieved a training accuracy of 97.32% and a testing accuracy of 87.38%, the latter being 17.18 percentage points higher than that of the VGG-16 baseline (70.20%). The margin of 9.94 percentage points between training and testing accuracy

suggests reasonable generalisation to unseen samples. The number of samples falling into each classification category is shown in Figure 2. The model correctly identified 56 of 60 natural stones (recall of 0.93) and 34 of 43 synthetic stones (recall of 0.79), demonstrating high sensitivity to the true micro-features of stones. Across the test set, the ensemble achieved a macro F1-score of 0.87.

Figure 2

Final Confusion Matrix



Conclusions and Implications

The results of this research show that the multi-expert ensemble approach performs better than the single-path approach and transfer learning models in the fine-grained analysis of gemstones. By simulating a "consensus" among three branches, the system appears to provide a more stable and reliable classification, as single models often struggle to capture all subtle features equally. However, these findings are conditional on the specific, constrained dataset used. This research could lead to a cost-effective, automated authentication system that can be implemented in retail settings, although future work must expand the size and diversity of the dataset to ensure real-world generalisation.

***Keywords*:** Artificial intelligence, computer vision, ensemble learning, gemmology, triple convolutional neural network

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Combined Assessment of HER2/CEP17 Gene Status and TNF-α Expression: A Retrospective Analysis

Dissanayake E.[1,*], Hewagama N.[1], Jeyakumaran T.[1], Seneviratne B.[2] and Jeewandara T.M.[3]
[1]*Department of Medical Laboratory Sciences, Faculty of Allied Health Sciences, University of Sri Jayewardenepura, Sri Lanka,* [2]*Department of Pathology, Faculty of Medical Sciences, University of Sri Jayewardenepura, Sri Lanka,* [3]*Department of Immunology and Molecular Medicine, Faculty of Medical Sciences, University of Sri Jayewardenepura, Sri Lanka*
*Corresponding author (email: dkechathurika2000@gmail.com)

Introduction

Breast cancer remains one of the leading causes of cancer-related deaths among women worldwide and continues to pose a growing public health concern in Sri Lanka (Arnold et al., 2022). Owing to the complex biological heterogeneity of breast tumours, accurate diagnosis and treatment planning require reliable predictive and prognostic biomarkers. Current clinical assessment focuses primarily on conventional tumour-associated antigens (TAAs) such as oestrogen receptor (ER), progesterone receptor (PR), human epidermal growth factor receptor 2 (HER2) and Ki-67 expression, assessed at the tissue and gene levels (Wolff et al., 2022). The characteristic HER2 upregulation in breast cancer is determined by gold-standard immunohistochemistry (IHC) and by HER2:CEP17 (chromosome 17 centromere) scores in cytogenetics. However, the role of the tumour microenvironment (TME), particularly the host immune response, in disease progression is often under-explored. Tumour necrosis factor-alpha (TNF-α) is a key pro-inflammatory cytokine that plays a dual role within the TME (Balkwill, 2009). Through its crosstalk with the HER2 signalling pathway, TNF-α can promote tumour progression, cellular proliferation and resistance to anti-HER2 therapies such as trastuzumab (Mercogliano et al., 2017). The principal aim of this study was to evaluate the relationship between TNF-α expression levels and TAA biomarkers of local peritumoral inflammation for multidimensional, personalised diagnostic profiling in breast cancer.

Methodology

This retrospective correlational pilot study used archived formalin-fixed paraffin-embedded (FFPE) tissue samples and clinical records collected between 2024 and 2025. A total of 136 samples were included in the study. The primary biomarker cohort consisted of 116 FFPE breast cancer tissue samples obtained from the Colombo South Teaching Hospital, while an additional 20 samples were used to observe HER2 expression at the tissue level by IHC and at the gene level by fluorescence in situ hybridisation (FISH), through observational training at the Lanka Hospitals. To assess local inflammatory responses, a sub-analysis was conducted on 30 samples, comprising 15 invasive breast carcinoma tissues and 15 benign fibroadenoma tissues. Haematoxylin and eosin (H&E) staining was performed, and inflammatory cell infiltration at the invasive margin was evaluated using the Klintrup–Mäkinen scoring system. Clinicopathological TAAs, including ER, PR, Ki-67 and the Nottingham Prognostic Index (NPI), were analysed by binary classification. Direct IHC for TNF-α detection was optimised using a Brilliant Violet 505™ anti-human TNF-α monoclonal primary antibody combined with

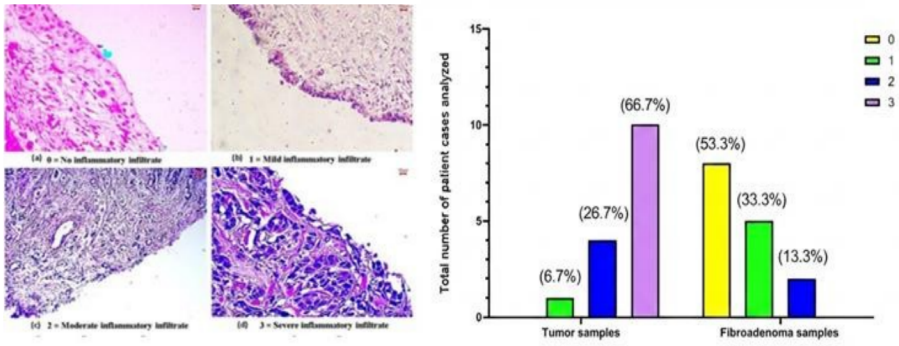
microwave-assisted heat-induced epitope retrieval (HIER). All experimental outcomes were analysed statistically with GraphPad Prism analysis software (Version 8.2.2; GraphPad Software, La Jolla, CA, USA). Ethical clearance for the study was obtained from the research ethics committee of the University of Sri Jayewardenepura, Sri Lanka.

Results and Discussion

Local inflammatory cell infiltration was observed in 94% of invasive breast cancer specimens, indicating a strong host immune response within the TME. Higher inflammatory scores (Klintrup–Mäkinen scores 2–3) were associated with adverse prognostic features, including higher histological grades (Nottingham Grades II and III), hormone receptor-negative status (ER−/PR−) and the presence of lymphovascular invasion (Figure 1; Mohammed et al., 2012).

Figure 1

Klintrup Scoring Criteria for Inflammatory Cell Infiltration



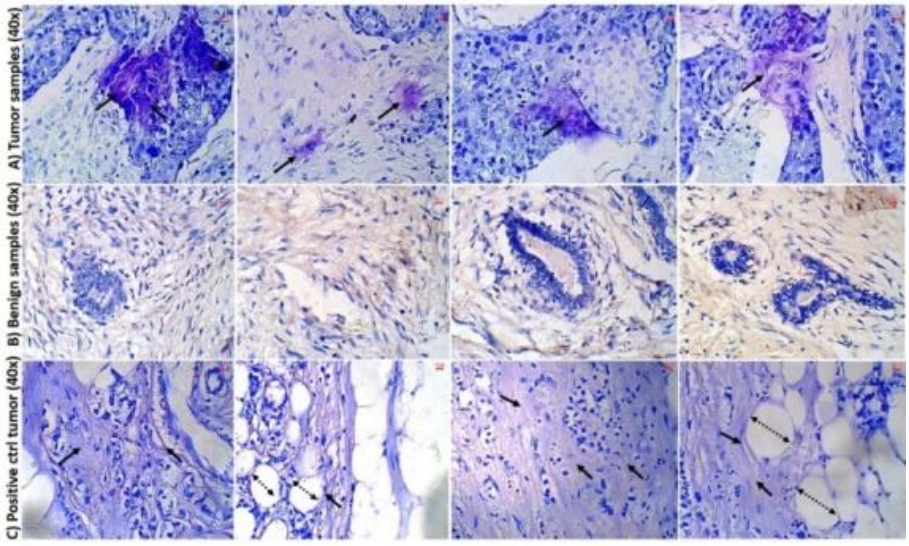
Note. Panels (a–d) illustrate the scoring range from 0 (none) to 3 (severe). The bar chart compares the frequency of these scores between malignant tumour samples and benign fibroadenoma samples.

During observational training conducted at the Lanka Hospitals, HER2 protein expression was evaluated by IHC (0 to 3+ scoring). HER2-equivocal tissues were suitable for reflex FISH, which was used exclusively to determine gene status in separate cohorts; these observational training outcomes were treated as qualitative components of the study. Future studies following this pilot investigation will aim to validate and correlate HER2 expression at the tissue level (by IHC) and the gene level (by HER2:CEP17 ratio) within the same tissue cohort, to confirm the significance of the HER2+ (equivocal) status for chemotherapy.

TNF-α immunostaining was optimised and demonstrated prominent purple staining deposits within malignant breast tumour tissues, whereas benign fibroadenoma samples showed no detectable cytokine expression (Figure 2). Although the initial findings suggested increased TNF-α activity in malignant tissues, attempts at a comprehensive quantitative analysis were limited by the experimental difficulty of achieving consistent epitope retrieval by HIER (García-Tuñón et al., 2006).

Figure 2

Comparison of TNF-α Expression Levels Between (A) Tumour Samples, (B) Benign Samples, and (C) Positive Control Samples (40× Magnification)



Note. The expression of the cytokine (purple sediment) is seen throughout the tumour samples and the positive control tissue, whereas this feature is notably absent from the benign samples. The black arrows indicate deposits in the regions of interest corresponding to TNF-α pro-inflammatory cytokine expression.

More extensive molecular profiling in this study further revealed trends among the standard TAAs, including elevated Ki-67 proliferation indices and HER2 amplification, which were strongly associated with poorer prognostic categories within the NPI framework ($p < .001$). These findings highlight the importance of these markers as prognostic biomarkers in disease progression and patient stratification, in agreement with previous investigations (Kurshumliu et al., 2014).

Conclusions and Implications

The initial findings of this pilot study highlight the importance of integrating pathological and immunological factors in the personalised assessment of the breast cancer TME. The host immune response defined by TAA expression levels appears to vary according to tumour aggressiveness, with pronounced inflammatory infiltration observed at the invasive front of high-grade, hormone receptor-negative tumours. The first outcomes of this study regarding differences in TNF-α expression and inflammatory cell infiltration between malignant and benign tissues showed promising initial trends supporting the hypothesis that aggressive breast tumours are characterised by a more active pro-inflammatory microenvironment, which eventually contributes to their cytokine-mediated resistance to chemotherapy.

These results suggest that combining the assessment of immune-related biomarkers with the gold-standard conventional HER2/CEP17 genomic assessments may provide

additional clinical value for breast cancer stratification and for determining effective immunotherapy. Further investigation of biomarker interactions (TAAs) in the TME at the molecular level could contribute to the development of more comprehensive prognostic models and support the design of patient-specific, personalised therapies aimed at overcoming chemotherapy resistance.

***Keywords*:** Breast carcinoma, cytokines, immunology, pathology, tumour necrosis factor-alpha

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The Impact of User Experience Quality on Customer Satisfaction in Mobile Commerce Applications: Evidence From Sri Lankan Users

Kalpani K.A.P.* and Munasinghe P.G.
Department of Information Systems, Faculty of Management Studies, Rajarata University of Sri Lanka, Mihintale, Sri Lanka
*Corresponding author (email: mgt2022060@mgt.rjt.ac.lk)

Introduction

Mobile commerce (m-commerce) has transformed how consumers access products and services through smartphones and mobile applications. The widespread adoption of mobile devices, internet connectivity and digital payment technologies has accelerated m-commerce growth worldwide. In Sri Lanka, m-commerce applications have become increasingly popular owing to their convenience and accessibility. Consequently, organisations are focusing on enhancing customer satisfaction through improved user experiences.

User experience (UX) quality is a critical factor influencing the success of mobile applications. It comprises dimensions such as usability, information quality, aesthetic quality and perceived security, which shape users' interactions and perceptions. Recent studies highlight the importance of UX quality dimensions in improving user satisfaction and trust in mobile applications (Jiang et al., 2021; Nani & Lina, 2022; Schrepp et al., 2023).

Despite the growing adoption of m-commerce applications, empirical evidence on the relationship between UX quality and customer satisfaction remains limited in the Sri Lankan context. Furthermore, previous studies have often examined UX dimensions independently rather than assessing their combined influence on customer satisfaction. This creates a gap in understanding how different aspects of UX quality collectively affect customer satisfaction among m-commerce users. Recent research further emphasises the need to examine UX quality as a multidimensional construct in the evolving m-commerce environment (Lakmal, 2025; Morsi, 2023).

On the basis of this research gap, four hypotheses were developed. H1 states that usability has a significant positive impact on customer satisfaction; H2, that aesthetic quality has a significant positive impact on customer satisfaction; H3, that information quality has a significant positive impact on customer satisfaction; and H4, that perceived security has a significant positive impact on customer satisfaction. Accordingly, this study examines the influence of UX quality on customer satisfaction in m-commerce applications, focusing on usability, information quality, aesthetic quality and perceived security among Sri Lankan users.

Methodology

This study adopted a quantitative approach with an explanatory research design based on a positivist research philosophy. The target population consisted of individuals aged 18 years and above in Sri Lanka who had used an m-commerce application at least once

during the previous 12 months. As the population size was unknown, Cochran's formula was used to determine the required sample size, resulting in a required sample of 384 respondents. A total of 385 valid responses were obtained using purposive sampling to ensure that participants met the study criteria (Cyr et al., 2006).

Primary data were collected through a structured, self-administered online questionnaire created with Google Forms and distributed through online communication and social media channels. Screening questions were used to ensure respondent eligibility. Participation was voluntary, informed consent was obtained, and responses were collected anonymously and confidentially for academic purposes (Cyr et al., 2006; Kim et al., 2008).

The questionnaire consisted of 24 measurement items covering usability (5), aesthetic quality (4), information quality (6), perceived security (5) and customer satisfaction (4), measured on a five-point Likert scale. The 385 valid responses were analysed using IBM SPSS Statistics 25. Descriptive statistics, Cronbach's alpha, the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test, skewness and kurtosis, Pearson correlation and multiple regression analysis were computed at a 5% significance level. Normality was assessed using skewness and kurtosis, with the reported values falling within the acceptable ranges used in the study.

Results and Discussion

A total of 385 valid responses from Sri Lankan m-commerce users were analysed. Reliability analysis confirmed strong internal consistency across all constructs, with Cronbach's alpha values ranging from .921 to .954. The KMO values ranged from .856 to .930, and Bartlett's tests were significant ($p < .001$), confirming the suitability of the data for factor analysis.

Descriptive statistics indicated generally favourable perceptions of m-commerce experiences. Among the UX quality dimensions, usability recorded the highest mean ($M = 4.503$, $SD = 0.612$), followed by aesthetic quality ($M = 4.479$, $SD = 0.650$), information quality ($M = 4.459$, $SD = 0.658$) and perceived security ($M = 4.233$, $SD = 0.770$). Customer satisfaction also recorded a high mean ($M = 4.477$, $SD = 0.671$), indicating generally positive user experiences with m-commerce applications.

Pearson correlation analysis revealed significant positive relationships between all UX quality dimensions and customer satisfaction. Usability ($r = .820$), aesthetic quality ($r = .803$), information quality ($r = .844$) and perceived security ($r = .703$) were all significantly correlated with customer satisfaction ($p < .001$). Multiple regression analysis showed that the overall model significantly predicted customer satisfaction, explaining 75.5% of its variance ($R^2 = .755$, $p < .001$). Information quality ($\beta = .401$), usability ($\beta = .302$) and perceived security ($\beta = .126$) had significant positive effects on customer satisfaction, supporting H1, H3 and H4. Information quality was the strongest predictor, indicating that accurate, relevant and complete information is particularly important to users. Usability also had a significant influence, emphasising the importance of easy navigation and efficient task completion. Perceived security contributed positively to

satisfaction by enhancing users' confidence in secure transactions and privacy protection. In contrast, aesthetic quality was not a significant predictor (β = .100, p = .095), resulting in the rejection of H2.

These findings are consistent with previous studies that identified usability, information quality and security as important predictors of customer satisfaction and continued technology use (Cyr et al., 2006; Kim et al., 2008). Overall, the results suggest that m-commerce providers should prioritise functional UX attributes over purely aesthetic improvements to enhance customer satisfaction.

Conclusions and Implications

This study examined the influence of UX quality on customer satisfaction in m-commerce applications among Sri Lankan users. The findings revealed that information quality, usability and perceived security significantly improve customer satisfaction, whereas aesthetic quality does not have a significant impact. Information quality emerged as the strongest predictor, emphasising the importance of accurate, relevant, timely and complete information on m-commerce platforms.

The study contributes empirical evidence from a developing-country context and confirms that functional UX aspects are more influential than visual appeal in shaping customer satisfaction. In practice, m-commerce providers should improve information quality, usability and transaction security by offering clear product details, user-friendly interfaces, secure payment systems and strong privacy protection. These improvements can enhance customer trust, satisfaction and continued use.

The study is limited by the use of purposive sampling and a cross-sectional design. Future research may examine additional factors such as perceived value, customer trust, service quality and purchase intention using longitudinal or mixed-method approaches.

Keywords**:** Customer satisfaction, information quality, mobile commerce applications, usability, user experience quality

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Molecular Identification of *Microbacterium schleiferi* From Black Rot-Symptomatic Cabbage From the Badulla District, Sri Lanka

Ranasinghe N., Rajan K. and Ranaweera D.*
Faculty of Life and Medical Sciences, BMS Campus, Sri Lanka
*Corresponding author (email: dinali.r@bms.ac.lk)

Introduction

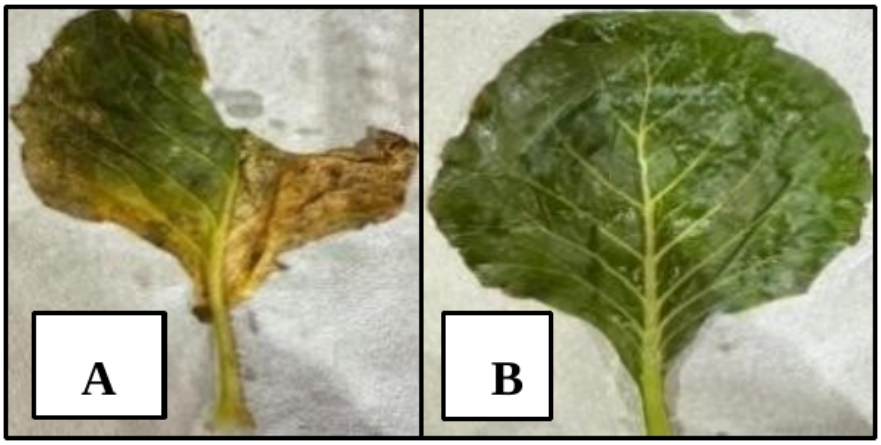
Cabbage (*Brassica oleracea*) is an economically important cruciferous crop cultivated throughout Sri Lanka. Its production can be affected by several bacterial infections, among which black rot caused by *Xanthomonas campestris* pv. *campestris* (Xcc) is crucial. Xcc grows rapidly at temperatures between 25 °C and 30 °C and can survive for up to two years on decomposing crop residue. This results in unmarketable cabbages that are prone to secondary infections in the field and during storage (Stearns, 2021). Typical symptoms include V-shaped chlorotic lesions extending from the leaf margins towards the midrib, and vein blackening (Dubrow & Bogdanove, 2021). Diseased plant tissues often harbour other pathogenic and beneficial microorganisms, such as endophytes and saprophytes, that may influence disease progression. However, information on the bacterial communities associated with black rot-symptomatic cabbage plants in Sri Lanka remains limited. This study focuses on the isolation, biochemical characterisation and molecular identification of *Microbacterium* species from cabbage leaf samples in Sri Lanka.

Methodology

Two symptomatic and asymptomatic cabbage leaf samples (Figure 1) were collected from Badulla District and transported under chilled conditions. Leaf tissues (1 cm^2 sections cut from the lesion margin) were surface-sterilised with 70% ethanol for 30 s and rinsed with sterile distilled water. The tissues were macerated in 2 mL of sterile saline (0.85% NaCl) and serially diluted from 10^{-1} to 10^{-6}. Aliquots of 100 µL from the 10^{6} dilution were spread-plated on nutrient agar (NA) plates and incubated at 37 °C for 48 h. Colonies exhibiting a distinct yellow pigment and characteristic morphology were subcultured on yeast dextrose calcium carbonate (YDC) agar.

Figure 1

Symptomatic and Asymptomatic Cabbage Leaf Samples



Note. (A) Symptomatic cabbage leaf; (B) asymptomatic cabbage leaf.

Gram staining and biochemical tests (catalase, oxidase, potassium hydroxide (KOH) and starch hydrolysis) were performed following the protocol of Sunil et al. (2024). Selected colonies were inoculated in Luria–Bertani (LB) broth, and DNA was extracted using the Promega Wizard Genomic DNA Purification Kit following the manufacturer's protocol (Promega Corporation, 2023). Lyophilised forward primer 341F (5′-CCTACGGGNGGCWGCAG-3′) and reverse primer 785R (5′-GACTACHVGGGTATCTAATCC-3′) were used to amplify the V3–V4 region of the 16S rRNA gene by polymerase chain reaction (PCR) (Thijs et al., 2017). Table 1 presents the master mix preparation details. A total reaction volume of 25 µL (including template DNA) was prepared per sample and amplified using the reaction conditions (Table 2) published by Klindworth et al. (2012).

Table 1

Master Mix Preparation for Four Samples

PCR component	Working concentration	Volume per reaction (µL)	× 4 (µL)
2× GoTaq Green master mix	1×	12.5	50
Forward primer	0.4 µM	1.0	4.0
Reverse primer	0.4 µM	1.0	4.0
Nuclease-free water	–	9.5	38
Total volume (without DNA template)	–	24	96

Table 2

PCR Cycling Conditions

Step	Temperature (°C)	Time	No. of cycles
Initial denaturation	95	5 min	1
Denaturation	95	40 s	34
Annealing	55	2 min	
Extension	72	1 min	
Final extension	72	7 min	1

Note. Denaturation, annealing and extension together form the 34 cycles.

After visualisation, the PCR products were outsourced for Sanger sequencing, and the sequences obtained were analysed using the National Center for Biotechnology Information (NCBI) BLASTn tool against GenBank reference sequences. Phylogenetic analysis was performed using phylogeny.fr (Version 2.0).

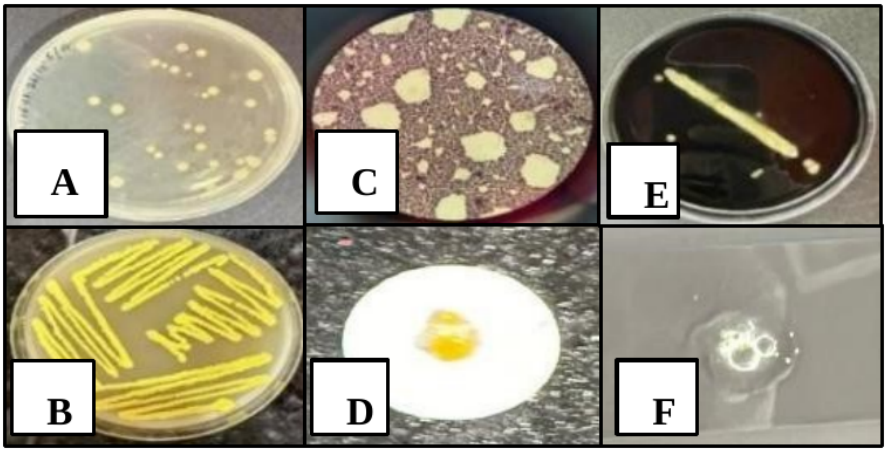
Results and Discussion

Yellow-pigmented colonies isolated from the spread plates could not be reliably differentiated on the basis of pigmentation alone, as both Xcc and *Microbacterium* species may produce yellow colonies (Figure 2, panels A and B). Therefore, colonies exhibiting yellow pigmentation together with a distinct colony morphology were selected for further biochemical and molecular characterisation (Kalsi et al., 2019).

The biochemical profile demonstrated the characteristics of Gram-positive bacteria (Figure 2, panels C–F). Specifically, the isolated colony exhibited positive catalase activity (formation of gas bubbles), while the oxidase (no colour change in the disc), KOH (no string formation) and starch hydrolysis (no clear zone formation) tests were negative.

Figure 2

Colony Morphology and Biochemical Test Results of the Isolate

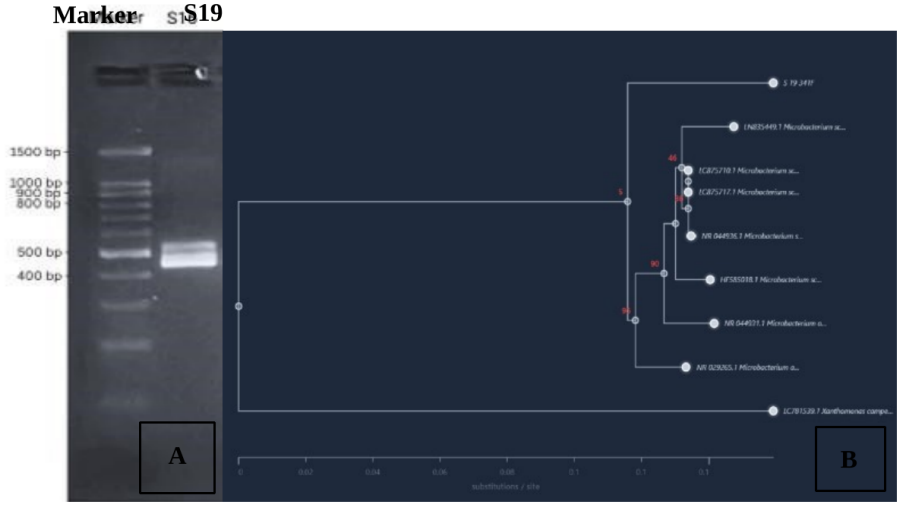


Note. (A) Colony growth on NA spread plate; (B) colony subcultured on YDC plate; (C) Gram staining; (D) oxidase test result; (E) starch hydrolysis test result; (F) catalase test result.

PCR amplification produced the expected amplicon of approximately 460 bp (Figure 3, panel A). BLASTn analysis showed the highest similarity to *M. schleiferi* (100% identity, 90% query coverage, accession no. KM874401.1). In the phylogenetic tree, the isolate (S19-34-1F) grouped with *Microbacterium* reference sequences but formed a separate branch with low bootstrap support and was clearly separated from Xcc (LC781539.1), which formed a distinct outgroup (Figure 3, panel B). Because the 460 bp V3–V4 fragment has limited resolution within the genus, the isolate is tentatively identified as *M. schleiferi*, and species-level confirmation is required.

Figure 3

PCR Product Visualisation and Phylogenetic Analysis



Note. (A) Gel image of PCR product visualisation; (B) phylogenetic tree.

The isolation and identification of a suspected *Microbacterium* sp. from cabbage leaf samples in Badulla District represents a significant finding for Sri Lankan agriculture. Members of the genus *Microbacterium* have previously been documented as plant-associated biocontrol agents (Kaneko et al., 2023; Liu et al., 2012; Tsavkelova et al., 2024). Despite these promising characteristics, information on the biocontrol potential of *M. schleiferi* specifically against Xcc remains limited, warranting investigation of the antagonistic capabilities of this isolate.

Conclusions and Implications

The phylogenetic analysis of the 16S rRNA gene suggests that the isolate is affiliated with *M. schleiferi* reference strains, expanding knowledge of beneficial bacteria in Sri Lankan agroecosystems. The presence of *M. schleiferi* suggests potential for sustainable disease management against Xcc. However, this study was limited to the molecular identification of a single isolate, without functional bioassays to assess its antagonistic activity or growth-promoting properties. The sample size and the number of collection locations could also be broadened to identify more *Microbacterium*-related species and their

biocontrol potential. Future investigations should include in vitro antagonism assays against Xcc and the evaluation of the plant growth-promoting traits of the identified species. The development of *M. schleiferi*-based bioformulations could reduce chemical pesticide use and promote sustainable agriculture.

***Keywords*:** Biocontrol agent, black rot, cabbage, *Microbacterium schleiferi*, ribosomal RNA gene sequencing

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A Comparative Parametric and Non-Parametric Regression Analysis of Factors Influencing South Asian Carbon Dioxide Emissions

Samaranayake K.[1,*], Ekanayake E.M.U.S.B.[1] and Atapattu M.S.[2]
[1]*Department of Physical Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,* [2]*Department of Statistics and Computer Science, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*
*Corresponding author (email: kalaanisamaranayake@gmail.com)

Introduction

Given the rapid acceleration and wide-ranging implications of climate change, reducing carbon emissions has become a crucial part of international efforts to mitigate its effects. South Asia, in particular, faces a significant sustainability challenge owing to rising carbon dioxide (CO_2) emissions. The analysis in this paper reveals that the effects of many parameters, including economic, social and environmental indicators, on CO_2 emissions differ significantly among eight South Asian countries. Numerous studies show that the effects of different factors on CO_2 emissions vary significantly among South Asian nations. In addition, much current research employs a single estimation technique, which raises concerns about whether the reported associations depend on particular distributional assumptions. This study fills these gaps by using 24 years (2000–2023) of panel data for eight South Asian countries to identify the key structural determinants of CO_2 emissions and by comparing the performance of parametric (ordinary least squares, OLS) and non-parametric (rank-based) regression models.

The main aim is to examine how environmental factors, especially CO_2 emissions, are related to economic stability and social well-being. Accordingly, this study has two objectives: first, to identify the key determinants of CO_2 emissions per capita across eight South Asian countries, including testing for non-linear effects of renewable energy adoption; and second, to compare the performance of parametric (OLS) and non-parametric (rank-based) regression models in estimating the relationships among economic, social and environmental variables.

Methodology

This study uses a quantitative research design based on panel data for eight South Asian countries (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka), covering 24 years from 2000 to 2023, sourced from the World Bank's World Development Indicators (World Bank, 2023). The study models CO_2 emissions per capita as the dependent variable, with predictors including gross domestic product (GDP) per capita, urban population (UP), total population (TP), foreign direct investment (FDI), unemployment (UNE), $PM_{2.5}$ air pollution (AP) and renewable energy consumption (RE).

Data preparation involved mean substitution for missing values and outlier screening prior to the standardisation of all variables. Normality was tested using the Shapiro–Wilk and Kolmogorov–Smirnov tests, along with Q–Q plots. Given the deviations from normality, Spearman's rank correlation was used to examine bivariate relationships. Candidate predictors were checked for multicollinearity using variance inflation factors (VIFs), and

reduced models were created by progressively removing high-VIF variables. Two estimation methods were applied to each specification: OLS regression and a rank-based non-parametric regression, the latter selected for its robustness to the non-normality found in the diagnostics. Model performance was measured using the adjusted R^2, residual standard error (RSE), 5-fold cross-validated mean squared error (CV-MSE) and the Akaike information criterion (AIC). Quadratic terms for urban population, air pollution and renewable energy were tested with nested analysis of variance (ANOVA) *F*-tests to identify non-linear relationships. All analyses were conducted in R and SPSS.

Results and Discussion

Bivariate analysis showed that GDP per capita had the strongest association with CO_2 emissions (Pearson $r = .893$, Spearman's $\rho = .841$, $p < .01$), followed by FDI ($r = .806$) and life expectancy ($r = .726$). Five candidate linear models were specified: Model 1, $CO_2 \sim$ GDP + FDI + FA + UP; Model 2, $CO_2 \sim$ GDP + UNE + AP + UP; Model 3, $CO_2 \sim$ GDP + UP + TP + RE; Model 4, $CO_2 \sim$ GDP + UP + TP + RE + UNE; and Model 5, $CO_2 \sim$ GDP + UP + TP + AP + FDI. Their performance metrics are summarised in Table 1.

Table 1

Summary of the Model Performance Metrics

Model	Parametric regression				Non-parametric regression			
	Adj. R^2	RSE	CV-MSE	AIC	Adj. R^2	RSE	CV-MSE	AIC
1	.8703	0.3602	0.1341	159.685	.8665	0.3654	0.1341	163.187
2	.8656	0.3667	0.1422	166.542	.8636	0.3694	0.1412	167.361
3	.8813	0.3445	0.1255	142.548	.8789	0.3480	0.1240	144.526
4	.8824	0.3429	0.1251	141.774	.8791	0.3478	0.1229	145.195
5	.9014	0.3139	0.1056	107.880	.8985	0.3186	0.1067	111.522

Note. Adj. R^2 = adjusted R^2; RSE = residual standard error; CV-MSE = 5-fold cross-validated mean squared error; AIC = Akaike information criterion. Model 5 is the best-performing linear model.

Model 5 ($CO_2 \sim$ GDP + urban population + total population + air pollution + FDI) was the best-performing linear model in both estimation approaches, achieving the highest adjusted R^2 (OLS = .9014, non-parametric = .8985), the lowest RSE (0.3139 vs. 0.3186) and the lowest CV-MSE (0.1056 vs. 0.1067), with results consistent across both estimation methods.

Turning to the quadratic model comparison, scatter plots showed non-linear trends for urban population, air pollution and particularly renewable energy consumption, which revealed a notable U-shaped pattern with CO_2 rather than the simple negative linear relationship often assumed. Testing for non-linearity provided important insights into a related specification that included renewable energy consumption ($CO_2 \sim$ GDP + urban population + total population + renewable energy + unemployment). Adding a quadratic renewable energy term significantly improved model fit, $F(1, 185) = 66.285$, $p < .001$. This adjustment raised the adjusted R^2 from .8824 to .9130 and reduced the AIC from 141.774 to 84.978. This model was preferred over an alternative with quadratic urban population and air pollution terms, which achieved a marginally higher adjusted R^2

(.9203) but was discarded owing to severe multicollinearity (GDP VIF = 11.21). The selected quadratic renewable energy model kept all VIF values below 5, providing a more stable and interpretable basis for policy analysis. The final environmental model is as follows:

$$\mathrm{CO_2} = -0.238 + 0.709(\mathrm{GDP}) + 0.177(\mathrm{UP}) + 0.268(\mathrm{TP}) \\ -0.041(\mathrm{RE}) + 0.239(\mathrm{RE}^2) - 0.064(\mathrm{UNE})$$

GDP per capita remained the strongest predictor (β = 0.709, $p < .001$), while the non-significant linear renewable energy term (β = −0.041, $p = .141$), combined with a highly significant positive quadratic term (β = 0.239, $p < .001$), revealed a U-shaped relationship between renewable energy adoption and CO_2 emissions. This suggests that at low-to-moderate levels of renewable energy, further adoption does not reduce emissions, possibly owing to the energy-intensive nature of renewable infrastructure development; significant reductions appear only at high levels of adoption. This finding extends earlier linear treatments of the renewable energy–emissions nexus and underscores the value of testing for non-linearity. However, given the associational nature of the analysis, this threshold pattern should be interpreted as a hypothesis warranting further investigation with causal identification strategies, rather than as definitive evidence of a causal threshold.

Conclusions and Implications

The final environmental model (CO_2 ~ GDP + urban population + total population + renewable energy + renewable energy² + unemployment) explains 91.3% of the variation in CO_2 emissions per capita across the eight South Asian countries. The parametric and non-parametric methods produced consistent results. GDP per capita is confirmed as the main driver of emissions, while the significant quadratic term for renewable energy shows that its emission-reducing benefits emerge only after a certain level of adoption is reached.

The analysis is associational rather than causal; the panel regression framework does not control for unobserved country-specific heterogeneity; and the use of mean substitution may understate uncertainty. The threshold effect identified here should be considered a robust empirical regularity worthy of further validation with causal identification strategies, rather than a definitively established causal mechanism.

These findings have clear policy implications. Renewable energy initiatives based on modest, incremental adoption may yield limited short-term benefits in reducing emissions; instead, sustained investment towards a high share of renewable energy is needed for significant decarbonisation. This study is limited by its focus on aggregated national-level indicators and a static panel regression that could capture lagged adjustment effects. Future research should extend this framework using dynamic panel estimators and disaggregated regional data to validate the threshold effect identified in this study.

***Keywords*:** Carbon dioxide emissions, non-parametric regression, parametric regression, renewable energy, South Asia

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Identifying AI-Generated Human Portraits and Applying Invisible Watermarks for Source Verification

Dasanayaka I.M., Bandara S.H., Divisekara C.K., Jayarathna S.P., Karunarathna D.K., Jayasinghe D.S. and Wickramaarachchi W.U.*

Department of Information and Communication Technology, Faculty of Technology, Rajarata University of Sri Lanka, Mihintale, Sri Lanka

*Corresponding author (email: wirajudara@tec.rjt.ac.lk)

Introduction

Recent advances in artificial intelligence (AI), especially generative adversarial networks (GANs) and diffusion models, have enabled the generation of highly realistic human portraits. However, the use of AI-generated images can also lead to problems such as misinformation, identity fraud and deepfakes, making digital image verification more challenging. Existing research has used deep learning to detect AI-generated images (Akshatha et al., 2026). However, watermarking techniques can still be affected by image manipulation, creating challenges for reliable source verification. To address this issue, this study proposes a dual framework that combines AI-generated human portrait detection with an invisible watermarking approach. Four deep learning models, VGG16, ResNet50, InceptionV3 and Xception, are evaluated for classifying real and AI-generated human portraits. The least significant bit (LSB) method is used to embed source-identifying information into AI-generated images without affecting their visual quality. The watermark is also tested against common image manipulations such as cropping, resizing, compression and filtering. The proposed approach aims to improve the authentication and traceability of AI-generated human portraits, particularly in sensitive applications where image integrity is important.

Methodology

This study uses a two-stage approach combining AI-generated human portrait detection and invisible watermarking. First, deep learning models were used to classify real and AI-generated human portraits. Then, an invisible watermark was embedded into AI-generated images using the LSB method for source verification.

For data collection and preprocessing, a balanced dataset of 3,000 images was prepared, comprising 1,000 real human portraits, 1,000 AI-generated human portraits and 1,000 non-human images. The dataset was divided into training (80%), validation (10%) and testing (10%) sets. Images were resized to 224 × 224 or 299 × 299 pixels, normalised and augmented by flipping, rotation and zooming.

For model training and evaluation, transfer learning was applied using four pre-trained convolutional neural network (CNN) models: VGG16, ResNet50, InceptionV3 and Xception. These models were evaluated to identify the most effective model for classifying real and AI-generated portraits. Deep learning was selected because it can learn visual features from images for classification. Classification accuracy was calculated as follows:

$$\text{Accuracy} = \left(\frac{\text{Number of correct predictions}}{\text{Total number of predictions}}\right) \times 100$$

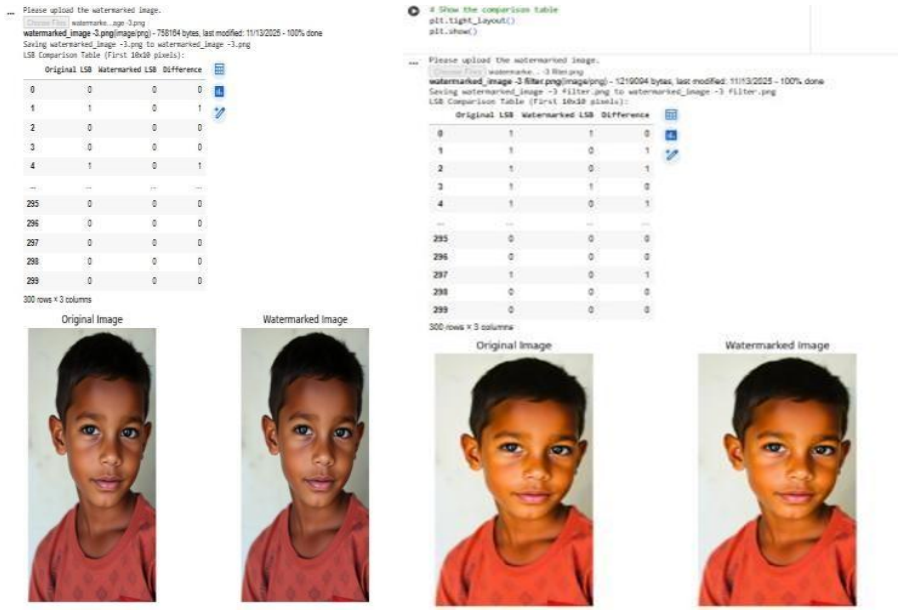
InceptionV3 achieved the best performance, with a classification accuracy of 94.67%.

In further testing, InceptionV3 was evaluated on 100 images, consisting of 50 AI-generated and 50 real portraits, achieving 92% accuracy. AI-generated images were then watermarked using the LSB method, with the selected LSB values set to "0". This method was selected because it allows source information to be embedded with minimal visual impact. The robustness of the watermark was tested against cropping, resizing, filtering and lossy compression. Cropping preserved the LSB values of the remaining pixels, whereas resizing, filtering and compression could alter them and affect the watermark. Verification was performed by checking whether the selected LSB values remained zero.

In the watermark embedding step, AI-generated human portraits are watermarked using the LSB method, whereby the watermark data are embedded into the pixel LSBs with minimal visual impact. All LSB values are set to "0" during embedding. Although cropping removes pixels, it does not alter the LSB values of the remaining pixels. In resizing, filtering or compression, pixel values are recalculated or approximated, altering the least significant bits. As a result, the LSB watermark may become distorted or lost under heavy image manipulations (Figure 1).

Figure 1

Comparison of LSB Differences Between the Original Watermarked Image and the Filtered Image



Note. When an image is filtered, the pixel values are recalculated or approximated, which alters the least significant bits. As a result, the LSB watermark becomes distorted or lost under these heavier manipulations.

For robustness testing, the watermarked images were subjected to resizing, filtering, cropping and compression. After each manipulation, the LSB values were checked to determine whether the embedded watermark remained available for verification. This testing was used to establish whether the watermark could still be detected after common image manipulations.

Results and Discussion

The results show that the fine-tuned InceptionV3 model was the most effective model for AI-generated human portrait classification, achieving a test accuracy of 94.67%. In further testing using 100 images (50 AI-generated and 50 real portraits), the model achieved 92% accuracy. The model was also evaluated using precision, recall, F1-score and the area under the receiver operating characteristic curve (ROC-AUC). As shown in Table 1, the overall precision, recall and F1-score were 0.9331, 0.9283 and 0.9280, respectively, while the ROC-AUC score was 0.9903. These results indicate strong classification performance. The performance of InceptionV3 also surpassed that of the classic ResNet50 and VGG16 models, consistent with the comparison reported by Esi Nyarko et al. (2022).

Table 1

Detailed Classification Report and Overall Model Evaluation Metrics

Class / metric	Precision	Recall	F1-score	Support
AI	0.86	0.98	0.91	200
Non-human	0.99	0.97	0.98	200
Real	0.95	0.83	0.89	200
Macro average	0.93	0.93	0.93	600
Weighted average	0.93	0.93	0.93	600

Note. Overall model accuracy = 92.83%. ROC-AUC score = 0.9903. Overall model precision, recall and F1-score are 0.9331, 0.9283 and 0.9280, respectively.

The watermarking results showed that the LSB method was effective against cropping, as the LSB values of the remaining pixels were not altered. However, resizing, lossy compression and filtering affected the embedded watermark because these operations can modify pixel values. This finding is consistent with the limitations of LSB-based watermarking discussed by Goel and Chandra (2013). Therefore, while the LSB method supports source verification under cropping, its sensitivity to other image manipulations remains a limitation. Future research can investigate more robust methods, such as discrete wavelet transform (DWT) or discrete cosine transform (DCT) watermarking, or deep learning-based watermarking methods such as HiDDeN.

Conclusions and Implications

The proposed two-part architecture successfully combines the InceptionV3 model with LSB watermarking for the verification of AI-generated human portraits. InceptionV3 achieved a test accuracy of 94.67% and an accuracy of 92% in further testing, while the LSB method provided invisible source identification with minimal visual impact. The results indicate that the combined approach can support image authentication and

traceability in sensitive applications. However, the LSB watermark remains sensitive to resizing, filtering and compression, which limits its reliability under these manipulations. Therefore, the proposed approach is effective under the tested conditions but requires further improvement to achieve stronger watermark robustness. Future work can explore more robust watermarking techniques to improve authentication and traceability under different types of image manipulation.

***Keywords*:** AI-generated images, deep learning, human portraits, InceptionV3, watermarking

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TinyML-Based Edge AI System for Human–Elephant Conflict Mitigation in Rural Sri Lanka

Senanayake S.M.B.L.[1,*] and Herath H.M.D.S.[2]
[1]*Department of Computer Engineering, Faculty of Computing, General Sir John Kotelawala Defence University, Sri Lanka,* [2]*Department of Computer Science, Faculty of Computing, General Sir John Kotelawala Defence University, Sri Lanka*
*Corresponding author (email: 41-bce-0017@kdu.ac.lk)

Introduction

Human–elephant conflict (HEC) remains one of the most pressing conservation and socio-economic challenges in rural Sri Lanka, where expanding agricultural settlements increasingly overlap with elephant corridors. Since 2019, HEC has accounted for an average of roughly 125 human deaths and 370 elephant deaths annually, with human fatalities having risen substantially over the past three decades, making Sri Lanka one of the countries with the highest recorded elephant and human death tolls from this conflict (Gunawansa et al., 2023). Conventional mitigation approaches, including physical and electric fencing, communal guarding and translocation, have shown limited long-term effectiveness because elephants are intelligent and learn to circumvent static barriers, while the financial burden of government compensation schemes continues to grow (Gunawansa et al., 2023).

Technology-driven early-warning systems have therefore attracted growing research interest. Prior work has explored diverse sensing modalities, including seismic geophone arrays that capture ground vibrations from elephant footfalls over long ranges (Wijayaraja et al., 2024), combined odour- and ear-flap-sound-based intrusion sensors with support vector classification (Weerawardhana et al., 2022), web–mobile tracking platforms based on the Global Positioning System (GPS) and geofencing (Rajapaksa et al., 2022), and unified end-to-end frameworks integrating infrared and seismic detection with acoustic and light deterrents (Bandara & Bandara, 2023). However, many of these systems depend on continuous cellular or cloud connectivity, consume substantial power or use detection models too large for prolonged field deployment in rural corridors where electricity and network coverage are scarce.

Tiny machine learning (TinyML) offers a promising alternative by enabling inference, and increasingly on-device training, directly on low-power microcontrollers at the network edge, removing the need to transmit raw sensor data continuously and thereby reducing latency, bandwidth demand and energy consumption (Ray, 2022). Recent advances demonstrate that convolutional models can be compressed and trained within kilobyte-scale memory budgets while retaining cloud-comparable accuracy (Lin et al., 2022), and that incremental on-device learning allows models to adapt to new, site-specific data streams without full retraining on external servers (Ren et al., 2021). This study proposes a TinyML-based, multi-modal edge artificial intelligence (AI) system that fuses acoustic and seismic sensing with on-device inference and incremental learning to provide a low-power, low-latency elephant early-warning solution suited to the connectivity and infrastructure constraints of rural Sri Lankan HEC corridors.

Methodology

The proposed system is designed as a network of solar-powered edge sensor nodes deployed along a known HEC corridor. Each node integrates a micro-electromechanical geophone interfaced through an instrumentation amplifier and a second-order Butterworth filter, following the noise-resilient signal-conditioning design validated for elephant footfall detection (Wijayaraja et al., 2024), together with a micro-electromechanical systems (MEMS) microphone to capture elephant vocalisations such as rumbles, roars and trumpets.

Raw seismic and acoustic signals are processed on-device using lightweight frequency-domain feature extraction, after which a compact convolutional classifier distinguishes elephant presence from ambient noise. This classifier is adapted from raw-audio elephant-call classification architectures (Dewmini et al., 2025) and compressed through pruning and quantisation, consistent with edge-deployment practice for wildlife-intrusion classifiers (Reddy et al., 2024). To keep the model within microcontroller memory limits while preserving adaptability, the design incorporates memory-efficient training techniques such as quantisation-aware scaling and sparse gradient updates (Lin et al., 2022), alongside an online-learning module (Ren et al., 2021) that allows each node to recalibrate its classifier incrementally to local background noise conditions, such as rainfall, wind or vehicular traffic, without transmitting raw data off-device.

Upon a positive detection with sufficient confidence, a node relays an event message through a low-power mesh communication layer, drawing on the coordinated alerting concepts of prior detection-and-warning systems (Bandara & Bandara, 2023; Weerawardhana et al., 2022), to a gateway that forwards short message service (SMS) and mobile-application alerts to farmers, community wardens and wildlife officers, in a manner comparable to the geofencing-based notification platforms already piloted in Sri Lankan national parks (Rajapaksa et al., 2022). A future field pilot will deploy a limited number of prototype nodes along one selected HEC corridor to evaluate classification accuracy, false-alarm rate, alert latency and node battery endurance under real ambient conditions. Because the study is currently at the design stage, the final node count, deployment duration and specific corridor will be defined during prototype deployment planning rather than treated as completed experimental parameters.

Results and Discussion

Because field implementation has not yet been completed, no original empirical results are reported in this study. The following discussion therefore uses design benchmarks and comparable results reported in the reviewed literature only to formulate the anticipated system performance. Comparable lightweight raw-audio classifiers for elephant vocalisations have been reported to achieve accuracies of around 89% (Dewmini et al., 2025), while pruned and quantised wildlife-classification models for edge deployment have been reported to reach accuracies above 96% with model sizes compressed to under 2 megabytes (Reddy et al., 2024). These published figures are reference benchmarks rather than results obtained by the proposed system. They suggest that the proposed fused

acoustic–seismic classifier, once compressed for microcontroller deployment, may plausibly achieve comparably high detection accuracy while remaining within the sub-megabyte flash and kilobyte-scale static random-access memory (SRAM) budgets demonstrated for on-device training frameworks (Lin et al., 2022).

The dual-modality design is expected to reduce false alarms relative to single-sensor systems: seismic sensing alone can be prone to spurious triggers from environmental vibration sources such as thunder, while purely acoustic systems may struggle, in isolation, to distinguish elephant vocalisations from other wildlife or human activity. The noise-filtering signal chain validated for geophone-based detection (Wijayaraja et al., 2024), combined with the classifier's cross-modal confirmation logic, is anticipated to mitigate both failure modes. These effects remain hypotheses to be tested during the planned field pilot and are not presented as measured outcomes. Furthermore, because inference and incremental adaptation both occur on-device, the system is designed to reduce average power draw and dependency on cellular infrastructure relative to cloud-reliant frameworks, subject to validation during field deployment.

Conclusions and Implications

This study proposes a TinyML-based, multi-modal edge AI early-warning system that combines seismic and acoustic sensing with on-device inference and incremental learning to address the operational limitations, connectivity dependence and power constraints of existing HEC mitigation technologies in rural Sri Lanka. By situating both detection and adaptive learning at the network edge, the proposed design offers a low-power, low-latency alternative capable of functioning in infrastructure-scarce corridors, with the potential to reduce response times to elephant intrusions and, over time, the human, elephant and economic costs associated with HEC.

The principal implication of this work is methodological: it demonstrates how recent advances in memory-efficient on-device training can be applied to a conservation technology problem that has historically relied on either power-hungry continuous sensing or cloud-dependent classification. Future work will focus on field deployment and multi-season validation of the prototype nodes, expansion of the training dataset across additional elephant corridors to improve cross-site generalisation, and integration with existing wildlife department alert infrastructure to support practical adoption by farmers and conservation authorities.

***Keywords*:** Edge artificial intelligence, human–elephant conflict, on-device learning, Sri Lanka, tiny machine learning

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