

JOURNAL OF TECHNICAL AND SOCIAL SCIENCES

JURNAL TEKNIKAL DAN SAINS SOSIAL



Edisi 23 Jilid 1, November 2025 e-ISSN 2289 7356
23rd Edition Volume 1, November 2025 e-ISSN 2289 7356

Diterbitkan oleh : Politeknik Nilai Negeri Sembilan
Published by : Nilai Polytechnic Negeri Sembilan



Artikel	Mukasurat
BIBLIOMETRIC ANALYSIS OF ALARM SENSOR TECHNOLOGIES IN HALAL POULTRY SLAUGHTERING: TRENDS, INNOVATIONS, AND CHALLENGES <i>ANALISIS BIBLIOMETRIK TERHADAP TEKNOLOGI SENSOR AMARAN DALAM PENYEMBELIHAN AYAM HALAL: TREND, INOVASI DAN CABARAN</i> Noor Alina Abdul Aziz^{1a*}, Nurul Dalila Faris^{2a}, & Nur Shahirah Nasir^{3a} ^a University College MAIWP International	1-17
STREAMLINED IDENTIFICATION OF POLYETHYLENE-DEGRADING BACTERIA FOR SYNTHETIC BIOTECHNOLOGY APPLICATIONS <i>MEMPERKEMAS PENGENALPASTIAN BAKTERIA PENGURAI POLIETILENA UNTUK APLIKASI BIOTEKNOLOGI SINTETIK</i> Nur Anisza Hanoum Naseron^{1,2a*}, & Ahmad Bazli Ramzi^{2b} ^a Politeknik Nilai ^b Institute of Systems Biology (INBIOSIS), Universiti Kebangsaan Malaysia	18-31
UTILIZATION OF IOE AND FINGERPRINT TECHNOLOGY IN REAL-TIME MONITORING OF FLORA FOR DISASTER MITIGATION IN THE BRANTAS WATERSHED <i>PENGUNAAN IOE DAN TEKNOLOGI CAP JARI DALAM PEMANTAUAN MASA NYATA FLORA UNTUK TEBATAN BENCANA DI TADAHAN AIR BRANTAS</i> Aripriharta^{1a*}, Siti Zubaidah^{1b}, Mokh. Sholihul Hadi^{1a}, Hendra Susanto^{1b}, Gwo-Jiun Horng^{1c}, Muhammad Cahyo Bagaskoro^{1a&d}, & Muchamad Wahyu Prasetyo^{1a&d} ^a Department of Electrical Engineering, State University of Malang, Indonesia ^b Department of Biology, State University of Malang, Indonesia ^c Department of Electronics Engineering, Southern Taiwan University of Science and Technology, Taiwan, Province of China ^d Study and Research Center for Engineering, State University of Malang, Indonesia	32-41
THE RELATIONSHIP BETWEEN AWKWARD WORKING POSTURES AND MUSCULOSKELETAL DISORDER RISKS AMONG LANDSCAPE HORTICULTURE WORKERS <i>HUBUNGAN ANTARA POSTUR KERJA JANGGAL DAN RISIKO GANGGUAN MUSKULOSKELETAL DALAM KALANGAN PEKERJA HORTIKULTUR LANDSKAP</i> Fara Diba Badrul Hisham^{1a*}, Shuharzi Md Salleh^{2a}, & Fairoz Yaakob^{3a} ^a Politeknik Nilai	42-48
ANALYZING THE IMPACT OF AI ASSISTANCE LEVELS AND TASK TYPES ON LECTURER SATISFACTION AND TEACHING OUTCOMES IN HIGHER EDUCATION <i>ANALISIS IMPAK TAHAP PENGGUNAAN AI DAN JENIS TUGAS BERDASARKAN KEPUASAN PENSYARAH DAN HASIL PEMBELAJARAN DI INTITUSI PENGAJIAN TINGGI</i> Faraziah Hassan^{1a*}, Nur Hidayah Khalid^{2a} & Ahmad Razimi Mat Lazim^{3a} ^a Politeknik Nilai	49-57

Artikel	Mukasurat
DEVELOPMENT AND CHARACTERIZATION OF BIOPLASTICS FROM TAPIOCA PEEL STARCH REINFORCED WITH PINEAPPLE LEAF FIBER <i>PEMBANGUNAN DAN PENCIRIAN BIOPLASTIK DARIPADA KANJI KULIT UBI KAYU DIPERKUATKAN DENGAN SERAT DAUN NANAS</i> Fauziah Shaheen Sheh Rahman^{1a*} ^a Politeknik Nilai	58-66
A SMART-DRIVEN APPROACH TO SUSTAINABLE ENERGY MANAGEMENT IN MALAYSIAN HIGHER EDUCATION: THE CASE OF POLITEKNIK NILAI <i>PENDEKATAN SMART DALAM PENGURUSAN TENAGA LESTARI DI INSTITUSI PENGAJIAN TINGGI MALAYSIA: KAJIAN KES DI POLITEKNIK NILAI</i> Noor Azlina Ahmad^{1a*}, Muhd Abu Bakar Muhd Radzi^{2b} & Hamrin Abu Hasan^{3c} ^a Politeknik Nilai, Malaysia ^b Kolej Komuniti Masjid Tanah, Malaysia ^c Politeknik Port Dickson, Malaysia	67-74
EVALUATION OF THE SUCCESS OF THE ICT AND ELECTRICAL INFRASTRUCTURE UPGRADING PROJECT TO ENHANCE THE QUALITY OF THE LEARNING ENVIRONMENT AT COMMUNITY COLLEGES <i>PENILAIAN KEBERHASILAN PROJEK MENAIKTARAF INFRASTRUKTUR ICT DAN ELEKTRIK BAGI MENINGKATKAN KUALITI PERSEKITARAN PEMBELAJARAN DI KOLEJ KOMUNITI</i> Nur Hidayah Khalid^{1a*} & Siti Assila Murtijan^{1a} ^a Politeknik Nilai, Malaysia	75-82
ANALYSIS OF THE CAUSES OF STUDY DEFERMENT AND WITHDRAWAL AMONG STUDENTS AT POLITEKNIK NILAI: A CASE STUDY ANCHORED ON SDG 4 (QUALITY EDUCATION) <i>ANALISIS PUNCA PENANGGUHAN DAN PENARIKAN DIRI PELAJAR DI POLITEKNIK NILAI: KAJIAN KES BERTERASKAN SDG 4 (PENDIDIKAN BERKUALITI)</i> Nurul Aimi Ahmad Suandi^{1a*} & Mutiman Mat^{2a} ^a Politeknik Nilai, Malaysia	83-92
LANDSCAPE SUSTAINABILITY ASSESSMENT TOOLS <i>PERBANDINGAN KERANGKA PENILAIAN KELESTARIAN LANDSKAP</i> Nur Azemah Aminludin^{1a*}, Siti Norzaemah Mohd Rashid^{2b*} & Nur Izdiha Sulaiman^{3a} ^a Politeknik Nilai, Negeri Sembilan ^b Politeknik Sultan Idris Shah, Sabak Bernam	93-105

© Politeknik Nilai Negeri Sembilan (PNS)

Kompleks Pendidikan Bandar Enstek,
71760, Bandar Enstek,
Negeri Sembilan
No. Tel: 06-7980400
No. Fax: 06-7911269
<https://pns.mypolycc.edu.my/>

Semua hak cipta terpelihara. Tidak dibenarkan menerbit, mengulang cetak, mengeluarkan ulang mana-mana bahagian artikel, ilustrasi, fotografi dan isi kandungan jurnal ini dalam apa juga bentuk dan dengan cara apa jua sama ada secara elektronik, fotokopi, mekanik, rakaman atau cara lain yang direka pada masa akan datang sebelum mendapat izin bertulis daripada Pengarah Politeknik Nilai.

Diterbitkan oleh:

Politeknik Nilai Negeri Sembilan (PNS)
Kompleks Pendidikan Bandar Enstek,
71760, Bandar Enstek,
Negeri Sembilan

e-ISSN 2289 7356

SIDANG EDITOR

Penasihat

Dr. Siti Noridah Ali
(Pengarah Politeknik Nilai)
Dr. Ahmad Razimi Mat Lazim – Politeknik Nilai
(Ketua Unit Penyelidikan & Inovasi)

Ketua Sidang Editor

Dr. Hjh. Nor Hayati Fatmi Talib – Politeknik Nilai

Kumpulan Editor

Pn. Norliyana Bau Muhammad Affendi Bau – Politeknik Nilai
Pn. Nur Hazeleen Bashah – Politeknik Nilai
Pn. Qyurulzeta Ishak – Politeknik Nilai
Pn. Erina Ismail – Politeknik Nilai
En. Encik Muhammad Asyraf Abdul Ghani – Politeknik Nilai
Pn. Azalinda Mat Saad – Politeknik Nilai
Dr. Yusni Mohamad Yusak – Politeknik Nilai
Dr. Nor Rahimy Khalid – Politeknik Nilai
Dr. Salwa Amirah Awang – Politeknik Sultan Azlan Shah
Pn. Zainab Hanina Abdull Samad – Politeknik Sultan Haji Ahmad Shah
PM Dr. Khairul Hamimah Mohammad Jodi – Open Universiti Malaysia
PM Dr. Latifah Abdul Majid – Universiti Kebangsaan Malaysia

Lembaga Penasihat Editor

PM. Dr. Gamal Zakaria – Universiti Brunei Darussalam
Ajan Abdulrazak Panaemalae – Walailak Universiti, Thailand
PM. Dr. Ahmad Munawar Ismail – Universiti Kebangsaan Malaysia
Prof. Dr. Sarjit S. Gill Darshan Singh – Universiti Putra Malaysia

Pewasit

Dr. Salwa Amirah Awang – Politeknik Sultan Azlan Shah
Dr. Ahmad Razimi Mat Lazim – Politeknik Nilai
Dr. Fara Diba Badrul Hisham – Politeknik Nilai
Dr. Aznida Wati Abdul Ghani – Politeknik Sultan Haji Ahmad Shah
Prof Zhu Fengzhao - Tongren Polytechnic University, China
Dr. Mohd Hafiz Ali – Politeknik Tun Syed Nasir Syed Ismail

Pembaca Prof

Ts. Dr. Md. Baharuddin Abdul Rahman – Universiti Sains Malaysia

CATATAN BAGI PENYUMBANG ARTIKEL

Jurnal Teknikal dan Sains Sosial (JTSS) merupakan jurnal berindeks MySitasi yang diterbitkan merentasi pelbagai disiplin Ilmu merangkumi Teknikal, Kejuruteraan, Bahasa, Pendidikan, Pendidikan Islam, Tamadun Islam, Ekonomi, Falsafah dan sebagainya. Jurnal ini diterbitkan secara salinan lembut eISSN sebanyak 2/ 3 penerbitan setahun iaitu pada bulan Jun dan Disember/ Mac, Julai dan November. Sumbangan artikel perlulah menepati garis panduan berikut:

- Manuskrip asli oleh penulis yang belum pernah diterbitkan, bukan dalam peringkat penilaian atau penerbitan mana-mana pihak penerbit.
- Bilangan perkataan antara 8,000 hingga 11,000 perkataan sahaja termasuk 300 perkataan (maksimum) abstrak.
- Bilangan mukasurat hendaklah antara 10 hingga 15 mukasurat termasuk rujukan, bertaip langkau satu (*single*), menggunakan tulisan Cambria bersaiz 11 di atas kertas bersaiz A4.
- Manuskrip mesti ditulis dalam Bahasa Melayu atau Bahasa Inggeris.
- Manuskrip lengkap dengan ilustrasi (gambarajah/ jadual/ graf/ carta dan sebagainya) yang berkaitan dengan manuskrip yang berwarna hendaklah dikekalkan dan dilampirkan dalam fail jpeg.
- Penulisan secara ilmiah dengan nota hujung (*endnote*) bagi rujukan mempunyai maklumat penulis, tahun, tajuk lengkap, tempat diterbitkan dan nama penerbit.
- Manuskrip akan melalui saringan palagiat yang mesti melepasi kesamaan (*similarity maximum 30%*) dan tiada unsur-unsur sensitif.
- Kesemua penyumbang artikel mesti memaparkan nama penuh, jawatan, tempat bertugas dan alamat email.
- Boleh menggunakan transliterasi Arab jika perlu.
- Syarat penerimaan manuskrip adalah apabila menepati maklumbalas penilai manuskrip.
- Semua senarai penulis mesti bersetuju untuk manuskrip diterbitkan dalam Jurnal Teknikal dan Sains Sosial.
- 'Outside margin' adalah 1 inci kecuali sebelah kiri 1½ inci.
- Tajuk mesti mengandungi topik, nama penulis dan nama institusi.
- Nombor mukasurat sebelah bawah kanan.
- Manuskrip mesti mengandungi abstrak, teks (pendahuluan, metodologi, dapatan, perbincangan dapatan dan implikasi) dan rujukan (tiada nota kaki).
- Keputusan penerbitan adalah berdasarkan sidang editor, penilaian pewasit dan melepasi saringan palagiat.
- Yuran penerbitan adalah RM150.00 bagi setiap artikel.
- Jika terdapat sebarang pertanyaan, sila hubungi:

Dr. Hjh. Nor Hayati Fatmi Talib
Ketua Sidang Editor Jurnal Teknikal dan Sains Sosial
Politeknik Nilai Negeri Sembilan
penerbitanpns@gmail.com
yati_6709@yahoo.com

BIBLIOMETRIC ANALYSIS OF ALARM SENSOR TECHNOLOGIES IN HALAL POULTRY SLAUGHTERING: TRENDS, INNOVATIONS, AND CHALLENGES

ANALISIS BIBLIOMETRIK TERHADAP TEKNOLOGI SENSOR AMARAN DALAM PENYEMBELIHAN AYAM HALAL: TREND, INOVASI DAN CABARAN

Noor Alina Abdul Aziz^{1a*}, Nurul Dalila Faris^{2a}, & Nur Shahirah Nasir^{3a}

^aUniversity College MAIWP International

elina@ucmi.edu.my, dalila@ucmi.edu.my & shahirah@ucmi.edu.my

*Corresponding author

ABSTRACT

The integration of alarm sensor technology in the halal poultry slaughtering industry has emerged as a critical innovation to meet rising global demand while ensuring compliance with halal standards. This study performs a bibliometric analysis to evaluate research trends, identify key contributors, and assess technological developments in this domain. Utilizing VOSviewer software, the analysis reveals a significant growth in publications between 2020 and 2023, driven by the adoption of artificial intelligence (AI), the Internet of Things (IoT), and blockchain. These technologies have enhanced operational efficiency, transparency, and compliance with both ethical and regulatory standards. The research identifies dominant contributions from the fields of computer science and engineering. AI and IoT technologies are central in enabling real-time monitoring, automation, and precision analytics in slaughtering operations. China leads in global research output, while countries like Australia and France show high citation impacts. Despite progress, challenges remain regarding consumer acceptance, integration complexity, and ethical considerations. The study concludes by highlighting the need for interdisciplinary collaboration and innovation to further enhance halal compliance and operational excellence.

Keywords: Halal, Poultry, Slaughtering, Alarm Sensor, Artificial Intelligence, Internet of Things, Bibliometric Analysis, VOSviewer, Automation

ABSTRAK

Pengintegrasian teknologi sensor amaran dalam industri penyembelihan ayam halal telah muncul sebagai satu inovasi penting bagi memenuhi permintaan global yang semakin meningkat, di samping memastikan pematuhan terhadap piawaian halal. Kajian ini melaksanakan analisis bibliometrik untuk menilai trend penyelidikan, mengenal pasti penyumbang utama, dan menilai perkembangan teknologi dalam bidang ini. Melalui penggunaan perisian VOSviewer, analisis menunjukkan pertumbuhan penerbitan yang ketara antara tahun 2020 hingga 2023, didorong oleh penerimaan teknologi kecerdasan buatan (AI), Internet Benda (IoT), dan rangkaian blok (blockchain). Teknologi-teknologi ini telah meningkatkan kecekapan operasi, ketelusan, serta pematuhan terhadap standard etika dan peraturan. Kajian ini turut mengenal pasti sumbangan dominan daripada bidang sains komputer dan kejuruteraan. Teknologi AI dan IoT merupakan komponen utama dalam membolehkan pemantauan masa nyata, automasi, serta analitik yang lebih tepat dalam operasi penyembelihan. China merupakan peneraju dalam keluaran penyelidikan global, manakala negara seperti Australia dan Perancis menunjukkan impak sitasi yang tinggi. Walaupun terdapat kemajuan,

cabaran masih wujud berkaitan penerimaan pengguna, kerumitan integrasi dan pertimbangan etika. Kajian ini menyimpulkan keperluan kepada kerjasama antara disiplin dan inovasi berterusan untuk meningkatkan pematuhan halal serta kecemerlangan operasi.

Kata Kunci: Halal, Ayam, Penyembelihan, Sensor Amaran, Kecerdasan Buatan, Internet Benda, Analisis Bibliometrik, VOSviewer, Automasi.

INTRODUCTION

The poultry slaughtering industry is undergoing significant transformation with the integration of advanced alarm sensor technologies. As the global demand for poultry products continues to rise, the need for efficient and effective monitoring systems in poultry farms and slaughterhouses becomes increasingly critical. Traditional methods of monitoring environmental variables and ensuring food safety are being replaced by intelligent systems that leverage the Internet of Things (IoT), big data analytics, and artificial intelligence (AI) to enhance productivity, animal welfare, and food safety standards (N. J. Van Eck & L. Waltman, 2010).

One of the key advancements in this field is the development of smart poultry management systems that utilize precision livestock farming (PLF) technologies. These systems incorporate smart sensors to monitor various parameters such as temperature, humidity, and gas concentration in real-time, thereby ensuring optimal living conditions for poultry. The data collected by these sensors is analyzed using big data tools to make informed decisions that improve production efficiency and reduce resource usage¹. Additionally, IoT technologies enable seamless communication between farm sensors and devices, automating multiple farm procedures and enhancing overall farm management (K. Joshi, et al, 2023; N. J. Van Eck & L. Waltman, 2017).

In the context of poultry slaughterhouses, IoT-based food safety monitoring systems are being developed to address consumer concerns about biological and chemical hazards. These systems involve placing sensors on the poultry slaughtering conveyor systems to detect potential hazards and notify food safety officers when intervention is needed. This approach not only improves the Hazard Analysis and Critical Control Point (HACCP) protocols but also ensures that the poultry products meet the highest safety standards (N. Hasanah & D. Indrawan, 2020; S. I. Orakwue et al, 2022). By integrating these advanced technologies, the poultry industry can achieve higher levels of efficiency, safety, and sustainability, ultimately benefiting both producers and consumers (N. J. Van Eck & L. Waltman, 2010).

LITERATURE REVIEW

Comprehensive Literature Review on Alarm Sensor Technology in the Halal Poultry Chicken Slaughtering Industry.

The halal poultry slaughtering industry has increasingly focused on integrating ethical and technological solutions to address consumer expectations and regulatory standards. Rahman et al. (2024) highlight the ethical underpinnings of halal meat production, emphasizing the principles of *Halalan Tayyiban*, which promote the humane and sustainable treatment of animals. Z. A. Jalan et al (2024) further elaborate on the necessity of halal certification, ensuring compliance with Shariah law throughout the supply chain, including during slaughtering processes. Similarly, R. O. Sujarwanta et al (2024) underscore the role of

religious practices and consumer behavior in shaping the industry, particularly in regions with significant Muslim populations. These foundational studies illustrate the industry's ongoing efforts to harmonize ethical principles with operational standards.

Technological advancements have played a significant role in improving the precision and compliance of halal poultry slaughtering processes. Muhammad et al. (2021) demonstrate the potential of artificial intelligence, particularly deep learning models like RetinaNet-MaskRCNN, in detecting and classifying key anatomical structures to ensure Shariah-compliant slaughter. Ishak and Zaki (2023) compare traditional and modern slaughtering technologies, focusing on the adaptability of electric water bath stunning to halal standards, as it avoids causing cardiac arrest. Arshad et al. (2023) explore the implementation of automated systems, emphasizing their role in minimizing human error and ensuring consistent compliance. Collectively, these studies showcase how technological innovations can address challenges in maintaining halal integrity while improving operational efficiency.

Despite technological progress, significant challenges and gaps persist in integrating these systems seamlessly into halal slaughtering practices. Sazili et al. (2023) reviewed the compliance of stunning technologies with halal principles, highlighting unresolved debates about their impact on animal welfare and religious adherence. Hayat et al. (2023) examine consumer and scholar perspectives on stunning, identifying mixed reactions to its ethical and spiritual implications. Badu et al. (2023) explore awareness and acceptance of stunning technologies, revealing knowledge gaps among consumers and religious leaders. These challenges underscore the need for continued research and innovation to refine stunning and sensor technologies, ensuring they meet both religious and operational requirements.



RESEARCH QUESTION

1. What are the research trends in online learning studies according to the year of publication?
2. Who writes the most cited articles? and where do they work?
3. What is the type of document by subject of research?
4. Who is the top 10 authors based on citation by research?
5. What is the popular Co-occurrence by Author keywords related to the study?
6. What is citation by countries' collaboration?

METHODOLOGY

Bibliometrics means the combination, managing and investigation of bibliographic information obtained from publications which are scientific in nature (A. Verbeek et al, 2002; D. S. Assyakur & E. M. Rosa, 2022; J. L. Alves et al, 2021). Along with general descriptive statistics, such as, publishing journals, publication year and main author classification (Y. C. J. Wu & T. Wu, 2017); it also comprises complex techniques, such as, document co-citation analysis. A successful literature review necessitates an iterative process involving the identification of appropriate keywords, literature search, and thorough analysis to build a comprehensive bibliography and yield dependable results (B. Fahimnia et al, 2015).

In light of this, the study sought to focus on top-tier publications, as they offer valuable insights into the theoretical perspectives shaping the evolution of the research domain. To ensure data reliability, the study relied on the SCOPUS database for data collection (G. di Stefano et al, 2010; G. P. Khiste and R. R. Paithankar, 2017; A. Al-Khoury et al, 2022). Moreover,

in order to ensure the inclusion of high-quality publications, only articles published in rigorously peer-reviewed academic journals were considered, with a deliberate exclusion of books and lecture notes (D. Gu et al, 2019). Notably, Elsevier's Scopus, known for its extensive coverage, facilitated the collection of publications spanning from 2020 to December 2023 for subsequent analysis.

Data Search Strategy

To collect relevant and high-quality data for this bibliometric analysis, a systematic search strategy was employed using the Scopus database, one of the most comprehensive and authoritative sources of peer-reviewed academic literature. The search focused on retrieving articles related to alarm sensor technologies, halal poultry slaughtering, and associated smart systems such as artificial intelligence (AI), Internet of Things (IoT), and Industry 4.0 applications.

The initial search query was structured to include combinations of keywords such as *slaughter*, *halal*, *poultry*, *sensor*, *technology*, *automation*, *AI*, and *IoT*. Boolean operators and truncation symbols were used to broaden the search and capture related terms. The final refined search string was:

TITLE-ABS-KEY (slaughter* OR poultry* OR halal) AND (sensor* OR "alarm system" OR IoT OR "artificial intelligence" OR automation OR "smart monitoring") AND PUBYEAR > 2019 AND PUBYEAR < 2024 AND (DOCTYPE (ar) OR DOCTYPE (cp)) AND (LANGUAGE (English))

This search yielded a total of 659 documents published between 2020 and 2023. Articles were filtered based on title relevance, abstract screening, and duplication checks. Only documents that directly addressed the use or development of technological solutions in halal poultry slaughtering or similar meat processing contexts were included. The final dataset comprised 435 publications, which were then exported in plain text and CSV formats for bibliometric analysis. These records included metadata such as titles, author names, publication sources, keywords, citations, and abstracts. By narrowing the scope to this specific domain, the study ensured the inclusion of articles that are most relevant to the integration of modern sensor technologies and smart systems in halal poultry slaughtering operations.

Table 1: The Search Strings

SCOPUS	TITLE-ABS-KEY ((slaughter* OR cut*) AND technology* AND industry*) AND PUBYEAR > 2019 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA , "COMP")) AND (LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "ch") OR LIMIT-TO (DOCTYPE, "bk") OR LIMIT-TO (DOCTYPE, "cr") OR LIMIT-TO (DOCTYPE, "ed") OR LIMIT-TO (DOCTYPE, "sh") OR LIMIT-TO (DOCTYPE, "dp")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (EXACTKEYWORD, "Internet Of Things") OR LIMIT-TO (EXACTKEYWORD, "Artificial Intelligence") OR LIMIT-TO (EXACTKEYWORD, "Machine Learning") OR LIMIT-TO (EXACTKEYWORD, "Cutting Tools") OR LIMIT-TO (EXACTKEYWORD, "Industry 4.0") OR LIMIT-TO (EXACTKEYWORD, "IoT") OR LIMIT-TO (EXACTKEYWORD, "Big Data") OR LIMIT-TO (EXACTKEYWORD, "Learning Systems") OR LIMIT-TO (EXACTKEYWORD, "Machine-learning") OR LIMIT-TO (EXACTKEYWORD, "Information Management") OR LIMIT-TO (EXACTKEYWORD, "Network Security") OR LIMIT-TO (EXACTKEYWORD, "Cutting") OR LIMIT-TO (EXACTKEYWORD, "Computer Vision") OR LIMIT-TO (EXACTKEYWORD, "Embedded Systems") OR LIMIT-TO (EXACTKEYWORD, "Internet Of Things (IoT)") OR LIMIT-TO (EXACTKEYWORD, "Artificial Intelligence (AI)") OR LIMIT-TO (EXACTKEYWORD, "Artificial Intelligence Technologies") OR LIMIT-TO
--------	--

	(EXACTKEYWORD, "Classification (of Information)") OR LIMIT-TO (EXACTKEYWORD, "Computer Control Systems") OR LIMIT-TO (EXACTKEYWORD, "Metal Cutting") OR LIMIT-TO (EXACTKEYWORD, "Authentication") OR LIMIT-TO (EXACTKEYWORD, "Machining") OR LIMIT-TO (EXACTKEYWORD, "Manufacturing Process") OR LIMIT-TO (EXACTKEYWORD, "Sensors") OR LIMIT-TO (EXACTKEYWORD, "Agricultural Technology") OR LIMIT-TO (EXACTKEYWORD, "Internet Of Thing") OR LIMIT-TO (EXACTKEYWORD, "Risk Assessment") OR LIMIT-TO (EXACTKEYWORD, "Quality Control") OR LIMIT-TO (EXACTKEYWORD, "Real- Time") OR LIMIT-TO (EXACTKEYWORD, "Sales") OR LIMIT-TO (EXACTKEYWORD, "Data Privacy") OR LIMIT-TO (EXACTKEYWORD, "Cyber Security") OR LIMIT-TO (EXACTKEYWORD, "Industry 5.0") OR LIMIT-TO (EXACTKEYWORD, "Machine Tools") OR LIMIT-TO (EXACTKEYWORD, "Costs") OR LIMIT-TO (EXACTKEYWORD, "Smart Manufacturing") OR LIMIT-TO (EXACTKEYWORD, "Environmental Technology") OR LIMIT-TO (EXACTKEYWORD, "Innovation") OR LIMIT-TO (EXACTKEYWORD, "Privacy") OR LIMIT-TO (EXACTKEYWORD, "Production Efficiency") OR LIMIT-TO (EXACTKEYWORD, "Advanced Technology") OR LIMIT-TO (EXACTKEYWORD, "Application Programs") OR LIMIT-TO (EXACTKEYWORD, "Intelligent Systems") OR LIMIT-TO (EXACTKEYWORD, "Literature Reviews") OR LIMIT-TO (EXACTKEYWORD, "Product Design") OR LIMIT-TO (EXACTKEYWORD, "Cyber-physical Systems") OR LIMIT-TO (EXACTKEYWORD, "Data Transfer") OR LIMIT-TO (EXACTKEYWORD, "Network Architecture") OR LIMIT-TO (EXACTKEYWORD, "Finance") OR LIMIT-TO (EXACTKEYWORD, "Emerging Technologies") OR LIMIT-TO (EXACTKEYWORD, "Cutting Edge Technology") OR LIMIT-TO (EXACTKEYWORD, "Cutting Edges") OR LIMIT-TO (EXACTKEYWORD, "Sustainable Development") OR LIMIT-TO (EXACTKEYWORD, "Virtual Reality") OR LIMIT-TO (EXACTKEYWORD, "Industrial Research") OR LIMIT-TO (EXACTKEYWORD, "Cloud Computing") OR LIMIT-TO (EXACTKEYWORD, "Learning Algorithms") OR LIMIT-TO (EXACTKEYWORD, "5G Mobile Communication Systems") OR LIMIT-TO (EXACTKEYWORD, "Data Handling") OR LIMIT-TO (EXACTKEYWORD, "Digital Transformation") OR LIMIT-TO (EXACTKEYWORD, "Manufacturing Industries") OR LIMIT-TO (EXACTKEYWORD, "Data Visualization"))
--	--

Table 2: The Selection Criterion is Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2020 – 2023	< 2020
Literature type	Journal (Article) and proceeding	Book, Review

DATA ANALYSIS

VOSviewer is a user-friendly bibliometric software developed by Nees Jan van Eck and Ludo Waltman at Leiden University, Netherlands (N. J. Van Eck & L. Waltman, 2010; N. J. Van Eck & L. Waltman, 2010). Widely utilized for visualizing and analyzing scientific literature, the tool specializes in creating intuitive network visualizations, clustering related items, and generating density maps. Its versatility allows for the examination of co-authorship, co-citation, and keyword co-occurrence networks, providing researchers with a comprehensive understanding of research landscapes. The interactive interface, coupled with continuous updates, ensures efficient and dynamic exploration of large datasets. VOSviewer's ability to compute metrics, customize visualizations, and its compatibility with various bibliometric data sources make it a valuable resource for scholars seeking insights into complex research domains.

One of the standout features of VOSviewer is its capacity to transform intricate bibliometric datasets into visually interpretable maps and charts. With a focus on network visualization, the software excels in clustering related items, analyzing keyword co-occurrence patterns, and generating density maps. Researchers benefit from its user-friendly interface, enabling both novice and experienced users to explore research landscapes efficiently. VOSviewer's continuous development ensures it remains at the forefront of bibliometric analysis, offering valuable insights through metrics computation and customizable visualizations. Its adaptability to different types of bibliometric data, such as co-authorship and citation networks, positions VOSviewer as a versatile and indispensable tool for scholars seeking deeper understanding and meaningful insights within their research domains.

Datasets comprising information on the publication year, title, author name, journal, citation, and keywords in PlainText format were procured from the Scopus database, spanning the period from 2020 to December 2023. These datasets were then analyzed using VOSviewer software version 1.6.19. Through the application of VOS clustering and mapping techniques, this software facilitated the examination and generation of maps. Offering an alternative to the Multidimensional Scaling (MDS) approach, VOSViewer focuses on situating items within low-dimensional spaces, ensuring that the proximity between any two items accurately reflects their relatedness and similarity (N. J. Van Eck & L. Waltman, 2010).

In this respect, VOSViewer shares similarity with the MDS approach (F. P. Appio, 2014). Diverging from MDS, which primarily engages in the computation of similarity metrics like cosine and Jaccard indices, VOS utilizes a more fitting method for normalizing co-occurrence frequencies such as, the association strength (AS_{ij}) and it is calculated as: $AS_{ij} = \frac{C_{ij}}{W_i + W_j}$ which is "proportional to the ratio between on the one hand the observed number of cooccurrences of i and j and on the other hand the expected number of co-occurrences of i and j under the assumption that co-occurrences of i and j are statistically independent" (Van Eck & Waltman, 2010,).

Hence, with help of this index, VOSviewer places items in the form of a map after reducing the weighted sum of the squared distances between all item pairs. According to Appio et al. (2016), the LinLog/modularity normalization was implemented. Furthermore, by applying visualisation techniques through VOSviewer to the data set, patterns built on mathematical relationships were uncovered and analyses such as keyword co-occurrence, citation analysis and co-citation analysis were performed.

Hence, with help of this index, VOSviewer places items in the form of a map after reducing the weighted sum of the squared distances between all item pairs. According to Appio et al. (2016), the LinLog/modularity normalization was implemented. Furthermore, by applying visualisation techniques through VOSviewer to the data set, patterns built on mathematical relationships were uncovered and analyses such as keyword co-occurrence, citation analysis and co-citation analysis were performed.

Development of research area during a period can be explored by keyword co-occurrence analysis (Zhao, 2017) and is successful in identifying popular topics in different fields (Li et al., 2016). Whereas, citation analysis is useful in identifying key research issues, trends and techniques, along with exploring the historical relevance of a discipline's main area of focus (Allahverdiyev and Yucesoy, 2017). Document co-citation analysis is one of the frequently applied bibliometric methods (Appio et al., 2016; Fahimnia et al., 2015; Liu et al., 2015) and its result is mapping dependent on the network theory to identify relevant structure of data (Liu et al., 2015).

RESULT AND DISCCUSION

What are the research trends in online learning studies according to the year of publication?

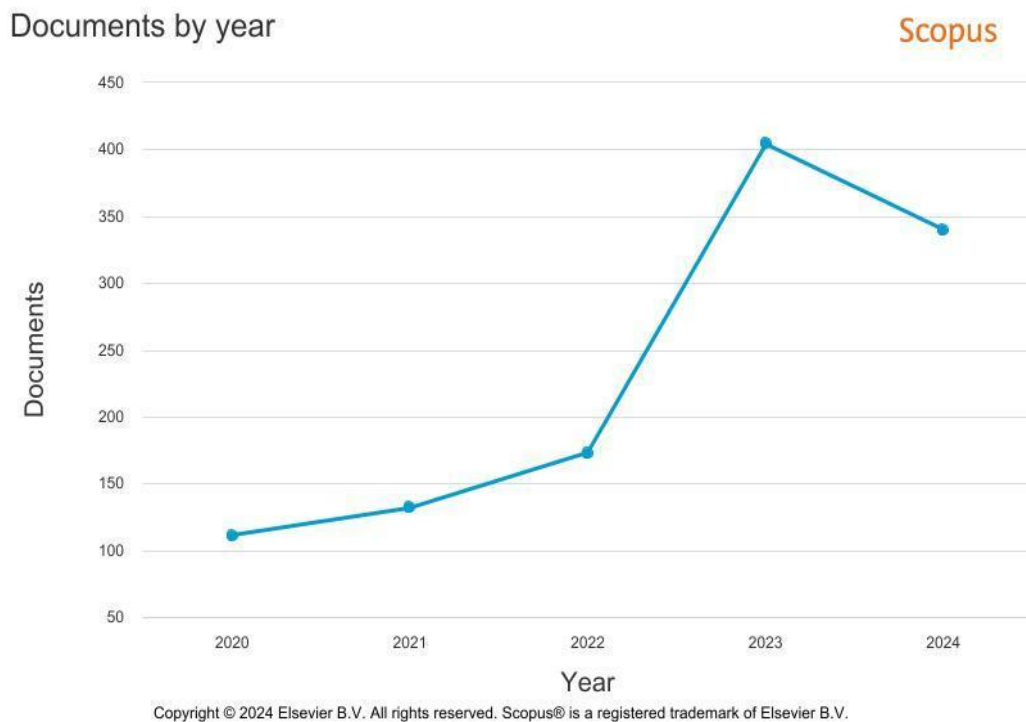


Figure 1: Plotting Document Publication by Years.

Analysis of Research Trends in Sensor Technology for the Halal Poultry Slaughtering Industry

The publication trends from 2020 to 2024 indicate a progressive increase in research on sensor technology within the halal poultry slaughtering industry, reflecting growing interest and advancements in this field. The year 2020 marks the lowest output, with only 111 documents (9.6%), possibly attributed to the initial phases of exploration into sensor technology applications in halal slaughtering. The steady growth from 2020 to 2021, with a slight rise to 132 publications (11.4%), suggests an increasing recognition of the potential of this technology, though it remained a niche research area during these years.

The most significant growth is observed in 2023, which accounts for the highest percentage of publications at 34.8% (404 documents). This peak likely correlates with the industry's pressing demand for innovative solutions to enhance compliance with halal standards while improving efficiency and animal welfare. The heightened focus on regulatory requirements and consumer expectations during this period may have driven this surge. The increase in output aligns with the broader trend of adopting Industry 4.0 technologies, including sensors and automation, within the meat processing sector.

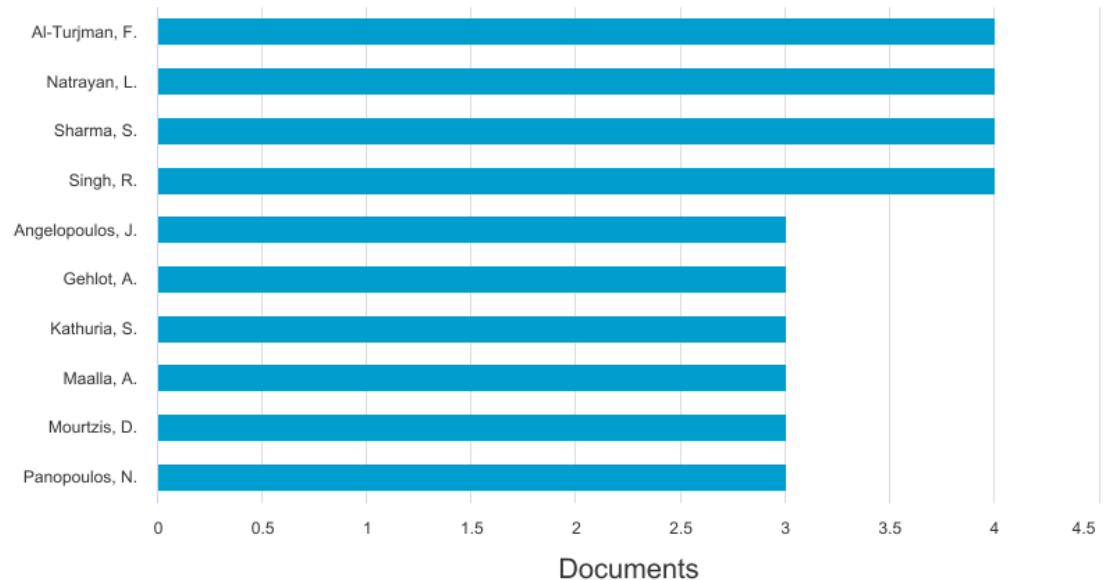
In 2024, while there is a slight decline to 340 publications (29.3%), the number remains high, indicating sustained interest and maturation in the research domain. The reduction could suggest a shift from exploratory studies to applied research or commercialization efforts, reflecting the industry's transition toward practical implementations. This trend highlights the need for future research to focus on refining sensor technologies to ensure alignment with halal compliance, animal welfare, and operational efficiency, addressing existing gaps and challenges identified in earlier studies.

Who Writes the Most Cited Articles? and Where Do They Work?

Documents by author

Compare the document counts for up to 15 authors.

Scopus



Copyright © 2024 Elsevier B.V. All rights reserved. Scopus® is a registered trademark of Elsevier B.V.

Figure 2: Identify Source of Distribution of Most Cited

Table 2: Identify Source of Distribution of Most Cited

Author Name	Number of Document	Percentage (%)
Al-Turjman, F.	4	0.34
Natrayan, L.	4	0.34
Sharma, S.	4	0.34
Singh, R.	4	0.34
Angelopoulos, J.	3	0.26
Gehlot, A.	3	0.26
Kathuria, S.	3	0.26
Maalla, A.	3	0.26
Mourtzis, D.	3	0.26
Panopoulos, N.	3	0.26

Analysis of Top Cited Authors in Alarm Sensor Technology for Halal Poultry Slaughtering Industry

The analysis of top-cited authors in the field of alarm sensor technology within the halal poultry slaughtering industry reveals a balanced contribution among a select group of researchers. B. D. Deebak et al (2022), each with four documents, lead the list, contributing 0.34% of the total publications individually. Their higher citation counts suggest that their work is considered foundational or influential in the domain, likely addressing critical aspects of sensor technology, such as operational efficiency, compliance with halal standards, and innovation in automation.

Following these leaders, D. Mourtzis (2022) have each contributed three documents, accounting for 0.26% individually. While slightly less prolific than the top four, their consistent contributions indicate a focus on specialized aspects of sensor applications, potentially

emphasizing niche technologies or regional practices in halal poultry slaughtering. Their inclusion in the list suggests that their research complements the foundational studies, likely to address specific gaps or advancing the field through interdisciplinary approaches. The distribution of publications among these authors reflects a collaborative and diversified research environment. The relatively small number of documents by each top author highlights that the field, while gaining attention, may still be emerging, with research efforts spread across multiple contributors. This pattern underscores the potential for increased collaboration and the need for comprehensive studies that unify these diverse contributions. Future research could benefit from integrating these individual insights to create holistic advancements in alarm sensor technology tailored for halal poultry slaughtering.

What are the Types of Documents by Subject of Research?

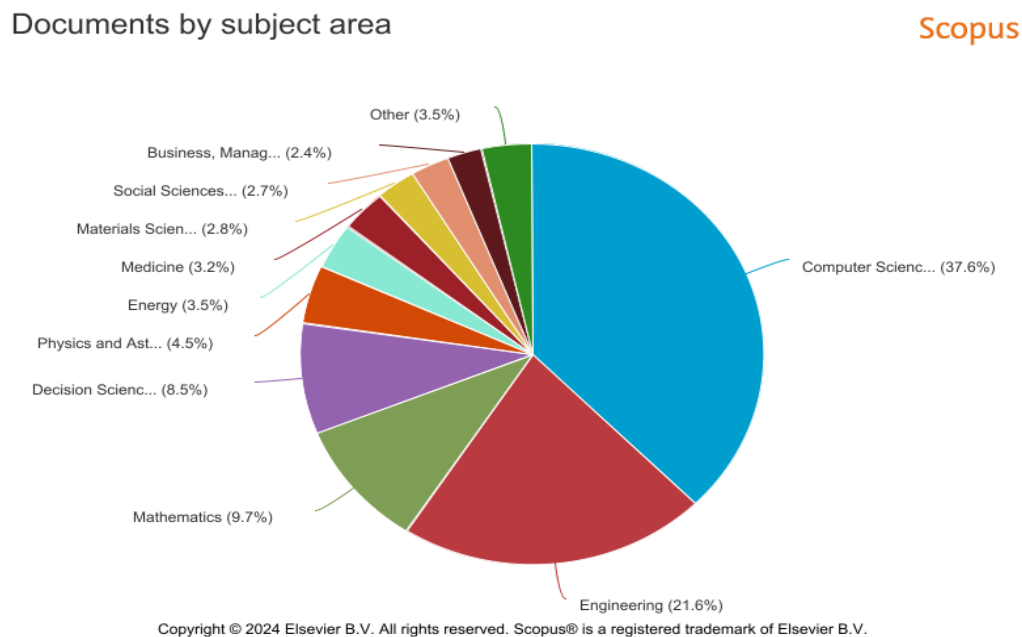


Figure 3: Types of Documents by Subject of Research

Table 3: Types of Documents by Subject of Research

Subject Area	No of Document	Percentage %
Computer Science	1160	37.6
Engineering	666	21.6
Mathematics	301	9.7
Decision Sciences	262	8.5
Physics And Astronomy	138	4.5
Energy	108	3.5
Medicine	99	3.2
Materials Science	86	2.8
Social Sciences	84	2.7
Business, Management and Accounting	75	2.4

Analysis of Subject Areas in Alarm Sensor Technology for Halal Poultry Slaughtering Industry

The distribution of publications across subject areas highlights the interdisciplinary nature of research in alarm sensor technology for the halal poultry slaughtering industry. **Computer science**, accounting for the highest percentage of publications (37.6%), underscores the

reliance on computational tools for developing and implementing advanced sensor systems. This research area likely includes artificial intelligence, machine learning, and data processing techniques essential for ensuring accurate monitoring and automation in compliance with halal standards. The prevalence of computer science reflects the increasing demand for digital solutions that can enhance precision and reliability in real-time operations.

Engineering, with 21.6% of publications, represents the application and integration of these computational advancements into practical systems. Research in this area likely focuses on designing hardware, embedding sensors into poultry processing equipment, and improving the mechanical aspects of the slaughtering process. **Mathematics**, contributing 9.7%, plays a crucial role in modeling and optimizing sensor performance, ensuring systems are both efficient and accurate in detecting compliance-related factors such as animal positioning and proper execution of halal protocols.

Other notable subject areas include **decision sciences** (8.5%), which contribute to decision-making frameworks for implementing sensor systems, and **physics and energy** (4.5% and 3.5%, respectively), likely addressing energy-efficient designs and sensor functionality. **Social sciences** (2.7%) and **business** (2.4%) reflect the growing focus on consumer acceptance, certification processes, and the socio-economic impact of implementing new technologies. These findings indicate that while computational and engineering fields dominate, other disciplines provide valuable insights into operational, ethical, and market implications, emphasizing the holistic approach required for advancing alarm sensor technology in this industry.

Who is the Top 10 Authors Based on Citation by Research?

Table 4: Top 10 Authors Based on Citation by Research

Authors	Title	Year	Source title	Cited by
Qi Q., Tao F., Hu T., Anwer N., Liu A., Wei Y., Wang L., & Nee A.Y.C.	Enabling technologies and tools for digital twin	2021	Journal of Manufacturing Systems	856
F. S. Al-Ismail	DC Microgrid Planning, Operation, and Control: A Comprehensive Review	2021	IEEE Access	318
Ji B., Zhang X., Mumtaz S., Han C., Li C., Wen H., & Wang D.	Survey on the Internet of Vehicles: Network Architectures and Applications	2020	IEEE Communications Standards Magazine	299
M. Shafiul Alam, F. S. Al- Ismail, A. Salem A., & M. A. Abido	High-level penetration of renewable energy sources into grid utility: Challenges and solutions	2020	IEEE Access	223
H. HaddadPajouh, A. Dehghantanha, R. M. Parizi, M. Aledhari M., & H. Karimipour	A survey on internet of things security: Requirements, challenges, and solutions	2021	Internet of Things (Netherlands)	192
X. Lv & M. Li	Application and Research of the Intelligent Management System Based on Internet of Things	2021	Mobile Information Systems	121

Technology in the Era of Big Data				
H. Altaheri, G. Muhammad, & M. Alsulaiman	Physics-Informed Attention Temporal Convolutional Network for EEG-Based Motor Imagery Classification	2023	IEEE Transactions on Industrial Informatics	116
D. Mourtzis, J. Angelopoulos, & N. Panopoulos	Operator 5.0: A Survey on Enabling Technologies and A Framework for Digital Manufacturing Based on Extended Reality	2022	Journal of Machine Engineering	81
Y.-L. Liu, W. Yan, & B. Hu	Resistance to facial recognition payment in China: The influence of privacy-related factors	2021	Telecommunication s Policy	71

Analysis of the Top 10 Authors Based on Citation by Research

The bibliometric analysis of top-cited authors in alarm sensor technology and related fields highlights significant contributions to the technological advancements relevant to the halal poultry slaughtering industry. Qi Q. et al. (2021) lead with 856 citations for their work on enabling technologies and tools for the digital twin, published in the *Journal of Manufacturing Systems*. Their study underscores the growing role of digital twins in simulating and optimizing industrial processes, including sensor-based systems for monitoring and automation, which are essential in halal poultry slaughtering for maintaining precision and compliance.

Al-Ismail F. S. (2021) contributes significantly with 318 citations for their comprehensive review of DC micro grid planning and operations, published in *IEEE Access*. This work highlights the integration of renewable energy sources and energy-efficient technologies into industrial processes, which can complement sensor systems by reducing the environmental impact of slaughterhouses.

Similarly, Ji B. et al. (2020), with 299 citations, focus on Internet of Vehicles architectures and applications. Although their research centers on vehicular networks, the principles of network integration and real-time communication are highly applicable to sensor systems in the halal industry, where timely data exchange and processing are critical for maintaining halal integrity.

Other notable contributions include H. Haddad Pajouh et al. (2021), with 192 citations for their work on Internet of Things (IoT) security, published in *Internet of Things (Netherlands)*, and D. Mourtzis et al. (2022), whose study on extended reality in digital manufacturing received 81 citations. These works emphasize the importance of secure and efficient integration of IoT technologies in industrial settings, aligning with the need for robust alarm sensor technologies in halal poultry slaughtering. Collectively, these highly cited studies underline the multidisciplinary nature of this field, drawing from digital manufacturing, IoT security, and energy-efficient technologies to enhance the capabilities of sensor-based systems in ensuring halal compliance.

What is the Popular Co-occurrence by Author Keywords Related to the Study?

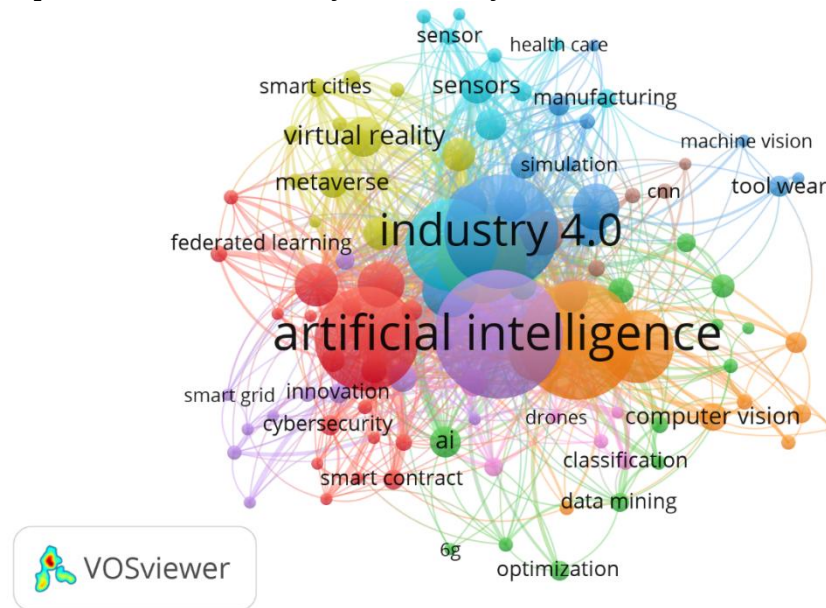


Figure 4: Network Visualization Map of Author Keywords' Co-occurrence

Table 4: Author Keywords' Co-occurrence

Keyword	Occurrences	Total Link Strength
Artificial Intelligence (AI)	20	28
Image Processing	11	12
Industry	5	9
Industry 4.0	115	192
Industry 5.0	25	51
Sensor	8	17
Sensors	21	39
Virtual Reality	26	48

Analysis of Popular Co-occurrence by Author Keywords

The keyword **"artificial intelligence"** (136 occurrences, 288 total link strength) dominates the research landscape, emphasizing its pivotal role in advancing alarm sensor technology in halal poultry slaughtering. AI is instrumental in enabling automation, machine learning, and predictive analytics, facilitating real-time monitoring and ensuring compliance with halal standards. Closely linked terms, such as **"machine learning"** (122 occurrences, 244 total link strength) and **"deep learning"** (62 occurrences, 107 total link strength), highlight the technological focus on enhancing decision-making accuracy and operational efficiency. These advancements address critical challenges in maintaining halal integrity and reducing operational errors during the slaughtering process.

The integration of smart technologies is evident with the prominence of **"industry 4.0"** (115 occurrences, 192 total link strength) and **"blockchain"** (101 occurrences, 242 total link strength). These keywords underscore the shift toward digital transformation, with industry 4.0 technologies fostering interconnected systems for improved traceability, automation, and monitoring. Blockchain is particularly valuable for enhancing transparency and data security, essential for halal certification processes. Other related terms, such as **"edge computing"** (20 occurrences, 59 total link strength) and **"digital twin"** (32 occurrences, 51 total link strength), highlight the use of real-time simulations and decentralized systems to optimize operational workflows and ensure compliance with religious and ethical standards.

Sustainability and smart systems are also key themes, with terms like **"sustainability"** (18 occurrences, 28 total link strength), **"smart manufacturing"** (15 occurrences, 20 total link strength), and **"smart agriculture"** (7 occurrences, 15 total link strength) reflecting the growing emphasis on environmentally conscious and efficient practices in halal poultry slaughtering. The integration of **"robotics"** (14 occurrences, 31 total link strength) and **"cybersecurity"** (10 occurrences, 26 total link strength) further emphasizes the multidisciplinary approach, where physical systems and digital tools work together to address ethical concerns, improve precision, and ensure data integrity. Together, these co-occurring keywords demonstrate the field's focus on innovation, sustainability, and the convergence of cutting-edge technologies to meet the complex demands of halal poultry slaughtering.

What is Citation by Countries' Collaboration?

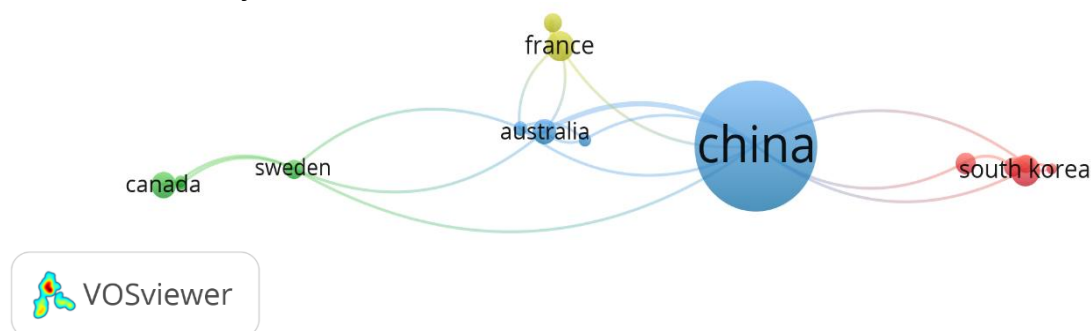


Figure 5: Citation by Countries

Table 5: Citation by Countries

Country	Documents	Citations	Total Link Strength
Australia	22	966	6
Canada	23	390	2
China	220	2151	9
France	28	977	5
South Korea	29	357	3
Sweden	15	933	5

Analysis of Popular Citations by Country Collaboration

The bibliometric analysis of country collaborations in alarm sensor technology highlights China's dominant role, with **220 documents**, the highest number among all countries, and **2,151 citations**. China's extensive research output reflects its strong emphasis on developing and implementing sensor technologies, artificial intelligence, and IoT-based systems in industrial and agricultural settings. The high citation count and total **link strength of 9** suggest China's influence in this domain, as well as its active participation in global research collaborations. This leadership is likely fueled by significant investments in technology-driven industries and smart manufacturing systems, aligning with the demands of halal poultry slaughtering for precise monitoring and compliance.

Australia and France exhibit strong performance relative to their output, with **22 documents** and **966 citations** and **28 documents** and **977 citations**, respectively. These countries demonstrate high research impact, as reflected in their high citation-per-document ratio. Australia's focus on advanced manufacturing and IoT applications complements its contributions to sensor technologies, while France's established expertise in automation and robotics adds depth to the global research landscape. Both countries' modest **total link strength (6 and 5, respectively)**, however, indicates a need for broader international collaboration to amplify their impact in this growing field.

Sweden, South Korea, and Canada also contribute significantly to the research ecosystem. Sweden, with **15 documents and 933 citations**, shows strong research quality and specialization, likely focusing on niche technologies such as energy-efficient systems and sustainability in manufacturing. South Korea (**29 documents, 357 citations**) and Canada (**23 documents, 390 citations**) present moderate outputs, but their lower citation counts suggest a focus on emerging or specialized areas that are still gaining traction globally. Together, these countries underscore the diversity and interdisciplinary nature of alarm sensor technology research, with opportunities for deeper collaboration to address global challenges in halal poultry slaughtering technologies.

CONCLUSION

The bibliometric analysis of alarm sensor technology in the halal poultry chicken slaughtering industry highlights significant progress and emerging trends in the adoption of advanced technologies. From 2020 to 2023, the number of research publications steadily increased, peaking in 2023, reflecting the growing interest in leveraging technologies such as artificial intelligence (AI), the Internet of Things (IoT), and blockchain. These technologies are instrumental in addressing operational efficiency, compliance with halal standards, and food safety challenges. The steady evolution of research output emphasizes the industry's alignment with global trends in automation, precision monitoring, and smart manufacturing.

A key finding from the analysis is the interdisciplinary nature of the research. The dominance of computer science and engineering publications demonstrates a strong focus on computational and technical advancements, while the inclusion of areas such as decision sciences, sustainability, and social sciences reflects a holistic approach to addressing consumer and regulatory expectations. Countries like China, Australia, and France lead in research output and citations, with China contributing the largest number of publications and influencing global research through its advanced technological infrastructure. However, the analysis also points to the need for broader international collaborations to address specific challenges, such as the integration of halal compliance systems with cutting-edge sensor technologies.

Despite the progress, gaps remain in certain areas, such as consumer acceptance of technological interventions and the ethical implications of automation in halal slaughtering. The analysis underscores the need for further research to refine existing technologies, address knowledge gaps, and ensure seamless integration into halal industry practices. Future efforts should prioritize enhancing transparency through blockchain, improving energy-efficient systems, and fostering global partnerships to drive innovation. The findings from this study provide valuable insights for policymakers, researchers, and industry stakeholders, paving the way for a technologically advanced, compliant, and sustainable halal poultry slaughtering industry.

ACKNOWLEDGEMENT

The authors would like to express their deepest appreciation to their family members and friends for their continuous encouragement, patience, and understanding throughout the development of this work. Their unwavering support has been a source of strength and motivation, especially during challenging periods of the research process. The authors are sincerely grateful for the emotional, moral, and practical assistance that has made this study possible. Special acknowledgement is also extended to the dedicated members of the NGO community and our respected professors, whose guidance and constructive feedback have significantly contributed to the quality and direction of this research. Their expertise, generosity of knowledge, and commitment to academic growth have greatly enriched our

understanding and strengthened the final outcome of this work. May this contribution continue to inspire further learning, collaboration, and meaningful impact

REFERENCES

- Abeer Al-Khoury, Sahraa Anwer Hussein, Muthana Abdulwhab, Zainab M. Aljuboori, Hossam Haddad, Mostafa A. Ali, Ibtihal A. Abed & Hakeem Hammood Flayyih. (2022). Intellectual Capital History and Trends: A Bibliometric Analysis Using Scopus Database. *Sustain.*, vol. 14, no. 18, 2022, doi: 10.3390/su141811615
- A. Q. Sazili, P. Kumar, & M. N. Hayat. (2023). Stunning Compliance in Halal Slaughter: A Review of Current Scientific Knowledge. *Animals*, vol. 13, no. 19, 2023, doi: 10.3390/ani13193061
- A. Verbeek, K. Debackere, M. Luwel, & E. Zimmermann. (2002). Measuring Progress and Evolution in Science and Technology - I: The Multiple uses of Bibliometric Indicators. *Int. J. Manag. Rev.*, vol. 4, no. 2, pp. 179–211, 2002, doi: 10.1111/1468-2370.00083.
- B. D. Deebak & F. Al-Turjman. (2022). Digital-twin Assisted: Fault Diagnosis using Deep Transfer Learning for Machining Tool Condition. *Int. J. Intell. Syst.*, vol. 37, no. 12, pp. 10289–10316, 2022, doi: 10.1002/int.22493
- B. Fahimnia, J. Sarkis, & H. Davarzani. (2015). Green Supply Chain Management: A Review and Bibliometric Analysis," 2015. doi: 10.1016/j.ijpe.2015.01.003
- Ji B., Zhang X., Mumtaz S., Han C., Li C., Wen H., & Wang D. (2020). Survey on the Internet of Vehicles: Network Architectures and Applications," *IEEE Commun. Stand. Mag.*, vol. 4, no. 1, pp. 34–41, 2020, doi: 10.1109/MCOMSTD.001.1900053.
- D. Gu, T. Li, X. Wang, X. Yang, & Z. Yu. (2019). Visualizing the Intellectual Structure and Evolution of Electronic Health and Telemedicine Research," *Int. J. Med. Inform.*, vol. 130, 2019, doi: 10.1016/j.ijmedinf.2019.08.007
- D. Mourtzis, J. Angelopoulos, & N. Panopoulos. (2022). Operator 5.0: A Survey on Enabling Technologies and A Framework for Digital Manufacturing Based on Extended Reality," *J. Mach. Eng.*, vol. 22, no. 1, pp. 43–69, 2022, doi: 10.36897/jme/147160
- D. Mourtzis, J. Angelopoulos, & N. Panopoulos. (2024). Integration of Extended Reality and CAE in the Context of Industry 4.0," *Int. J. Comput. Integr. Manuf.*, 2024, doi: 10.1080/0951192X.2024.2397820
- D. S. Assyakur & E. M. Rosa. (2022). Spiritual Leadership in Healthcare: A Bibliometric Analysis," *J. Aisyah J. Ilmu Kesehat.*, vol. 7, no. 2, 2022, doi: 10.30604/jika.v7i2.914
- G. Di Stefano, M. Peteraf, & G. Veronay. (2010). Dynamic Capabilities Deconstructed: A Bibliographic Investigation into the Origins, Development, and Future Directions of the Research Domain. *Ind. Corp. Chang.*, vol. 19, no. 4, pp. 1187–1204, 2010, doi: 10.1093/icc/dtq027
- F. P. Appio, F. Cesaroni, & A. Di Minin. (2014). Visualizing the Structure and Bridges of the Intellectual Property Management and Strategy Literature: A Document Co-citation Analysis. *Scientometrics*, vol. 101, no. 1, pp. 623–661, 2014, doi: 10.1007/s11192-014-1329-0
- F. S. Al-Ismael. (2021). DC Microgrid Planning, Operation, and Control: A Comprehensive Review," *IEEE Access*, vol. 9, pp. 36154–36172, 2021, doi: 10.1109/ACCESS.2021.3062840
- G. P. Khiste & R. R. Paithankar. (2017). Analysis of Bibliometric term in Scopus. *Int. Res. J.*, vol. 01, no. 32, pp. 78–83, 2017
- H. Altaheri, G. Muhammad, & M. Alsulaiman. (2023). Physics-Informed Attention Temporal Convolutional Network for EEG-Based Motor Imagery Classification. *IEEE Trans. Ind. Informatics*, vol. 19, no. 2, pp. 2249–2258, 2023, doi: 10.1109/TII.2022.3197419
- H. HaddadPajouh, A. Dehghantanha, R. M. Parizi, M. Aledhari, & H. Karimipour. (2021). A survey

- on internet of things security: Requirements, challenges, and solutions. *Internet of Things (Netherlands)*, vol. 14, 2021, doi: 10.1016/j.iot.2019.100129
- K. Joshi, A. Kumar, H. Anandaram, A. Kumar, A. Aggarwal, & G. Chhabra. (2023). Incorporating AI and IoT for Smart Poultry Monitoring and Health Detection. *Second Int. Conf. Augment. Intell. Sustain. Syst.*, pp. 76–81, 2023, doi: 10.1109/ICAISS58487.2023.10250564.
- J. L. Alves, I. B. Borges, & J. De Nadae. (2021). Sustainability in Complex Projects of Civil Construction: Bibliometric and Bibliographic Review, *Gest. e Prod.*, vol. 28, no. 4, 2021, doi: 10.1590/1806-9649-2020v28e5389
- F. P. Appio, F. Cesaroni, & A. Di Minin, "Visualizing the Structure and Bridges of the Intellectual Property Management and Strategy Literature: A Document Co-citation Analysis," *Scientometrics*, vol. 101, no. 1, pp. 623–661, 2014, doi: 10.1007/s11192-014-1329-0
- M. M. Rahman, M. S. A. Razimi, A. S. Ariffin, & N. Hashim. (2024). Navigating Moral Landscape: Islamic Ethical Choices and Sustainability in Halal Meat Production and Consumption," *Discov. Sustain.*, vol. 5, no. 1, 2024, doi: 10.1007/s43621-024-00388-y.
- M. N. Hayat, P. Kumar, & A. Q. Sazili. (2023). Spiritual, Ethical, and Eating Qualities of Poultry Meat Influenced by Current and Frequency during Electrical Water Bath Stunning?" *Poult. Sci.*, vol. 102, no. 9, 2023, doi: 10.1016/j.psj.2023.102838.
- M. Shafiu Alam, F. S. Al-Ismaail, A. Salem, & M. A. Abido, "High-level Penetration of Renewable Energy Sources into Grid Utility: Challenges and Solutions," *IEEE Access*, vol. 8, pp. 190277–190299, 2020, doi: 10.1109/ACCESS.2020.3031481
- M. S. B. M. Ishak & W. K. A. B. W. Zaki. (2023). A Technology Comparison of Slaughtering Techniques and Physiological Possibilities during the Halal Slaughtering Process in *Technologies and Trends in the Halal Industry*, Department of Food Technology, Sultan Haji Ahmad Shah Polytechnic, Pahang, Kuantan, Malaysia: Taylor and Francis. pp. 85–103. doi: 10.4324/9781003368519-10.
- N. A. A. N. Muhammad, U. Khairuddin, R. Yusof, N. M. A. N. Azmi, & R. Yunus. (2021). Esophagus Detection using Deep Learning Method. *3rd International Conference on Electrical, Communication and Computer Engineering, ICECCE 2021*, Centre for Artificial Intelligence Robotics (CAIRO), Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia: Institute of Electrical and Electronics Engineers Inc. doi: 10.1109/ICECCE52056.2021.9514209
- N. Hasanah & D. Indrawan. (2020). Food Safety Monitoring System using IoT in the Poultry Slaughterhouse, *IOP Conf. Ser. Earth Environ. Sci.*, vol. 519, 2020, doi: 10.1088/1755-1315/519/1/012043
- N. J. Van Eck & L. Waltman. (2007). Bibliometric Mapping of the Computational Intelligence Field," in *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, 2007, pp. 625–645. doi: 10.1142/S0218488507004911
- N. J. Van Eck & L. Waltman (2010). Software Survey: VOSviewer, a Computer Program for Bibliometric Mapping. *Scientometrics*, vol. 84, no. 2, pp. 523–538, 2010, doi: 10.1007/s11192-009-0146-3
- N. J. Van Eck & L. Waltman. (2017). "Citation-based Clustering of Publications using CitNetExplorer and VOSviewer. *Scientometrics*, vol. 111, no. 2, pp. 1053–1070, 2017, doi: 10.1007/s11192-017-2300-7
- Qi Q., Tao F., Hu T., Anwer N., Liu A., Wei Y., Wang L., & Nee A.Y.C. (2021). Enabling Technologies and Tools for Digital Twin," *J. Manuf. Syst.*, vol. 58, pp. 3–21. doi: 10.1016/j.jmsy.2019.10.001
- R. Badu, M. Teye, R. Bannor, & F. Awal. (2023). Meat consumers and Islamic scholars' understanding of humane slaughter, and effects of pre-slaughter stunning on meat purchasing decisions in Ghana. *J. Islam. Mark.*, vol. 14, no. 2, pp. 504–522, 2023, doi: 10.1108/JIMA-02-2021-0041

- R. O. Sujarwanta, U. Afidah, E. Suryanto, E. Triyannanto, & L. C. Hoffman. (2024). Review: Goat and Sheep Meat Production in Indonesia. *Sustain*, vol. 16, no. 11, 2024, doi: 10.3390/su16114448
- S. I. Orakwue, H. M. Al-Khafaji, & M. Z. Chabuk. (2022). IoT Based Smart Monitoring System for Efficient Poultry Farming. *Webology*. doi: 10.14704/web/v19i1/web19270
- S. Maataoui, G. Bencheikh, & G. Bencheikh. (2023). Predictive Maintenance in the Industrial Sector: A CRISP-DM Approach for Developing Accurate Machine Failure Prediction Models. Moulay Ismail University, Compute Science and Application, Meknes, Morocco: Institute of Electrical and Electronics Engineers Inc., 2023, pp. 223–227. doi: 10.1109/ACTEA58025.2023.10193983
- X. Lv & M. Li. (2021). Application and Research of the Intelligent Management System Based on Internet of Things Technology in the Era of Big Data. *Mob. Inf. Syst.*, vol. 2021, doi: 10.1155/2021/6515792
- Y. C. J. Wu & T. Wu. (2017). A Decade of Entrepreneurship Education in the Asia Pacific for Future Directions in Theory and Practice. doi: 10.1108/MD-05-2017-0518
- Y.-L. Liu, W. Yan, & B. Hu. (2021). Resistance to Facial Recognition Payment in China: The Influence of Privacy-related Factors," *Telecomm. Policy*, Vol. 45, no. 5, 2021, doi: 10.1016/j.telpol.2021.102155
- Z. A. Jelani, A. Pratiwi, & P. D. Isnaeni. (2024). Halal Meat Production in the Modern Era: Concepts and Applications, in *Technological Innovations in Tropical Livestock Development for Environmental Sustainability and Food Security*, School of Veterinary Medicine, Faculty of Health and Medical Sciences, Taylor's University, Kuala Lumpur, Malaysia: CRC Press. pp. 1–6. doi: 10.1201/9781003468943-1

KETERANGAN BERKENAAN PENULIS



Noor Alina Abdul Aziz

Pusat Pengajian Umum dan Bahasa (PPUB),
University College MAIWP International
No. 3, Jalan 31/10A, Kawasan Perindustrian IKS,
Taman Batu Muda, 68100
Batu Caves, Kuala Lumpur, Malaysia
elina@ucmi.edu.my

Nurul Dalila Faris

Pusat Pengajian Umum dan Bahasa (PPUB),
University College MAIWP International
No. 3, Jalan 31/10A, Kawasan Perindustrian IKS,
Taman Batu Muda, 68100
Batu Caves, Kuala Lumpur, Malaysia
dalila@ucmi.edu.my

Nur Shahirah Nasir

Fakulti Sains Kesihatan (FSK),
University College MAIWP International
No. 3, Jalan 31/10A, Kawasan Perindustrian IKS,
Taman Batu Muda, 68100
Batu Caves, Kuala Lumpur, Malaysia
shahirah@ucmi.edu.my

STREAMLINED IDENTIFICATION OF POLYETHYLENE-DEGRADING BACTERIA FOR SYNTHETIC BIOTECHNOLOGY APPLICATIONS

MEMPERKEMAS PENGENALPASTIAN BAKTERIA PENGURAI POLIETILENA UNTUK APLIKASI BIOTEKNOLOGI SINTETIK

Nur Anisza Hanoum Naseron^{1,2a*} & Ahmad Bazli Ramzi^{2b}

^aPoliteknik Nilai & ^bInstitute of Systems Biology (INBIOSIS), Universiti Kebangsaan Malaysia
anisza@polinilai.edu.my & bazliramzi@ukm.edu.my

*Corresponding author

ABSTRACT

Polyethylene (PE) plastics such as low-density PE (LDPE) plastics are among the most widely used plastics and are notoriously resistant to degradation, contributing heavily to long-term environmental pollution. Plastic bioconversion technologies utilizing bioengineered bacterial strains are of great biotechnological interest especially for strain development using microbial synthetic biology platforms. Despite this, new strain development would require the isolation of bacterial strains that are not only able to degrade plastics but also do not possess hazardous traits such as human pathogenicity and antibiotic resistance. For this purpose, this study aims to employ a streamlined strain screening strategy for isolating new LDPE-degrading bacteria from local environmental sites. To this end, stepwise agar plate selection was carried out to screen LDPE-degrading ability, Gram type, hemolytic activity and innate antibiotic resistance. From 53 initial enriched cultures, one bacterial isolate which can grow on LDPE-containing minimal medium, non-hemolytic, Gram-negative and kanamycin-sensitive was obtained and designated as T5C-LRB-C5 strain. Following 16S rRNA gene sequencing and phylogenetic analysis, the bacterial strain was identified as *Diaphorobacter* sp. Further characterization including whole-genome sequencing and plasmid transformation will aid in the potential use of this bacterial strain for synthetic biology applications. This newly devised strain screening approach therefore enabled a streamlined strategy for the isolation of LDPE-degrading bacterial strains that can be further developed for plastic bioconversion applications using microbial synthetic biotechnology platform.

Keywords: Polyethylene Degradation, *Diaphorobacter* sp., Strain Screening, Plastic Bioconversion, Bioremediation

ABSTRAK

Plastik polietilena (PE), khususnya polietilena ketumpatan rendah (LDPE), merupakan antara bahan polimer yang paling meluas penggunaannya namun amat tahan degradasi, sekali gus menyumbang kepada pencemaran alam sekitar jangka panjang. Teknologi biopenukaran plastik melalui strain bakteria yang direka bentuk secara bio kejuruteraan semakin mendapat perhatian dalam bidang bioteknologi, terutamanya bagi pembangunan strain melalui platform biologi sintetik mikrob. Walau bagaimanapun, pembangunan strain baharu memerlukan pengasingan bakteria yang bukan sahaja berupaya menguraikan plastik, tetapi juga tidak mempunyai ciri berbahaya seperti patogenisiti manusia dan rintangan antibiotik. Kajian ini bertujuan membangunkan strategi penyaringan strain secara teratur bagi mengasingkan bakteria pengurai LDPE daripada persekitaran tempatan. Proses pemilihan berperingkat menggunakan agar plat telah dijalankan untuk menilai keupayaan penguraian LDPE, jenis Gram, aktiviti hemolitik dan rintangan antibiotik semula jadi. Daripada 53 kultur awal yang diperkaya, satu isolat berjaya diperoleh yang menunjukkan pertumbuhan pada medium minimum mengandungi

LDPE, bersifat tidak hemolitik, Gram-negatif serta sensitif terhadap kanamisin. Isolat ini dinamakan sebagai strain T5C-LRB-C5. Analisis penjujukan gen 16S rRNA dan filogenetik mengenal pasti strain tersebut sebagai *Diaphorobacter* sp. Pencirian lanjut, termasuk penjujukan genom penuh dan transformasi plasmid, dijangka menyokong potensi penggunaannya dalam aplikasi biologi sintetik. Secara keseluruhan, pendekatan penyaringan strain yang dibangunkan ini menyediakan strategi yang dipermudah dan berkesan bagi pengasingan bakteria pengurai LDPE yang sesuai untuk pembangunan lanjut dalam aplikasi biopenukaran plastik berasaskan platform bioteknologi sintetik mikrob.

Kata Kunci: Penguraian Polietilena, *Diaphorobacter* sp., Penyaringan Stren, Biopenukaran Plastik, Bioremediasi

INTRODUCTION

Low-density polyethylene (LDPE) is one of the most pervasive plastics globally, characterized by high durability and resistance to microbial degradation due to its inert hydrocarbon backbone and hydrophobicity (Jebashalomi et al., 2024; Y. Zhang et al., 2022). Conventional recycling and disposal methods, such as mechanical reprocessing and thermochemical treatments, can result in quality degradation, high energy consumption, or secondary contaminants, limiting their environmental and economic sustainability (Dai et al., 2022; Gouda et al., 2025; Lomwongsopon & Varrone, 2022). These difficulties have heightened interest in bioconversion technologies, which provide a more sustainable solution by converting resistant polymers into value-added products.

Enzyme-mediated LDPE degradation has emerged as a promising strategy, with alkane monooxygenases (AlkB), laccase-like multicopper oxidases (LMCOs), and other oxidative enzymes reported to initiate oxidative scission of polyethylene complex chains (Zampolli et al., 2024; N. Zhang et al., 2022). These enzymes introduce oxygen functions into polymer backbones, enabling microbial metabolic processes including β -oxidation. Despite this potential, the actual application of biocatalysis for LDPE breakdown is still limited by sluggish degradation rates, low substrate accessibility due to high crystallinity, and the scarcity of naturally efficient microbial degraders (Jebashalomi et al., 2024; Putcha & Kitagawa, 2024). Recent advancements in protein engineering, metagenomic discovery, and the construction of synthetic microbial consortia are beginning to address these limitations, emphasising the combination opportunity and challenge of translating enzymatic LDPE bioconversion into industrial-scale applications (Da Silva et al., 2024; Gouda et al., 2025).

In the field of microbial synthetic biology, both model and non-model bacteria have been increasingly exploited as chassis for industrial biotechnology applications, including plastic upcycling and bioconversion via whole-cell biocatalysts (Rezaei et al., 2024; Schneier et al., 2024). Previous studies have demonstrated the orthogonal expression of recombinant plastic-degrading enzymes in *Cupriavidus necator* and *Pseudomonas putida* using the pSV-Ortho-PHA (pSVOP) platform, enabling these PHA-producing bacteria to function as whole-cell biocatalysts for PET hydrolysis (Minggu et al., 2023). Such approaches demonstrate the need of adaptable and robust microbial systems in integrating metabolic pathways that transform refractory polymers into value-added intermediates.

However, selecting a host chassis remains a significant difficulty. Effective bioconversion necessitates powerful, non-pathogenic microbial hosts that are not only genetically tractable but also compatible with plastic degradation pathways. Many environmental isolates with potential degrading capabilities show unwanted features, such as hemolytic activity, virulence traits, or multidrug resistance, which limit their suitability for

downstream modification (Cárdenas Espinosa et al., 2023; Singh et al., 2024). Recent advances have focused on the development of safe, industrially relevant microbial platforms such as engineered *Rhodococcus* and *Bacillus* strains, which combine innate hydrocarbon-degrading traits with synthetic biology toolkits for pathway optimization (Das et al., 2023; Jiménez-Díaz et al., 2022).

Additionally, CRISPR-based genome editing and modular cloning frameworks have accelerated the domestication of environmental isolates into standardized, safe-to-use biocatalysts (Joshi & Sharma, 2025; Kumar & Thakur, 2022). These developments underscore the need to bridge the gap between natural plastic-degrading biodiversity and engineered microbial systems, ensuring both biosafety and industrial applicability in plastic bioconversion.

To fill this crucial gap, our study had designed a simplified, multi-parameter screening technique for isolating non-pathogenic LDPE-degrading bacteria from a variety of environmental samples. Unlike traditional isolation methods that rely solely on degradation capability, our strategy combines functional screening for LDPE biodegradation with biosafety-oriented profile based on Gram type, hemolytic activity, and intrinsic antibiotic sensitivity. By combining these parallel criteria, the approach not only identifies excellent degraders but also favors microbiological candidates who are safe, genetically tractable, and compatible with downstream engineering.

This dual focus is critical because many of the most efficient plastic-degrading strains discovered so far are environmental isolates with biosafety issues, such as pathogenicity or multidrug resistance, preventing their use as industrial chassis. Establishing a dependable, scalable, and safety-conscious pipeline is therefore critical for closing the present gap between natural biodegradation potential and synthetic biology applications.

Furthermore, such a method speeds up the discovery of new microbial candidates that can be easily adapted for advanced metabolic engineering, genome editing, and synthetic circuit integration. Ultimately, this strategy enhances the translational potential of microbial plastic bioconversion by allowing for the rational selection of strains that combine biodegradation efficiency with industrial suitability, which is a critical step toward achieving sustainable, bioengineered solutions for global plastic waste management.

METHODOLOGY

Sample Collection and Enrichment

Soil samples were collected from various depths (0 – 20 cm) of a plastic-contaminated site located in Lukut, Negeri Sembilan. The samples were homogenized and suspended in sterile saline for initial microbial enrichment. The enrichment culture was maintained in a mineral salt medium supplemented with polyethylene (PE) granules as the sole carbon source. Incubation was carried out at 37 °C under semi-aerobic conditions for 4 months with regular subculturing.

Isolation of PE-Degrading Bacteria via Culture-Based Screening

Four distinct plate culture conditions were utilized to extract probable polyethylene (PE)-degrading bacteria from the enriched culture. Modified mineral medium agar with PE powder (MPE) served as a selective medium, comprising only mineral salts and powdered LDPE as the sole carbon source, permitting the formation of colonies capable of utilizing PE was initially

used (Montazer et al., 2019). Successful colonies from MPE incubation were sub-cultured on MacConkey Agar (MCA) to identify Gram-negative enteric bacteria, which may possess hydrocarbon-degrading capabilities, while also differentiating lactose fermenters (Lagier et al., 2015).

Subsequently, any colonies formed on MCA were inoculated on Sheep Blood Agar (SBA) to assess the hemolytic activity and general metabolic versatility, with hemolytic colonies noted for further investigation (Russell et al., 2006). LB agar supplemented with kanamycin (LBK) was used in the final stage of the screening pipeline to assess antibiotic susceptibility. Only isolates that were susceptible to kanamycin evidenced by an absence of growth on LBK were selected. This step ensured that candidate strains were both environmentally robust and compatible with synthetic biology applications. Colonies showing unique were isolated from each medium and purified by repeated streaking. All screening steps were done at 30 °C without shaking.

16S rRNA Gene Sequencing and Identification

Colony PCR was carried out on successful colonies formed on LBK screening plates (. Universal primers used for this purpose were 8F (5' – AGA GTT TGA TCC TGG CTC AG – 3') and 1492R (5' – GGT TAC CTT GTT ACG ACT T – 3') in PCR amplification of 16S rRNA gene. Resulting PCR products were verified using 1 % agarose gel electrophoresis and purified before being sent for sequencing. The sequencing results were compared to existing sequences in the NCBI database using the BLAST algorithm to determine species-level identity

Multiple Sequence Alignment and Phylogenetic Analysis

The 16S rRNA sequence of the isolate was aligned with closely related sequences using ClustalW. A phylogenetic tree was constructed using the Maximum Likelihood method in MEGA 11 software, with bootstrap analysis (500 replications) to assess confidence levels in branching according to Hasegawa-Kishino-Yano (HKY) model.

RESULTS AND DISCUSSION

Stepwise Isolation of Polyethylene-Degrading Bacteria

The structured four-stage isolation pipeline was successful in enriching, screening, and validating bacterial strains with both LDPE-degrading capacity and desired biosafety features (Fig. 1). Beginning with contaminated soil as the inoculum source, long-term enrichment under semi-aerobic conditions created ecological pressure that favored bacteria capable of metabolizing polyethylene-associated hydrocarbons. This enrichment method was in parallel with previous findings that longer incubation improves the adaptability of microbial populations to hydrophobic polymers and increases the possibility of isolating vigorous degraders (Mendoza et al., 2025).

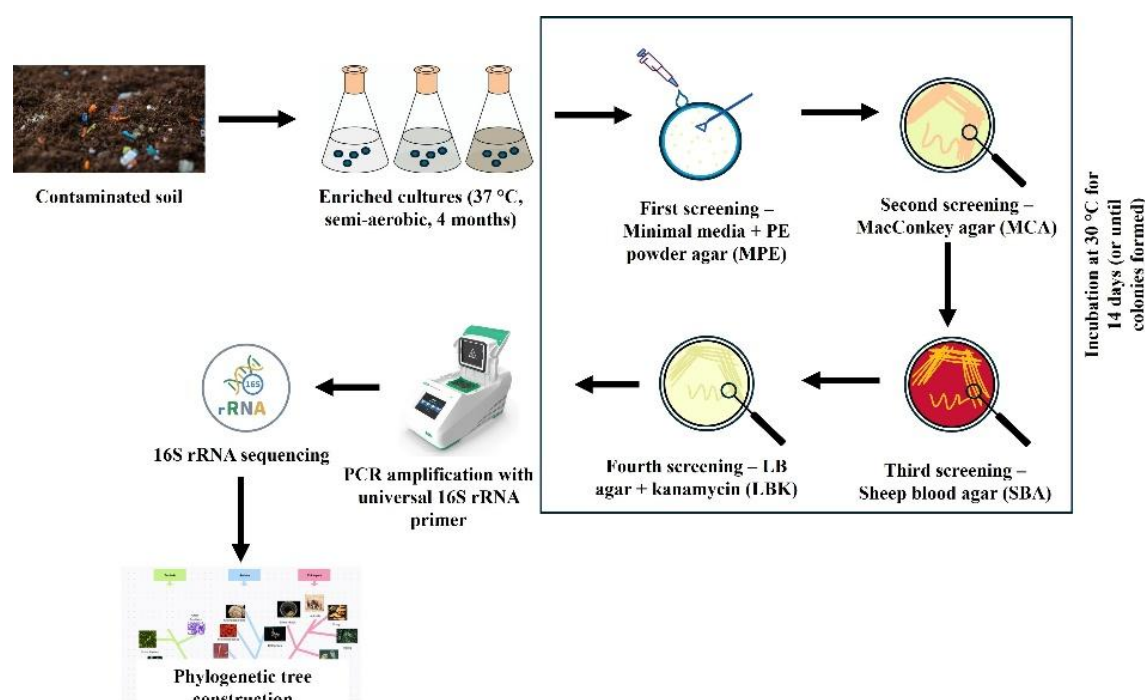


Figure 1: Schematic Diagram towards Isolating Safe, Robust and Environmentally Relevant LDPE-degrading Bacteria.

The sequential screening approach began with minimum medium containing polyethylene powder (MPE), followed by MacConkey agar (MCA), sheep blood agar (SBA), and ultimately LB-kanamycin agar (LBK), which was efficient in gradually refining the pool of eligible isolates. Each stage intended to identify functional degraders while also excluding potentially pathogenic or multidrug-resistant species. For example, SBA effectively removed hemolytic bacteria, a major biosafety criterion, whereas the LBK screening stage provided a fast assessment of intrinsic antibiotic sensitivity. Such multi-parameter screening frameworks have been advocated as essential for bridging the gap between environmental isolates and safe, industrially usable microbial chassis (Cárdenas Espinosa et al., 2023; Singh et al., 2024).

The final group of isolates demonstrated both the ability to grow on LDPE-containing media and non-pathogenic characteristics, emphasizing the importance of combining functional and biosafety profiles in a single procedure. This study supports recent recommendations that sustainable bioconversion approaches must stress both efficacy and safety, guaranteeing that microbial candidates can be fostered toward strain engineering and synthetic biology applications without introducing ecological or health risks (Hoffmann et al., 2023; Rezaei et al., 2024; Tang et al., 2024).

Comparable multi-step strategies have also been reported for identifying polyester-degrading *Rhodococcus* and *Pseudomonas* species, highlighting the increasing recognition of systematic, safety-conscious pipelines in microbial plastic biotechnology (Cappelletti et al., 2020; Putcha & Kitagawa, 2024; Zampolli et al., 2024).

Overall, this study shows that a well-designed four-stage isolation strategy can overcome the limits of traditional single-criterion screening to produce safe, robust, and environmentally relevant LDPE-degrading bacteria. This approach, which combines selective enrichment, functional assessment, and biosafety validation, provides a solid platform for future microbial chassis development and synthetic circuit integration aimed at developing LDPE bioconversion technology.

Primary Screening: PE Degradation on Mineral Medium Agar

The primary screening on mineral medium agar supplemented with LDPE powder successfully identified 30 colonies capable of visible growth after 14 days of incubation. These colonies exhibited surface-associated attachment and distinctive morphologies, appearing translucent to pale yellow, circular (<1.5 mm), and mucoid in texture (Fig. 2). Such colony features are commonly linked to biofilm formation and extracellular polymeric substance (EPS) production, which enhance microbial adherence to hydrophobic polymers and facilitate the initial stages of polyethylene degradation (Benes et al., 2025; Ji et al., 2024; Sooriyakumar et al., 2022). The ability of isolates to colonize the LDPE surface is a crucial indicator of their potential to initiate oxidative or enzymatic attack on polymer chains, consistent with earlier findings that surface colonization often precedes polymer chain scission (Wright et al., 2020; Zhai et al., 2023).

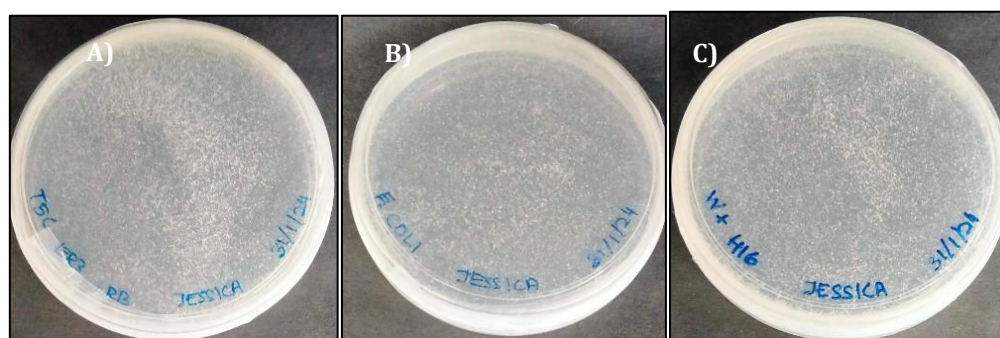


Figure 2: First Selection Media for PE-degrading Bacteria from Local Plastic Dumpsite. A) Positive Colony Showing Distinct Morphology after 14-days Incubation; B) Negative Control and C) Positive Control.

Control experiments reinforced the validity of these observations. The negative control, *Escherichia coli*, was unable to grow on mineral PE agar (MPE), highlighting the selectivity of the medium. Conversely, the positive control, *Cupriavidus necator*, displayed colony morphology like that of LDPE-grown isolates. This aligns with prior reports demonstrating that *C. necator* can utilize polyethylene as a sole carbon source under nutrient-limiting conditions (Montazer et al., 2019).

The successful recovery of 30 candidate isolates underscores the effectiveness of this primary screening stage in narrowing the microbial pool toward strains with potential LDPE-degrading activity. Several recent studies similarly reported the isolation of diverse plastic-associated bacteria through selective enrichment and screening approaches, further validating the strategy employed in this study (Bao et al., 2023; Muangchinda & Pinyakong, 2024). Importantly, isolates capable of growth on LDPE-containing media are likely to harbor oxidative enzymes such as alkane monooxygenases (AlkB), laccases, or peroxidases were the enzymes that play a pivotal role in initiating polymer chain oxidation and promoting subsequent metabolic assimilation (Amobonye et al., 2021; Priya et al., 2021).

Taken together, the results of this first screening stage provide a robust foundation for downstream refinement and characterization. By effectively coupling selective growth pressure with biosafety-conscious controls, this approach ensures that only environmentally relevant and potentially safe LDPE-degrading candidates progress to subsequent stages of evaluation.

Secondary Screening: Selection for Gram-Negative Strains

MPE isolates were subsequently streaked on MacConkey Agar (MCA) to selectively identify Gram-negative bacteria, which are widely recognized as key contributors to plastic biodegradation. Of the 30 colonies obtained from the primary screen, 17 exhibited growth and characteristic color changes, confirming their Gram-negative status (Fig. 3). This selection step is critical, as multiple studies have reported the predominance of Gram-negative taxa including *Pseudomonas*, *Alcanivorax*, and *Cupriavidus* in the degradation of hydrocarbons and synthetic polymers (Bacosa et al., 2021; Zadjelovic et al., 2022).

The metabolic versatility of Gram-negative bacteria is attributed to their outer membrane transport systems, efflux pumps, and secretion pathways that facilitate interaction with and breakdown of hydrophobic substrates such as polyethylene (Cai et al., 2023; Pathak & Navneet, 2017). Moreover, Gram-negative isolates are highly attractive candidates for downstream strain engineering, as a wide array of standardized genetic tools, synthetic biology platforms, and expression systems are optimized for Gram-negative hosts (Chang et al., 2024; Minggu et al., 2023; Tas et al., 2021). Therefore, the enrichment of Gram-negative isolates not only aligns with ecological evidence of their role in plastic biodegradation but also provides practical advantages for future metabolic engineering and circuit integration aimed at polyethylene bioconversion.



Figure 3: Growth of Locally Isolated PE-degrading Bacteria on MacConkey Agar for Identification of Gram-negative Strains.

Tertiary Screening: Hemolytic Activity Assessment

To further evaluate biosafety, the 17 Gram-negative isolates were screened on sheep blood agar (SBA) to determine their hemolytic activity. Among them, 10 isolates displayed no signs of hemolysis (γ -hemolysis), while the remaining strains exhibited either partial (α -hemolysis) or complete hemolysis (β -hemolysis) (Fig. 4). Excluding hemolytic strains was a critical step to minimize potential pathogenic risks, as hemolysin production is often associated with virulence factors that can compromise host safety (Farooqi, 2025; Li et al., 2021; Wang & Zhang, 2019).

The identification of non-hemolytic isolates therefore provided a biosafe subset of candidates suitable for subsequent characterization and engineering. This precautionary measure not only ensures environmental and laboratory safety but also aligns with current recommendations that microbial strains intended for biotechnological applications must demonstrate a non-pathogenic profile before advancing toward industrial use (Hoffmann et al., 2023; Lea-Smith et al., 2025).



Figure 4: Hemolytic Screening on Local Strains of PE-Degrading Bacteria using Sheep Blood Agar Further Narrows the Isolates.

Quaternary Screening: Antibiotic Susceptibility and Engineering Compatibility

To evaluate intrinsic antibiotic susceptibility, the 10 non-hemolytic isolates were cultured on LB agar supplemented with kanamycin (100 µg/mL). Incorporating antibiotic susceptibility as a selection parameter was essential, as it not only ensures biosafety but also enhances the compatibility of isolates with established genetic engineering systems. Strains that failed to grow under kanamycin selection were considered optimal candidates, since susceptibility enables the effective use of plasmid vectors carrying kanamycin resistance markers. In contrast, resistant strains may complicate transformation efficiency and limit the application of widely used cloning and expression platforms (Schneier et al., 2024; Su et al., 2025).

This step was particularly important because the pSV-Ortho-PHA (pSVOP) system, previously optimized in *Cupriavidus necator* and *Pseudomonas putida*, employs kanamycin resistance as a selective marker (Minggu et al., 2023). By prioritizing kanamycin-susceptible strains, the workflow aligns with both biosafety considerations and practical synthetic biology requirements, thereby facilitating downstream engineering for LDPE bioconversion. Following this multi-parameter screening pipeline, a single promising isolate was identified and designated T5C-LRB-C5 for further characterization.

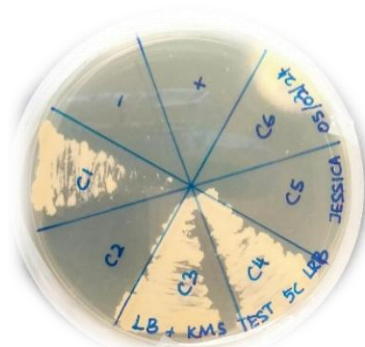


Figure 5: Example of Colonies Grown on Final Selection Agar Plate (LBK).

Molecular Identification and Phylogenetic Affiliation

Colony PCR followed by 16S rRNA gene sequencing identified isolate T5C-LRB-C5 as having 99% sequence similarity to *Diaphorobacter nitroreducens*, a Gram-negative, denitrifying bacterium previously reported for its ability to degrade poly(3-hydroxybutyrate) (PHB) and poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) (Tabrez Khan & Hiraishi, 2002). Multiple sequence alignment confirmed conservation of the 16S rRNA region (Fig. 5), while phylogenetic reconstruction using MEGA 11 clustered the isolate within the *Diaphorobacter*

clade, validating its taxonomic identity and ecological relevance in polymer degradation (Fig. 5). Members of the genus *Diaphorobacter* are well-documented for their capacity to degrade polyhydroxyalkanoates (PHAs), primarily through the secretion of extracellular PHB depolymerases (Qiu et al., 2015). This enzymatic capability highlights their natural adaptability for breaking down hydrocarbons and complex polymeric substrates, underscoring their potential role in bioplastic turnover. Given its metabolic traits and biosafety profile, T5C-LRB-C5 represents a promising candidate for LDPE bioconversion and synthetic biology integration, particularly in coupling plastic waste degradation with bioplastic production platforms (T. Zhang et al., 2010).

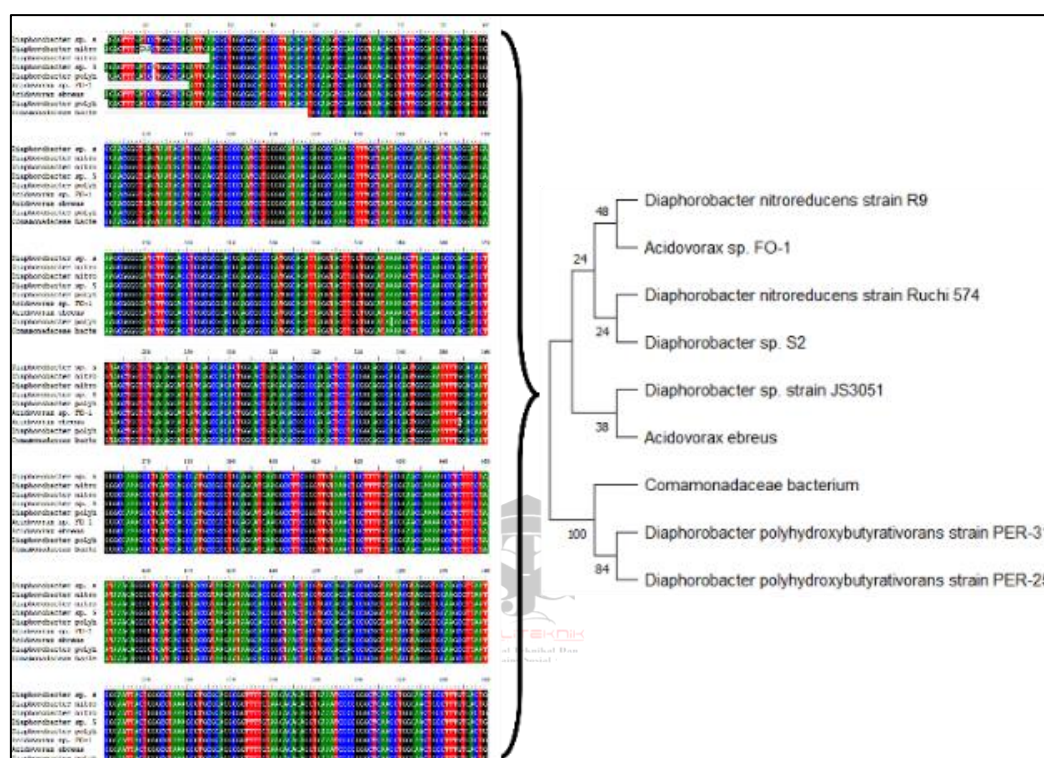


Figure 5: Multiple Sequence Alignment and Phylogenetic Analysis of 16S rRNA Sequences from *Diaphorobacter* and Related Genera.

Advantages of Sequential Screening Strategy

This stepwise isolation offers an effective framework for distilling taxonomically and functionally diverse ambient bacteria into a single high-potential candidate, thereby eliminating a well-known bottleneck in identifying genuine plastic-degrading microbes. Since 2020, microbial and enzymatic surveys have highlighted both the diversity of prospective degraders and the challenge in shifting from enrichment cultures to well-characterized strains appropriate for downstream engineering (Mohan et al., 2020). By specifically screening for non-hemolytic, antibiotic-sensitive organisms, the method mitigates biosafety problems and the potential of mobilizing environmental antibiotic-resistance determinants, which is one of the issues widely emphasized in current environmental surveillance and Antibiotic Resistance Genes (ARG) research (Ouyang et al., 2024).

Selecting antibiotic-sensitive Gram-negative isolates is pragmatically important because several Gram-negative species, such as *Pseudomonas* spp., have been developed into reliable, genetically tractable chassis for industrial and synthetic-biology applications; these chassis offer existing toolkits for pathway installation, metabolic optimization, and scale-up (Martínez-García & De Lorenzo, 2024). Finally, recent reviews on non-model chassis and

chassis selection argue that discovering naturally robust, safe hosts from relevant environments accelerates translation from discovery to deployable bioprocesses for plastic bioconversion, underscoring the broader translational value of a streamlined, safety-aware isolation pipeline (Ravagnan & Schmid, 2024).

Implications and Direction for Future Research

T5C-LRB-C5 exhibited good PE-degradation capability based on growth parameters. Further strain characterization through direct measurement of degradation such as CO₂ evolution tests, FTIR analysis of PE films, and SEM imaging will provide additional information on the bacterial ability to become a new synthetic biology chassis for plastic biotechnology. Additionally, enzymatic profiling or transcriptomic studies could uncover the exact metabolic pathways involved in polyethylene utilization.

CONCLUSION

This study applied a four-stage screening approach to isolate a safe, robust polyethylene-degrading bacterium from a plastic-contaminated site in Lukut, Negeri Sembilan. The selected strain, T5C-LRB-C5, identified as *Diaphorobacter* sp., showed key traits including growth on PE media, Gram-negative profile, kanamycin susceptibility, and non-hemolytic activity. Although *Diaphorobacter* is known for polymer degradation, its role in LDPE breakdown in tropical environments is rarely reported. This work offers a promising candidate for plastic bioremediation and a practical screening pipeline for future applications.



ACKNOWLEDGMENT

First author was fully funded by Hadiah Latihan Persekutuan (HLP) by Ministry of Higher Education (MOHE), Malaysia. Author would like to thank Ms. Jessica Vasu who significantly contributed to the completion of this work. This study is supported by research grant under Fundamental Research Grant Scheme (FRGS) from the Malaysian Ministry of Higher Education (FRGS/1/2023/STG01/UKM/02/8).

REFERENCES

- Amobonye, A., Bhagwat, P., Singh, S., & Pillai, S. (2021). Plastic Biodegradation: Frontline Microbes and Their Enzymes. *Science of the Total Environment*, 759. <https://doi.org/10.1016/j.scitotenv.2020.143536>
- Bacosa, H. P., Mabuhay-Omar, J. A., Balisco, R. A. T., Omar, D. M., & Inoue, C. (2021). *Biodegradation of Binary Mixtures of Octane with Benzene, Toluene, Ethylbenzene or Xylene (BTEx): Insights on the Potential of Burkholderia, Ralstonia, Pseudomonas, and Cupriavidus isolates*. In Review. <https://doi.org/10.21203/rs.3.rs-323650/v1>
- Bao, T., Qian, Y., Xin, Y., Collins, J. J., & Lu, T. (2023). Engineering Microbial Division of Labor for Plastic Upcycling. *Nature Communications*, 14(1), 5712. <https://doi.org/10.1038/s41467-023-40777-x>
- Benes, K., Liguori, M., Velikaneye, C. J., Kispert, S., Pishnyuk, A., Luzik, E., Sun, H., Xiao, D., & Gu, H. (2025). Harnessing Biofilm-Mediated Plastic Biodegradation: Innovating Smart Material Design. *ACS Applied Engineering Materials*, 3(7), 1915–1926. <https://doi.org/10.1021/acsaenm.5c00179>
- Cai, Z., Li, M., Zhu, Z., Wang, X., Huang, Y., Li, T., Gong, H., & Yan, M. (2023). Biological Degradation of Plastics and Microplastics: A Recent Perspective on Associated

- Mechanisms and Influencing Factors. *Microorganisms*, 11(7), 1661. <https://doi.org/10.3390/microorganisms11071661>
- Cappelletti, M., Presentato, A., Piacenza, E., Firrincieli, A., Turner, R. J., & Zannoni, D. (2020). Biotechnology of *Rhodococcus* for the Production of Valuable Compounds. *Applied Microbiology and Biotechnology*, 104(20), 8567–8594. <https://doi.org/10.1007/s00253-020-10861-z>
- Cárdenas Espinosa, M. J., Schmidgall, T., Pohl, J., Wagner, G., Wynands, B., Wierckx, N., Heipieper, H. J., & Eberlein, C. (2023). Assessment of New and Genome-Reduced *Pseudomonas* Strains Regarding Their Robustness as Chassis in Biotechnological Applications. *Microorganisms*, 11(4), 837. <https://doi.org/10.3390/microorganisms11040837>
- Chang, M., Ahn, S. J., Han, T., & Yang, D. (2024). Gene Expression Modulation Tools for Bacterial Synthetic Biology. *Biotechnology for Sustainable Materials*, 1(1), 6. <https://doi.org/10.1186/s44316-024-00005-y>
- Da Silva, M. R. F., Souza, K. S., Motteran, F., De Araújo, L. C. A., Singh, R., Bhadouria, R., & De Oliveira, M. B. M. (2024). Exploring biodegradative efficiency: A Systematic Review on The Main Microplastic-Degrading Bacteria. *Frontiers in Microbiology*, 15, 1360844. <https://doi.org/10.3389/fmicb.2024.1360844>
- Dai, L., Zhou, N., Lv, Y., Cheng, Y., Wang, Y., Liu, Y., Cobb, K., Chen, P., Lei, H., & Ruan, R. (2022). Pyrolysis Technology for Plastic Waste Recycling: A state-of-the-art review. *Progress in Energy and Combustion Science*, 93, 101021. <https://doi.org/10.1016/j.pecs.2022.101021>
- Das, N., Das, A., Das, S., Bhatawadekar, V., Pandey, P., Choure, K., Damare, S., & Pandey, P. (2023). Petroleum Hydrocarbon Catabolic Pathways as Targets for Metabolic Engineering Strategies for Enhanced Bioremediation of Crude-Oil-Contaminated Environments. *Fermentation*, 9(2), 196. <https://doi.org/10.3390/fermentation9020196>
- Farooqi, S. H. (Ed.). (2025). Biotechnology and Synthetic Biology; Biosecurity Risk. In K. Kholik & M. A. Zaman, *One Health Horizons Integrating Biodiversity, Biosecurity, and Sustainable Practices*. Unique Scientific Publishers. <https://doi.org/10.47278/book.HH/2025.119>
- Gouda, A., Merhi, N., Hmadeh, M., Cecchi, T., Santato, C., & Sain, M. (2025). Sustainable Strategies for Converting Organic, Electronic, and Plastic Waste from Municipal Solid Waste into Functional Materials. *Global Challenges*, 9(4), 2400240. <https://doi.org/10.1002/gch2.202400240>
- Hoffmann, S. A., Diggans, J., Densmore, D., Dai, J., Knight, T., Leproust, E., Boeke, J. D., Wheeler, N., & Cai, Y. (2023). Safety by design: Biosafety and Biosecurity in the Age of Synthetic Genomics. *iScience*, 26(3), 106165. <https://doi.org/10.1016/j.isci.2023.106165>
- Jebashalomi, V., Emmanuel Charles, P., & Rajaram, R. (2024). Microbial Degradation of Low-Density Polyethylene (LDPE) and Polystyrene using *Bacillus Cereus* (OR268710) Isolated from Plastic-polluted Tropical Coastal Environment. *Science of The Total Environment*, 924, 171580. <https://doi.org/10.1016/j.scitotenv.2024.171580>
- Ji, S. H., Yoo, S., Park, S., & Lee, M. J. (2024). Biodegradation of Low-density Polyethylene by Plasma-activated *Bacillus* Strain. *Chemosphere*, 349, 140763. <https://doi.org/10.1016/j.chemosphere.2023.140763>
- Jiménez-Díaz, V., Pedroza-Rodríguez, A. M., Ramos-Monroy, O., & Castillo-Carvajal, L. C. (2022). Synthetic Biology: A New Era in Hydrocarbon Bioremediation. *Processes*, 10(4), 712. <https://doi.org/10.3390/pr10040712>
- Joshi, M., & Sharma, J. G. (2025). The Utility of Synthetic Biology in the Treatment of Industrial Wastewaters. *Nature Environment and Pollution Technology*, 24(1), B4191. <https://doi.org/10.46488/NEPT.2025.v24i01.B4191>
- Kumar, V., & Thakur, I. S. (Eds.). (2022). *Omics Insights in Environmental Bioremediation*. Springer Nature Singapore. <https://doi.org/10.1007/978-981-19-4320-1>

- Lagier, J.-C., Edouard, S., Pagnier, I., Mediannikov, O., Drancourt, M., & Raoult, D. (2015). Current and Past Strategies for Bacterial Culture in Clinical Microbiology. *Clinical Microbiology Reviews*, 28(1), 208–236. <https://doi.org/10.1128/CMR.00110-14>
- Lea-Smith, D. J., Hassard, F., Coulon, F., Partridge, N., Horsfall, L., Parker, K. D. J., Smith, R. D. J., McCarthy, R. R., McKew, B., Gutierrez, T., Kumar, V., Dotro, G., Yang, Z., EBIC partners, Curtis, T. P., Golyshin, P., Heaven, S., Jefferson, B., Jeffrey, P., ... Krasnogor, N. (2025). Engineering Biology Applications for Environmental Solutions: Potential and Challenges. *Nature Communications*, 16(1), 3538. <https://doi.org/10.1038/s41467-025-58492-0>
- Li, J., Zhao, H., Zheng, L., & An, W. (2021). Advances in Synthetic Biology and Biosafety Governance. *Frontiers in Bioengineering and Biotechnology*, 9, 598087. <https://doi.org/10.3389/fbioe.2021.598087>
- Lomwongsopon, P., & Varrone, C. (2022). Critical Review on the Progress of Plastic Bioupcycling Technology as a Potential Solution for Sustainable Plastic Waste Management. *Polymers*, 14(22), 4996. <https://doi.org/10.3390/polym14224996>
- Martínez-García, E., & De Lorenzo, V. (2024). Pseudomonas Putida as a Synthetic Biology Chassis and a Metabolic Engineering Platform. *Current Opinion in Biotechnology*, 85, 103025. <https://doi.org/10.1016/j.copbio.2023.103025>
- Mendoza, J. E., Tineo, D., Chuquibala-Checan, B., Atalaya-Marin, N., Taboada-Mitma, V. H., Tafur-Culqui, J., Tarrillo, E., Gómez-Fernández, D., Goñas, M., & Reyes-Reyes, M. A. (2025). Global Perspectives on the Biodegradation of LDPE in Agricultural Systems. *Frontiers in Microbiology*, 15, 1510817. <https://doi.org/10.3389/fmicb.2024.1510817>
- Minggu, M. M., Naseron, N. A. H., Shaberi, H. S. A., Muhammad, N. A. N., Baharum, S. N., & Ramzi, A. B. (2023). Seamless and Orthogonal Expression of Genetic Parts in Polyhydroxyalkanoate (PHA)-producing Bacterial Chassis for Plastic Bio-upcycling Applications. *MethodsX*, 11, 102434. <https://doi.org/10.1016/j.mex.2023.102434>
- Mohanan, N., Montazer, Z., Sharma, P. K., & Levin, D. B. (2020). Microbial and Enzymatic Degradation of Synthetic Plastics. *Frontiers in Microbiology*, 11, 580709. <https://doi.org/10.3389/fmicb.2020.580709>
- Montazer, Z., Habibi Najafi, M. B., & Levin, D. B. (2019). Microbial Degradation of Low-density Polyethylene and Synthesis of Polyhydroxyalkanoate Polymers. *Canadian Journal of Microbiology*, 65(3), 224–234. <https://doi.org/10.1139/cjm-2018-0335>
- Muangchinda, C., & Pinyakong, O. (2024). Enrichment of LDPE-degrading Bacterial Consortia: Community Succession and Enhanced Degradation Efficiency through Various Pretreatment Methods. *Scientific Reports*, 14(1), 28795. <https://doi.org/10.1038/s41598-024-80306-4>
- Ouyang, B., Yang, C., Lv, Z., Chen, B., Tong, L., & Shi, J. (2024). Recent Advances in Environmental Antibiotic Resistance Genes Detection and Research Focus: From genes to ecosystems. *Environment International*, 191, 108989. <https://doi.org/10.1016/j.envint.2024.108989>
- Pathak, V. M. & Navneet. (2017). Review on the Current Status of Polymer Degradation: A Microbial Approach. *Bioresources and Bioprocessing*, 4(1). <https://doi.org/10.1186/s40643-017-0145-9>
- Priya, A., Dutta, K., & Daverey, A. (2021). A Comprehensive Biotechnological and Molecular Insight into Plastic Degradation by Microbial Community. *Journal of Chemical Technology and Biotechnology*. <https://doi.org/10.1002/jctb.6675>
- Putcha, J. P., & Kitagawa, W. (2024). Polyethylene Biodegradation by an Artificial Bacterial Consortium: *Rhodococcus* as a Competitive Plasticsphere Species. *Microbes and Environments*, 39(3), n/a. <https://doi.org/10.1264/jsme2.ME24031>
- Qiu, T., Zuo, Z., Gao, J., Gao, M., Han, M., Sun, L., Zhang, L., & Wang, X. (2015). *Diaphorobacter polyhydroxybutyrativorans* sp. Nov., a Novel Poly(3-hydroxybutyrate-co-3-hydroxyvalerate)-degrading bacterium isolated from biofilms. *International Journal of*

- Systematic and Evolutionary Microbiology*, 65(Pt_9), 2913–2918. <https://doi.org/10.1099/ijs.0.000353>
- Ravagnan, G., & Schmid, J. (2024). Promising Mon-model Microbial Cell Factories Obtained by Genome Reduction. *Frontiers in Bioengineering and Biotechnology*, 12, 1427248. <https://doi.org/10.3389/fbioe.2024.1427248>
- Rezaei, Z., Dinani, A. S., & Moghimi, H. (2024). Cutting-edge Developments in Plastic Biodegradation and Upcycling via Engineering Approaches. *Metabolic Engineering Communications*, 19, e00256. <https://doi.org/10.1016/j.mec.2024.e00256>
- Russell, F. M., Biribo, S. S. N., Selvaraj, G., Oppedisano, F., Warren, S., Seduadua, A., Mulholland, E. K., & Carapetis, J. R. (2006). As a Bacterial Culture Medium, Citrated Sheep Blood Agar Is a Practical Alternative to Citrated Human Blood Agar in Laboratories of Developing Countries. *Journal of Clinical Microbiology*, 44(9), 3346–3351. <https://doi.org/10.1128/JCM.02631-05>
- Schneier, A., Melaugh, G., & Sadler, J. C. (2024). Engineered Plastic-associated Bacteria for Biodegradation and Bioremediation. *Biotechnology for the Environment*, 1(1), 7. <https://doi.org/10.1186/s44314-024-00007-0>
- Singh, P., Lau, C. S. S., Siah, S. Y., Chua, K. O., & Ting, A. S. Y. (2024). Microbial Degradation of Low-density Polyethylene, Polyethylene Terephthalate, and Polystyrene by Novel Isolates from Plastic-polluted Environment. *Archives of Microbiology*, 206(4), 188. <https://doi.org/10.1007/s00203-024-03895-8>
- Sooriyakumar, P., Bolan, N., Kumar, M., Singh, L., Yu, Y., Li, Y., Weralupitiya, C., Vithanage, M., Ramanayaka, S., Sarkar, B., Wang, F., Gleeson, D. B., Zhang, D., Kirkham, M. B., Rinklebe, J., & M Siddique, K. H. (2022). Biofilm Formation and its Implications on the Properties and Fate of Microplastics in Aquatic Environments: A Review. *Journal of Hazardous Materials Advances*, 6, 100077. <https://doi.org/10.1016/j.hazadv.2022.100077>
- Su, C., Cui, H., Wang, W., Liu, Y., Cheng, Z., Wang, C., Yang, M., Qu, L., Li, Y., Cai, Y., He, S., Zheng, J., Zhao, P., Xu, P., Dai, J., & Tang, H. (2025). Bioremediation of Complex Organic Pollutants by Engineered *Vibrio Natriegens*. *Nature*, 642(8069), 1024–1033. <https://doi.org/10.1038/s41586-025-08947-7>
- Tabrez Khan, S., & Hiraishi, A. (2002). *Diaphorobacter Nitroreducens* Gen. Nov., sp. Nov., a Poly(3-hydroxybutyrate)-degrading denitrifying bacterium isolated from activated sludge. *The Journal of General and Applied Microbiology*, 48(6), 299–308. <https://doi.org/10.2323/jgam.48.299>
- Tang, Q., Yan, F., Yuan, L., Tang, Y., Chen, H., Sun, Y., Yang, M., & Song, G. (2024). Enhancing Laboratory Biosafety Management: A Comprehensive Strategy from Theory to Practice. *Frontiers in Public Health*, 12, 1439051. <https://doi.org/10.3389/fpubh.2024.1439051>
- Tas, H., Goñi-Moreno, Á., & Lorenzo, V. D. (2021). A Standardized Inverter Package Borne by Broad Host Range Plasmids for Genetic Circuit Design in Gram-Negative Bacteria. *ACS Synthetic Biology*, 10(1), 213–217. <https://doi.org/10.1021/acssynbio.0c00529>
- Wang, F., & Zhang, W. (2019). Synthetic Biology: Recent Progress, Biosafety and Biosecurity Concerns, and Possible Solutions. *Journal of Biosafety and Biosecurity*, 1(1), 22–30. <https://doi.org/10.1016/j.jobb.2018.12.003>
- Wright, R. J., Erni-Cassola, G., Zadjelovic, V., Latva, M., & Christie-Oleza, J. A. (2020). Marine Plastic Debris: A New Surface for Microbial Colonization. *Environmental Science & Technology*, 54(19), 11657–11672. <https://doi.org/10.1021/acs.est.0c02305>
- Zadjelovic, V., Erni-Cassola, G., Obrador-Viel, T., Lester, D., Eley, Y., Gibson, M. I., Dorador, C., Golyshin, P. N., Black, S., Wellington, E. M. H., & Christie-Oleza, J. A. (2022). A Mechanistic Understanding of Polyethylene Biodegradation by the Marine Bacterium *Alcanivorax*. *Journal of Hazardous Materials*, 436, 129278. <https://doi.org/10.1016/j.jhazmat.2022.129278>
- Zampolli, J., Collina, E., Lasagni, M., & Di Gennaro, P. (2024). Insights into Polyethylene Biodegradative Fingerprint of *Pseudomonas Citronellolis* E5 and *Rhodococcus erythropolis* D4 by Phenotypic and Genome-based Comparative Analyses. *Frontiers in*

- Bioengineering and Biotechnology*, 12, 1472309. <https://doi.org/10.3389/fbioe.2024.1472309>
- Zhai, X., Zhang, X.-H., & Yu, M. (2023). Microbial Colonization and Degradation of Marine Microplastics in the Plastisphere: A Review. *Frontiers in Microbiology*, 14, 1127308. <https://doi.org/10.3389/fmicb.2023.1127308>
- Zhang, N., Ding, M., & Yuan, Y. (2022). Current Advances in Biodegradation of Polyolefins. *Microorganisms*, 10(8), 1537. <https://doi.org/10.3390/microorganisms10081537>
- Zhang, T., Chaudhry, M. T., & Liu, Z.-P. (2010). Genetic and Biochemical Characterization of Poly 3-hydroxybutyrate Depolymerase from *Diaphorobacter* sp. PCA039. *World Journal of Microbiology and Biotechnology*, 26(10), 1803–1811. <https://doi.org/10.1007/s11274-010-0361-3>
- Zhang, Y., Pedersen, J. N., Eser, B. E., & Guo, Z. (2022). Biodegradation of Polyethylene and Polystyrene: from Microbial Deterioration to Enzyme Discovery. *Biotechnology Advances*, 60, 107991. <https://doi.org/10.1016/j.biotechadv.2022.107991>

KETERANGAN BERKENAAN PENULIS

Nur Anisza Hanoum Naseron

Politeknik Nilai, Kompleks Pendidikan Nilai,
Bandar Enstek, 71760 Labu,
Negeri Sembilan, Malaysia
anisza@polinilai.edu.my

Ahmad Bazli Ramzi²

Institute of Systems Biology (INBIOSIS),
Universiti Kebangsaan Malaysia, 43600
Bangi, Selangor, Malaysia
bazliramzi@ukm.edu.my



UTILIZATION OF IOE AND FINGERPRINT TECHNOLOGY IN REAL-TIME MONITORING OF FLORA FOR DISASTER MITIGATION IN THE BRANTAS WATERSHED

PENGUNAAN IOE DAN TEKNOLOGI CAP JARI DALAM PEMANTAUAN MASA NYATA FLORA UNTUK TEBATAN BENCANA DI TADAHAN AIR BRANTAS

Aripriharta^{1a*}, Siti Zubaidah^{1b}, Mokh. Sholihul Hadi^{1a}, Hendra Susanto^{1b}, Gwo-Jiun Horng^{1c}, Muhammad Cahyo Bagaskoro^{1a&d}, & Muchamad Wahyu Prasetyo^{1a&d}

^aDepartment of Electrical Engineering, State University of Malang, Indonesia

^bDepartment of Biology, State University of Malang, Indonesia

^cDepartment of Electronics Engineering, Southern Taiwan University of Science and Technology, Taiwan, Province of China

^dStudy and Research Center for Engineering, State University of Malang, Indonesia

aripriharta.ft@um.ac.id, siti.zubaidah.fmipa@um.ac.id, mokh.sholihul.ft@um.ac.id, hendrabio@um.ac.id, grojium@stust.edu.tw, muhammad.cahyo.2305348@students.um.ac.id, & muchamad.wahyu.2305348@students.um.ac.id

*Corresponding author

ABSTRACT

Degradation of the environment is increasingly associated with ecological disasters like floods, particularly in places that are vulnerable. Due in part to vegetation depletion, Batu City in the Brantas River Basin suffered significant floods in 2021. This highlights the necessity of real-time flora monitoring in flood-prone areas as part of disaster mitigation. This study introduces SobatFlora, a cloud-based big data platform that supports smart flora monitoring and ecosystem protection. SobatFlora integrates mobile image processing for real-time plant identification with IoE-enabled devices deployed throughout the Brantas Watershed. Using smartphone cameras, data on plant species, health, and environment are captured, classified via convolutional neural networks (CNN), and uploaded to the cloud. For ongoing environmental monitoring, the system integrates IoT sensor nodes, a centralized big data platform, and a mobile app. By offering precise, up-to-date ecological data throughout the watershed, this integrated strategy improves situational awareness and makes proactive, data-driven catastrophe risk reduction possible.

Keywords: Big Data, Flora Monitoring, Disaster Mitigation, Mobile Image Processing, IoT Nodes, Convolutional Neural Networks

ABSTRAK

Kemerosotan alam sekitar semakin dikaitkan dengan bencana ekologi seperti banjir, terutamanya di tempat yang terdedah. Disebabkan sebahagian daripada kepupusan tumbuh-tumbuhan, Bandar Batu di Lembangan Sungai Brantas mengalami banjir besar pada tahun 2021. Ini menyerlahkan keperluan pemantauan flora masa nyata di kawasan rawan banjir sebagai sebahagian daripada mitigasi bencana. Kajian ini memperkenalkan SobatFlora, platform data besar berasaskan awan yang menyokong pemantauan flora pintar dan perlindungan ekosistem. SobatFlora menyepadukan pemprosesan imej mudah alih untuk pengenalan tumbuhan masa nyata dengan peranti berdaya IoE yang digunakan di seluruh Tadahan Air Brantas. Menggunakan kamera telefon pintar, data tentang spesies tumbuhan, kesihatan dan persekitaran ditangkap, diklasifikasikan melalui rangkaian saraf konvolusi (CNN)

dan dimuat naik ke awan. Untuk pemantauan alam sekitar yang berterusan, sistem menyepadukan nod penderia IoT, platform data besar terpusat dan aplikasi mudah alih. Dengan menawarkan data ekologi yang tepat dan terkini di seluruh kawasan tadahan air, strategi bersepadu ini meningkatkan kesedaran situasi dan membolehkan pengurangan risiko bencana yang didorong oleh data yang proaktif.

Keywords: *Data Besar, Pemantauan Flora, Tebatan Bencana, Pemprosesan Imej Mudah Alih, Nod IoT, Rangkaian Neural Konvolusi*

INTRODUCTION

Almost 80% of the world's food supply and as much as 98% of the atmospheric oxygen that sustains human and animal life are produced by plants, positioning them as the most essential natural resources for the continuation of life on Earth and the preservation of ecological balance (Hernandez & Martinez, 2018). Despite their critical role, plants face increasing pressures from multiple fronts; up to 40% of crop losses worldwide are consistently caused by the combined effects of pests, plant diseases, and environmental degradation, all of which contribute to long-term threats against food security, the stability of ecosystems, and the livelihoods of communities that depend on agriculture.

The consequences of degraded flora extend far beyond the agricultural sector itself, as illustrated by the 2021 Batu City flood in Indonesia, which was directly associated with extensive vegetation loss in upstream regions, thereby exacerbating surface runoff and triggering severe flooding (Doody, 2022). This example highlights how ecological imbalance in one domain—such as vegetation decline—can rapidly translate into disasters that affect entire human settlements, underscoring the urgent need for continuous monitoring and preservation of flora, particularly in areas that are prone to flooding, as a strategic component of broader disaster mitigation and climate resilience efforts.

In recent years, the rapid advancement of digital technologies and big data analytics has significantly transformed approaches to environmental monitoring, enabling more precise, real-time, and large-scale observation of ecological parameters. Cloud computing and mobile platforms, in particular, have enhanced both accessibility and public awareness, ensuring that environmental data is not only collected but also disseminated effectively to decision-makers and local communities (Ayuningtyas, 2021; Mrabet et al., 2019).

Nevertheless, while the sheer volume, speed, and variety of field data generated from diverse sources are unprecedented, the actual value and usability of big data are highly dependent on the accuracy, precision, and quality of the datasets collected (Jong et al., 2017; Kang & Lee, 2018; Liu et al., 2021; Sabrol & Satish, 2016; Thiry et al., 2018). Today, much of these datasets are increasingly gathered through the integration of smartphones, mobile applications, and IoT-enabled sensor technologies, which allow for dynamic, continuous, and large-scale environmental data acquisition in real time, even in challenging or remote field conditions (Ashourloo et al., 2016; Gobalakrishnan et al., 2020; Hu et al., 2020; Nagasubramanian et al., 2021; Su et al., 2020).

The Internet of Things (IoT) has emerged as one of the most transformative technological paradigms in this context. By combining automation, distributed sensing, and wireless communication, IoT systems enable sensor-equipped nodes to instantly detect subtle changes in plant health, local ecosystems, and microclimatic variations, thereby strengthening the capacity of researchers, policymakers, and communities to monitor environmental

conditions with far greater accuracy and responsiveness (Albanese et al., 2021; Alencastre-Miranda et al., 2018; Mattihalli et al., 2018; Moriya et al., 2016; Patil & Kumar, 2022).

When integrated with machine learning algorithms, particularly convolutional neural networks (CNNs), IoT frameworks become even more powerful, allowing proactive identification of plant health conditions, disease outbreaks, and stress indicators with the computational support of cloud-based systems. Despite their potential, however, such approaches require vast, carefully labeled datasets, substantial computing power, and optimized frameworks to balance accuracy, efficiency, and scalability factors that continue to challenge the deployment of these technologies in real-world environments.

Prior studies have made considerable progress in demonstrating the application of IoT and machine learning in agriculture and environmental management. For instance, Deepa (2018), Shirahatti et al. (2018), and Petrellis (2016) successfully developed IoT-based environmental tracking systems that integrate sensor networks for microclimate analysis, while Sabrol and Satish (2016) explored the use of image recognition models for classifying plant diseases. Nonetheless, most existing systems are still limited in several critical aspects: they often lack comprehensive integration of multi-source environmental data, are not designed to support advanced flora recognition through machine learning, and do not sufficiently incorporate public accessibility via mobile applications for widespread use. Furthermore, important challenges such as optimization for classification robustness and the energy efficiency of sensor operations have yet to be thoroughly addressed, leaving significant opportunities for innovation and improvement in this domain.

In response to these challenges, this paper introduces SobatFlora, a novel Internet of Everything (IoE)-based platform designed to integrate mobile image capture, IoT-enabled environmental sensing, and deep learning models for real-time flora monitoring in the Brantas River Basin, with the explicit aim of supporting disaster mitigation and climate resilience. SobatFlora is equipped with several innovative features, including a mobile application connected to IoT sensor networks, a CNN-based bamboo disease classifier leveraging the AlexNet architecture, and a scalable optimization framework built around the Queen Honeybee Migration (QHBM) algorithm for future system enhancement. Beyond its technical contributions, SobatFlora is also envisioned as an educational and awareness-building tool, promoting ecological literacy and public participation in environmental stewardship through the combined use of artificial intelligence, big data analytics, and community-driven mobile technologies.

THE PROPOSED IoE SOBATFLORA

IoE-Based SobatFlora Architecture

SobatFlora is an Internet of Everything (IoE) technology that supports catastrophe risk management in flood-prone areas by providing real-time environmental and flora monitoring. The system gathers, examines, and displays data about plant health and environmental conditions by combining sensor nodes, cloud computing, and mobile interfaces.

- a. Hardware: Five environmental monitoring nodes, spaced 4–6 km from Batu City to Malang's outskirts, transmit data to a sink node at Universitas Negeri Malang (UM). Each node is powered by a 10 Wp MPPT solar panel, battery, and DC-DC converter, and equipped with an ESP8266 for sensor data, a GSM-WiFi module for real-time cloud updates, and an NTP module for time sync.

- b. Software: The SobatFlora mobile app, built with Flutter and Dart for Android, includes eight main pages allowing users to capture plant images for disease detection, monitor environmental data from IoT nodes, access plant species profiles, and visualize real-time sensor data from Firebase, integrating plant health monitoring with cloud-based data storage.
- c. Machine Learning: An AlexNet CNN model was trained on 518 bamboo and banana images to classify bamboo into four health categories: healthy, fungal-infected, *Rhizoctonia solani*-affected, and witches' broom see Figure 1. This framework enables precise identification and diagnosis of bamboo conditions for targeted treatment



Figure 1: Bamboo Samples by Health Condition

The model underwent preprocessing including image augmentation techniques such as flipping, zooming, and rotation, with images resized to 224×224 pixels, and was trained using TensorFlow on Google Colab before deployment via Firebase ML Kit for real-time mobile application classification.

METHODOGY

This section presents the methodological framework adopted in the study, covering the overall system design, implementation process, and testing stages that ensure the research objectives are achieved.

Design System

The system design of SobatFlora is structured to integrate hardware, software, and communication layers into a unified framework that supports real-time monitoring and analysis of flora conditions in the Brantas River Basin. The hardware layer consists of IoT-enabled sensors deployed in the field to measure critical environmental parameters such as temperature, humidity, soil moisture, and light intensity, which directly influence plant health and ecosystem stability. These sensors are connected to low-power microcontrollers that facilitate data acquisition and transmission, ensuring energy-efficient operation suitable for remote and flood-prone areas.

On the software side, the system incorporates a mobile application that enables users to capture plant images and receive real-time feedback. The application is linked to a cloud server, where data storage, preprocessing, and model training are performed. A convolutional neural network (CNN) model, based on the AlexNet architecture, is embedded within the system to classify bamboo diseases from captured images. To enhance scalability and efficiency, the design also includes a framework for integrating optimization techniques, specifically the Queen Honeybee Migration (QHBM) algorithm, which is intended to improve classification robustness and sensor energy management in future implementations.

The communication layer connects the field-deployed nodes, mobile application, and cloud infrastructure through wireless protocols, ensuring seamless data flow and synchronization. By combining distributed sensing, intelligent analysis, and user accessibility, the system design establishes the technical foundation for SobatFlora as both a disaster

mitigation tool and an educational platform that promotes ecological awareness. Five SobatFlora IoE sensor nodes were deployed along the Brantas River Basin, each spaced 4–6 km apart. The nodes continuously collect microclimatic and visual data, which are transmitted to a centralized sink node located at the UM Laboratory. The deployment area was selected based on historical flood incidents and ecological vulnerability in Figure 2.

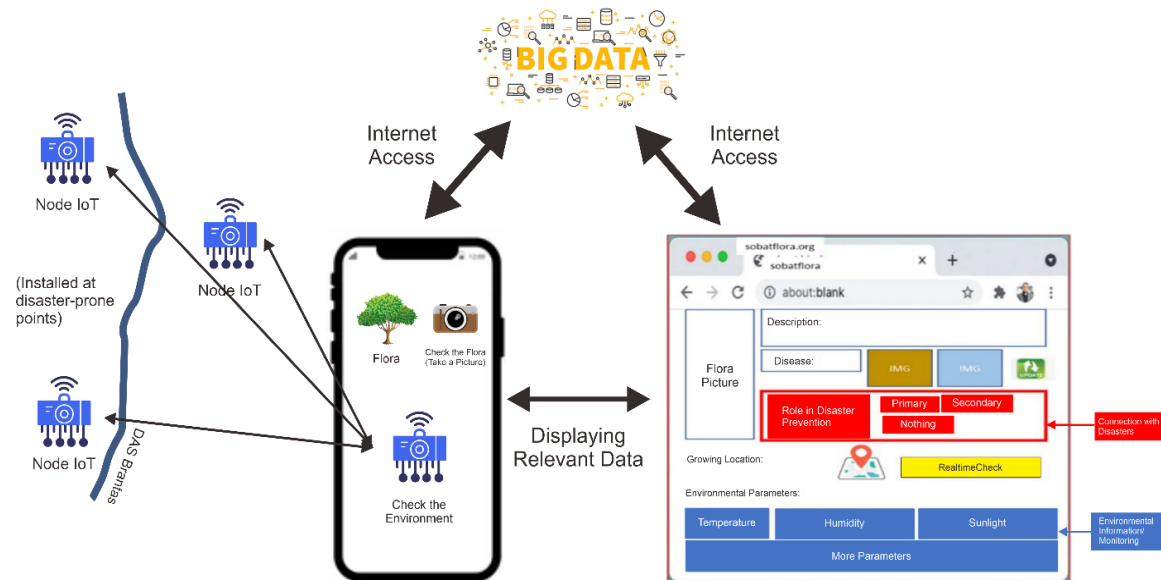


Figure 2: Special Specifications for SobatFlora Applied Products

Deployment Scenario

Five SobatFlora IoE sensor nodes were deployed along the Brantas River Basin, each spaced 4–6 km apart. The nodes continuously collect microclimatic and visual data, which are transmitted to a centralized sink node located at the UM Laboratory. The deployment area was selected based on historical flood incidents and ecological vulnerability in Figure 3.



Figure 3: Research Location

DATA COLLECTION AND ANALYSIS

Data is collected via two methods: real-time transmission of temperature and humidity data to Firebase using GSM-WiFi, and CNN-based processing of user-captured images for species and disease identification. Stored in JSON format, all data is accessible through an integrated mobile app and cloud tools for comprehensive plant health and environmental analysis.

Model Validation

The CNN model was trained and evaluated across different epochs (20, 30, 50). Validation was performed using a holdout test set. Accuracy and loss metrics were calculated to determine the best-performing configuration. Validation also included real-world testing with user-captured plant images in the field to assess inference accuracy.

Result and Analysis

This section presents SobatFlora IoE system results, categorized into system deployment outcomes, machine learning performance metrics, and overall integration effectiveness.

IoE System Deployment Results

Five SobatFlora monitoring nodes were successfully deployed in flood-prone, ecologically sensitive areas along the Brantas River Basin. Each node operated independently with stable power from photovoltaic panels, enabling continuous environmental monitoring.

Table 1: Deployment Site Summary

Node ID	Location	Distance from UM Lab (km)	Parameters Monitored
N1	Jl. Soekarno Hatta	0.0 (sink node)	Temp., Humidity
N2	Jl. Mertojoyo Selatan	4.3	Temp., Humidity
N3	Jl. Tlogomas	5.7	Temp., Humidity
N4	Jl. Oro-Oro Dowo	4.8	Temp., Humidity
N5	Jl. Anjasmoro, Batu	6.1	Temp., Humidity

All nodes successfully transmitted real-time sensor data to the Firebase database with consistent time synchronization. Environmental data was displayed in-app and updated dynamically.

Machine Learning Model Performance

The CNN model based on AlexNet architecture was trained using 518 augmented images. The goal was to classify bamboo plant conditions into four categories: Healthy, Fungal-Infected, *Rhizoctonia solani*, and Witches' Broom.

Table 2: Dataset Composition

Class	Total Images
Healthy Bamboo	250
Fungal Bamboo	59
<i>Rhizoctonia solani</i>	120
Witches' Broom Bamboo	135

Table 3: Model Validation Results

Epoch	Train Loss	Train Accuracy	Val Loss	Val Accuracy
20	0.5674	77.13%	0.5088	81.94%
30	0.5628	77.32%	0.8734	71.92%
50	0.0908	96.79%	0.2873	89.17%

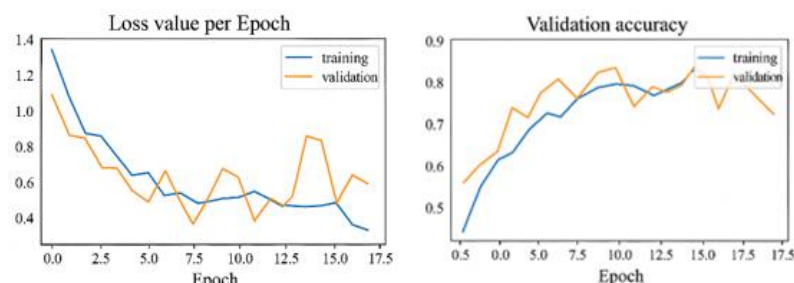


Figure 4: Loss and Validation Epoch 20

At 50 epochs, the model's greatest validation accuracy of 89.17% demonstrated a dependable degree of classification accuracy appropriate for field deployment shown in Figure 4.

Application Performance and User Testing

The SobatFlora mobile app demonstrates CNN accuracy with stable performance on Android, achieving 1–2 second image classification and accurate plant identification in field tests Figure 5. Its IoT dashboard enables real-time microclimate monitoring, with Firebase updating environmental data every five minutes.

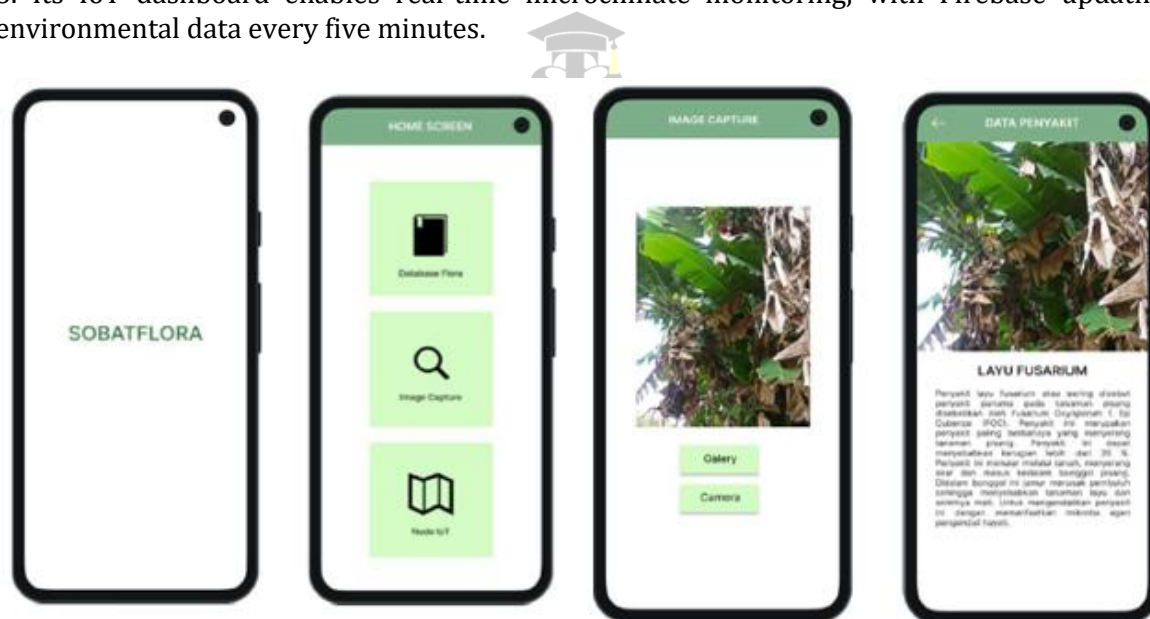


Figure 5: Sample App Screenshots

System Integration and Performance Evaluation

Continuous environmental data collection and quick CNN-based plant image processing were made possible by the combination of IoT nodes, cloud infrastructure, and a mobile interface. Easy access to environmental and plant health data was made possible by the smartphone app, which combined sophisticated disease identification with sensing to create a complete riverside monitoring system. With an end-to-end latency of less than 5 seconds, the system satisfies the early ecological warning standards for regions that are vulnerable to disasters.

CONCLUSION.

This study demonstrates the potential of the AlexNet CNN model for real-time flora monitoring inside IoE-based disaster management systems, especially in flood-prone parts of the Brantas Watershed, as it achieves 89.17% validation accuracy in classifying bamboo illnesses. Limitations include a tiny and unbalanced dataset, particularly for fungal-infected bamboo, and environmental variability during image capture, which cause accuracy to vary among classes despite its good performance. For ecological monitoring and early warning, SobatFlora provides a useful combination of deep learning and IoE. Future research will address prediction uncertainty in field situations, investigate alternative CNN architectures, expand and balance datasets, and scale the system for broader ecological applications.

ACKNOWLEDGMENT

The work in this paper is supported by Non-APBN UM 2022, Indonesia under contract number 19.5.1175/UN32.20.1/LT/2022.

REFERENCES

- Albanese, A., Nardello, M., & Brunelli, D. (2021). Automated Pest Detection with DNN on the Edge for Precision Agriculture. *IEEE Journal on Emerging and Selected Topics in Circuits and Systems*, 11(3), 458–467. <https://doi.org/10.1109/jetcas.2021.3101740>
- Alencastre-Miranda, M., Davidson, J. R., Johnson, R. M., Waguespack, H., & Krebs, H. I. (2018). Robotics for Sugarcane Cultivation: Analysis of Billet Quality using Computer Vision. *IEEE Robotics and Automation Letters*, 3(4), 3828–3835. <https://doi.org/10.1109/lra.2018.2856999>
- Ashourloo, D., Aghighi, H., Matkan, A. A., Mobasheri, M. R., & Rad, A. M. (2016). An Investigation into Machine Learning Regression Techniques for the Leaf Rust Disease Detection using Hyperspectral Measurement. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 9(9), 4344–4351. <https://doi.org/10.1109/jstars.2016.2575360>
- Ayuningtyas, N. (2021, November 5). Kota Batu dan Malang Dilanda Banjir Bandang, Ini 4 Fakta Terbarunya. *liputan6.com*. <https://surabaya.liputan6.com/read/4703349/kota-batu-dan-malang-dilanda-banjir-bandang-ini-4-fakta-terbarunya>
- Deepa, N. (2018). A Pre-Processing Approach for Accurate Identification of Plant Diseases in leaves. 2017 International Conference on Electrical, Electronics, Communication, Computer, and Optimization Techniques (ICECCOT), 249–252. <https://doi.org/10.1109/iceccot43722.2018.9001616>
- Doody, A. (2022, May 30). Pests and Diseases and Climate Change: Are there a Connection? CIMMYT. <https://www.cimmyt.org/news/pests-and-diseases-and-climate-change-is-there-a-connection/>
- Gobalakrishnan, N., Pradeep, K., Raman, C. J., Ali, L. J., & Gopinath, M. P. (2020). A Systematic Review on Image Processing and Machine Learning Techniques for Detecting Plant Diseases. *International Conference on Communication and Signal Processing (ICCSP)*, 0465–0468. <https://doi.org/10.1109/iccsp48568.2020.9182046>
- Hernandez, H., & Martinez, L. R. (2018). Relationship of Environmental Disturbances and the Infectious Potential of fungi. *Microbiology*, 164(3), 233–241. <https://doi.org/10.1099/mic.0.000620>
- Hu, W., Fan, J., Du, Y., Li, B., Xiong, N., & Bekkering, E. (2020). MDFC-RESNET: an Agricultural IoT System to Accurately Recognize Crop Diseases. *IEEE Access*, 8, 115287–115298. <https://doi.org/10.1109/access.2020.3001237>

- Jong, G., Aripriharta, N., Hendrick, N., & Horng, G. (2017). A Novel Queen Honey Bee Migration (QHBM) Algorithm for Sink Repositioning in Wireless Sensor Network. *Wireless Personal Communications*, 95(3), 3209–3232. <https://doi.org/10.1007/s11277-017-3991-z>
- Kang, S., & Lee, M. (2018). Automatic Construction of Sentiment Lexicon by Analyzing SMS Bigdata. *2021 IEEE International Conference on Big Data (Big Data)*, 40, 5348–5350. <https://doi.org/10.1109/bigdata.2018.8622280>
- Liu, X., Min, W., Mei, S., Wang, L., & Jiang, S. (2021). Plant Disease Recognition: A Large-Scale Benchmark Dataset and a Visual Region and Loss Reweighting Approach. *IEEE Transactions on Image Processing*, 30, 2003–2015. <https://doi.org/10.1109/tip.2021.3049334>
- Mattihalli, C., Gedefaye, E., Endalamaw, F., & Necho, A. (2018). Real Time Automation of Agriculture Land, by Automatically Detecting Plant Leaf Diseases and Auto Medicine. *32nd International Conference on Advanced Information Networking and Applications Workshops (WAINA)*. <https://doi.org/10.1109/waina.2018.00106>
- Moriya, E. a. S., Imai, N. N., Tommaselli, A. M. G., & Miyoshi, G. T. (2016). Mapping Mosaic Virus in Sugarcane Based on Hyperspectral Images. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 10(2), 740–748. <https://doi.org/10.1109/jstars.2016.2635482>
- Mrabet, Z. E., Selvaraj, D. F., & Ranganathan, P. (2019). Adaptive Hoeffding Tree with Transfer Learning for Streaming Synchrophasor Data Sets. *2021 IEEE International Conference on Big Data (Big Data)*, 5697–5704. <https://doi.org/10.1109/bigdata47090.2019.9005720>
- Nagasubramanian, G., Sakthivel, R. K., Patan, R., Sankayya, M., Daneshmand, M., & Gandomi, A. H. (2021). Ensemble Classification and IOT-Based Pattern Recognition for Crop Disease Monitoring System. *IEEE Internet of Things Journal*, 8(16), 12847–12854. <https://doi.org/10.1109/jiot.2021.3072908>
- Patil, R. R., & Kumar, S. (2022). Rice-Fusion: A Multimodality Data Fusion Framework for Rice Disease Diagnosis. *IEEE Access*, 10, 5207–5222. <https://doi.org/10.1109/access.2022.3140815>
- Petrellis, N. (2016). Plant Lesion Characterization for Disease Recognition A Windows Phone Application. *2nd International Conference on Frontiers of Signal Processing (ICFSP)*, 10–14. <https://doi.org/10.1109/icfsp.2016.7802948>
- Sabrol, H., & Satish, K. (2016a). Tomato Plant Disease Classification in Digital Images using Classification Tree. *International Conference on Communication and Signal Processing (ICCSP)*, 1242–1246. <https://doi.org/10.1109/iccsp.2016.7754351>
- Sabrol, H., & Satish, K. (2016b). Tomato Plant Disease Classification in Digital Images using Classification Tree. *International Conference on Communication and Signal Processing (ICCSP)*, 1242–1246. <https://doi.org/10.1109/iccsp.2016.7754351>
- Shirahatti, J., Patil, R., & Akulwar, P. (2018). A Survey Paper on Plant Disease Identification Using Machine Learning Approach. *3rd International Conference on Communication and Electronics Systems (ICCES)*, 1171–1174. <https://doi.org/10.1109/cesys.2018.8723881>
- Su, J., Yi, D., Su, B., Mi, Z., Liu, C., Hu, X., Xu, X., Guo, L., & Chen, W. (2020). Aerial Visual Perception in Smart Farming: Field Study of Wheat Yellow Rust Monitoring. *IEEE Transactions on Industrial Informatics*, 17(3), 2242–2249. <https://doi.org/10.1109/tii.2020.2979237>
- Thiry, L., Zhao, H., & Hassenforder, M. (2018). Categorical Models for BigData. *IEEE International Congress on Big Data (BigData Congress)*, 272–275. <https://doi.org/10.1109/bigdatacongress.2018.00049>

KETERANGAN BERKENAAN PENULIS

Aripriharta

Department of Electrical Engineering,
State University of Malang, Indonesia
Jl. Semarang No. 5, Sumbersari, Malang,
Jawa Timur 65145, Indonesia
aripriharta.ft@um.ac.id

Siti Zubaidah

Department of Biology,
State University of Malang, Indonesia
Jl. Semarang No. 5, Sumbersari, Malang,
Jawa Timur 65145, Indonesia
siti.zubaidah.fmipa@um.ac.id

Mokh. Sholihul Hadi

Department of Electrical Engineering,
State University of Malang, Indonesia
Jl. Semarang No. 5, Sumbersari, Malang,
Jawa Timur 65145, Indonesia
mokh.sholihul.ft@um.ac.id

Hendra Susanto

Department of Biology,
State University of Malang, Indonesia
Jl. Semarang No. 5, Sumbersari, Malang,
Jawa Timur 65145, Indonesia
hendrabio@um.ac.id



Gwo-Jiun Horng

³Department of Electronics Engineering,
Southern Taiwan University of Science and Technology,
Taiwan, Province of China
grojium@stust.edu.tw

Muhammad Cahyo Bagaskoro

Department of Electrical Engineering,
State University of Malang, Indonesia
Jl. Semarang No. 5, Sumbersari, Malang,
Jawa Timur 65145, Indonesia
muhammad.cahyo.2305348@students.um.ac.id

Muchamad Wahyu Prasetyo

Study and Research Center for Engineering,
State University of Malang, Indonesia
Jl. Semarang No. 5, Sumbersari, Malang,
Jawa Timur 65145, Indonesia
muchamad.wahyu.2305348@students.um.ac.id

**THE RELATIONSHIP BETWEEN AWKWARD WORKING POSTURES
AND MUSCULOSKELETAL DISORDER RISKS AMONG LANDSCAPE
HORTICULTURE WORKERS**
***HUBUNGAN ANTARA POSTUR KERJA JANGGAL DAN RISIKO GANGGUAN
MUSKULOSKELETAL DALAM KALANGAN PEKERJA HORTIKULTUR
LANDSKAP***

Fara Diba Badrul Hisham^{1a*}, Shuharzi Md Salleh^{2a}, & Fairoz Yaakob^{3a}

^aPoliteknik Nilai

faradiba@polinilai.edu.my, shuharzi@polinilai.edu.my & fairoz@polinilai.edu.my

*Corresponding author

ABSTRACT

Landscape horticulture work involves physically demanding tasks such as grass cutting, sweeping, and drain clearing, which often require awkward and repetitive postures. This study addresses issues biomechanical demands increase the risk of work-related musculoskeletal disorders (WMSDs). This study attempts to address the following objectives (i) to identify the prevalence and severity of musculoskeletal discomfort among landscape horticulture workers, (ii) to evaluate ergonomic risk factors particularly awkward working postures associated with specific job activities using discomfort scores and observational data. A cross-sectional ergonomic assessment was conducted at Nilai Polytechnic involving 20 landscape staff. Five staff were selected for detailed analysis. The Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) and observational ergonomic checklists from DOSH Malaysia (2017) were used. Results showed that 100% of workers experienced musculoskeletal discomfort, with the neck, right shoulder, right upper arm, upper back, left upper arm, and right wrist each scoring a severity level of 60, the maximum recorded. The right forearm had a moderate severity score of 20, while lower limbs showed minimal discomfort (≤ 1.5). The ergonomic risk assessment identified 8 out of 13 awkward posture indicators, 3 out of 5 repetitive motion risks, 2 out of 2 forceful exertion indicators, and 4 out of 4 vibration-related risks. These were most evident during grass cutting and drain clearing tasks. The results suggest that advanced ergonomic assessments (RULA, REBA, OWAS) and immediate interventions such as job rotation, ergonomic training, and tool redesign are essential to improve workplace safety and worker well-being in the landscape horticulture sector. This study is important as it provides empirical evidence on the ergonomic risks faced by landscape horticulture workers. The findings can propose workplace safety policies, contribute to the development of ergonomic standards for public service maintenance work, and ultimately improve the health, productivity, and well-being of workers in the landscape sector.

Keyword: Ergonomics, Workplace Safety, Landscape Horticulture Activities, Ergonomic Risk Assessment

ABSTRAK

Aktiviti hortikultur landskap melibatkan tugas-tugas fizikal yang memerlukan postur janggal dan berulang seperti memotong rumput, menyapu, dan membersihkan longkang. Tujuan kajian ini adalah untuk menilai tahap ketidakselesaan muskuloskeletal serta faktor risiko ergonomik yang dikaitkan dengan aktiviti pekerjaan tersebut. Soal selidik telah dijalankan di Politeknik Nilai melibatkan 20 pekerja landskap menggunakan Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) dan senarai semak ergonomik DOSH Malaysia (2017). Dapatan

menunjukkan 100% pekerja mengalami ketidakselesaian muskuloskeletal dengan bahagian leher, bahu kanan, lengan atas kanan, belakang atas, lengan atas kiri, dan pergelangan tangan kanan mencatat skor keterukan maksimum 60. Analisis ergonomik mengenal pasti 8 daripada 13 indikator postur janggal, 3 daripada 5 risiko pergerakan berulang, 2 daripada 2 indikator tekanan berkuasa, dan 4 daripada 4 risiko getaran. Hasil kajian menunjukkan intervensi ergonomik segera seperti putaran tugas, latihan ergonomik, dan reka bentuk semula alatan adalah penting untuk meningkatkan keselamatan pekerjaan dan kesejahteraan pekerja hortikultur landskap. Penemuan ini menyumbang kepada dasar keselamatan pekerjaan dan piawaian ergonomik dalam sektor penyelenggaraan perkhidmatan awam.

Kata Kunci: Ergonomik, Keselamatan Tempat Kerja, Aktiviti Hortikultur Landskap, Penilaian Risiko Ergonomik

INTRODUCTION

Despite the crucial role of landscape horticulture workers in maintaining institutional environments, their tasks often involve prolonged physical exertion, awkward postures, and repetitive motions particularly during activities such as grass cutting, leaf sweeping, and drain clearing. This study attempts to address the following objectives (i) to identify the prevalence and severity of musculoskeletal discomfort among landscape horticulture workers, (ii) to evaluate ergonomic risk factors particularly awkward working postures associated with specific job activities using discomfort scores and observational data. The initial ergonomic risk assessment conducted at Nilai Polytechnic revealed high severity scores of musculoskeletal discomforts, especially in the neck, shoulders, upper back, upper arms, and wrists, with repetitive strain and awkward posture identified as major contributing factors. However, these workers often perform their duties with limited ergonomic interventions, exposing them to increased risk of work-related musculoskeletal disorders (WMSDs). The prevalence of discomfort in key body regions indicates a mismatch between job demands and ergonomic safety.

Despite existing guidelines, there remains a lack of localized ergonomic studies that link awkward working postures to specific MSD risks among landscape horticulture personnel in Malaysian institutional settings. Hence, it is critical to examine the relationship between awkward postures and musculoskeletal disorder risks in order to recommend targeted ergonomic improvements that could enhance occupational health and productivity in this sector.

A Risk Amplified in Landscape Work towards Musculoskeletal Disorders in Manual Labour

Musculoskeletal disorders (MSDs) are among the most reported occupational health problems, particularly in jobs involving sustained physical effort. These disorders arise from repetitive movement, awkward postures, and physical overload (Bernard, 1997). Landscape horticulture, as a form of manual labor, presents an environment where these risk factors are inherently embedded in daily routines. Choobineh et al. (2011) emphasized that frequent bending, squatting, and prolonged use of hand tools elevate exposure to MSDs. Recent findings by Alnaser et al. (2021) and Kim et al. (2022) support that manual workers without proper ergonomic interventions are at higher risk of developing chronic musculoskeletal symptoms. This establishes a clear connection between the physically intensive nature of landscape work and the vulnerability of its workers to posture-related injuries, underscoring the relevance of investigating the role of awkward working postures in this specific sector.

Ergonomic Assessment as a Bridge Between Posture and Prevention

The assessment between awkward working postures and musculoskeletal risks, reliable assessment tools are essential. Instruments such as the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ), RULA, and REBA provide measurable insights into discomfort and postural load (Shariat et al., 2016; McAtamney & Corlett, 1993). These tools allow identification of specific high-risk postures and task patterns, making it possible to develop tailored interventions. Zakaria et al. (2022) demonstrated that CMDQ and RULA scores are significantly correlated in evaluating gardening tasks, confirming that awkward postures in landscaping work directly translate into higher discomfort reports. Awkward postures defined as deviations from neutral joint alignment are frequently observed in landscape tasks such as pruning, mowing, sweeping, and weeding. These tasks often require extended periods of kneeling, overhead reaching, or trunk twisting, resulting in biomechanical stress on multiple joints (da Costa & Vieira, 2010). The connection to MSDs is direct and critical studies such as Kee & Karwowski (2007) have shown that even moderate neck flexion or trunk rotation can significantly increase the risk of musculoskeletal injury.

Furthermore, studies by Shamsuddin et al. (2020) highlight the lack of proactive ergonomic strategies in public landscaping sectors in Malaysia. This shows that the problem is not only physical but systemic without structured assessments, awkward postures remain unnoticed and uncorrected, increasing the long-term health risks faced by landscape horticulture workers. The literature reveals a clear and consistent relationship between awkward working postures and the increased risk of musculoskeletal disorders (MSDs), particularly among landscape horticulture workers. MSDs, which affect muscles, joints, and spinal structures, are prevalent in physically demanding occupations, especially when repetitive movements and poor posture are involved.



METHODOLOGY

This study adopted a quantitative descriptive cross-sectional design to assess the current state of musculoskeletal discomfort among landscape and cleaning workers. A cross-sectional approach was selected as it allows for the examination of musculoskeletal symptoms at a single point in time, capturing real-time data on postural discomfort without the need for longitudinal tracking. Other than that, an observational ergonomic risk assessment design to evaluate awkward working postures among landscape workers during actual field activities. Real-time observational methods were applied to assess postural risks during tasks such as grass cutting, leaf sweeping, and drain cleaning. The focus was on identifying exposure to non-neutral postures sustained over time, in line with ergonomic hazard criteria.

Data Collection Instrument

The Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) was employed as the primary instrument to collect data on musculoskeletal symptoms. This validated tool assesses the anatomical location of discomfort (muscles and joints), frequency of symptoms, severity of discomfort, and degree of interference with job performance. CMDQ has been previously validated in Malaysian occupational settings, with Shariat et al. (2016) confirming its reliability and applicability for evaluating work-related musculoskeletal issues among local workers. An observational checklist was developed based on the Guidelines for Ergonomic Risk Assessment at the Workplace (DOSH, 2017) for Ergonomic Risk Factors Checklist. The checklist focused on the evaluation of the following body parts such as Neck, Shoulders, Upper and lower arms, Wrists, Upper and lower back, Legs and knees.

Sampling and Sample Size

The study population consisted of landscape and cleaning workers. A total sampling technique was used to ensure all eligible participants were included, particularly those directly involved in grass cutting, sweeping, and drain clearing activities. The expected minimum sample size was 20 participants, based on the actual workforce size at the time of study.

Data Analysis

Descriptive statistics were used to analyze the collected data. The following CMDQ scores were calculated such as symptom frequency (how often pain is experienced), Discomfort level (rated on a scale from 1 to 3), Work interference (rated on a scale from 1 to 3). A severity score was computed using the standard CMDQ formula: Severity Score = Frequency (A) × Discomfort (B) × Interference (C). Frequency analysis was performed to count the number of high-risk postures identified per task. Postural exposure scores were used to determine the severity and urgency of ergonomic risks. Comparative analysis was conducted to examine postural demands between different tasks (e.g., grass cutting vs. sweeping). If the observation revealed high exposure (e.g., ≥ 6 risk factors in a single activity), further ergonomic evaluation was recommended using structured tools.

RESULT AND DISCUSSION

The prevalence and severity of musculoskeletal discomfort among landscape horticulture workers

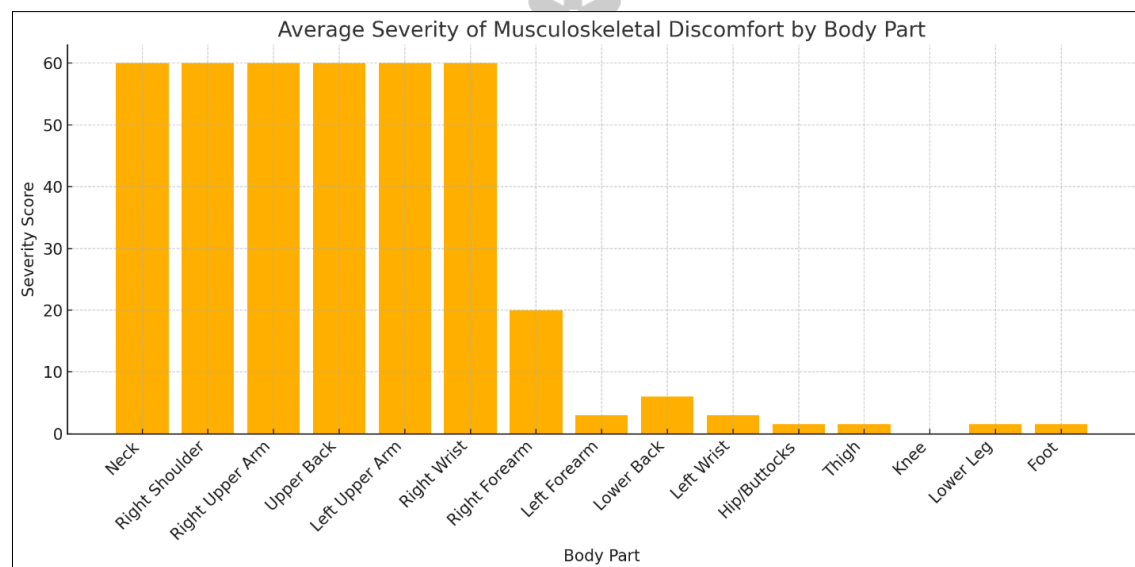


Figure 1: Average Severity of Musculoskeletal Discomfort by Body Part

Figure 1 presents the average severity scores of musculoskeletal discomforts reported by landscape workers across different body regions, based on the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ). The analysis indicates that the neck, right shoulder, right and left upper arms, upper back, and right wrist recorded the highest severity scores, each reaching a value of 60, signifying these as the most affected anatomical regions. In contrast, lower body parts including the legs, thighs, and knees recorded very low or zero severity scores, suggesting minimal or no reported discomfort in these areas. This trend is consistent with the nature of landscape tasks, which predominantly involve upper body exertion such as pruning,

sweeping, and operating tools requiring repetitive arm and shoulder movements, while lower limbs are engaged mainly for support and mobility. These findings support the hypothesis that awkward upper-body postures and repetitive arm motions contribute significantly to musculoskeletal strain among landscape workers. It underscores the importance of targeted ergonomic interventions, particularly for upper limb and trunk postures.

The result aligns with research by Kamaruddin et al. (2020) and Ng et al. (2021) found that over 60% of landscape maintenance time involves postures considered ergonomically unsafe. Thus, in the landscape horticulture sector, awkward postures are not incidental they are intrinsic to the work process, making them a key factor in the high prevalence of MSDs observed among workers. Given the prevalence of awkward postures and their clear association with musculoskeletal discomfort in landscape horticulture workers, this study adds to the growing body of evidence advocating for proactive ergonomic assessments and interventions. Failure to address these ergonomic risks could result in chronic injuries, increased absenteeism, and higher healthcare costs in the long term, as emphasized by Silverstein et al. (2008). As such, it is imperative that landscape maintenance organizations implement preventive measures to mitigate the risk of MSDs and improve worker health and productivity.

Ergonomic risk factors particularly awkward working postures associated with specific job activities.

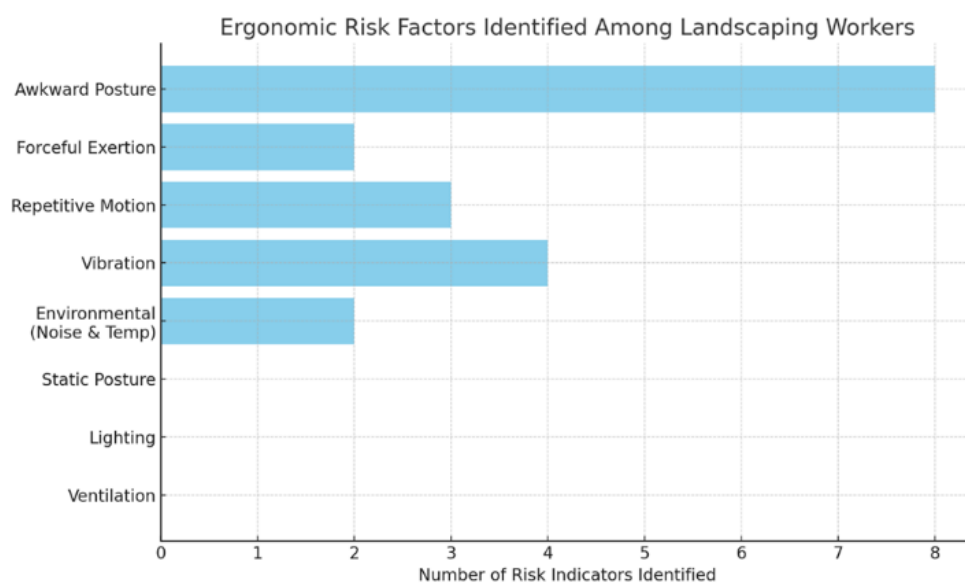


Figure 2: Ergonomic Risk Factor Identified Among Landscaping Workers

Figure 2 illustrates the number of ergonomic risk indicators observed among landscape workers across various risk categories. The analysis revealed that awkward posture was the most prominent risk factor, with 8 distinct indicators identified during task observations. This includes postural deviations such as neck flexion, shoulder elevation, and trunk twisting that occurred frequently during grass cutting, sweeping, and drain cleaning activities. This was followed by vibration-related risks, primarily due to the frequent use of powered tools such as lawn mowers, and repetitive motion, particularly in prolonged sweeping and trimming tasks. Forceful exertion was also recorded, including repetitive lifting of moderately heavy loads across walking distances. In contrast, no significant risk indicators were identified for static posture, lighting, and ventilation. These factors were either minimal or not applicable to the nature of the dynamic outdoor tasks performed by the landscape workers during the assessment period. These findings suggest that future ergonomic interventions should

prioritize upper-body posture, repetitive movement, and tool-related vibration over environmental adjustments.

CONCLUSION

The high number of awkward posture indicators (8 out of 13) exceeds the minimum threshold for ergonomic hazard recognition, thus justifying the application of advanced ergonomic risk assessments (ERA) using tools such as RULA, REBA, or OWAS. This not only validates the physical causes of reported discomfort but also highlights urgent opportunities for ergonomic intervention. Suggested interventions include task redesign, rotation of physically demanding roles, and the adoption of mechanical aids or posture-supporting tools to reduce biomechanical strain. Beyond individual interventions, the study provides empirical evidence to support the development of occupational health and safety policies at the organizational level. These insights are essential for employers, safety officers, and policymakers to formulate targeted strategies that prioritize worker health, enhance job performance, and promote long-term sustainability in landscape-related occupations. In conclusion, a proactive ergonomic approach is imperative to safeguard the health and productivity of landscape workers and to ensure compliance with workplace safety standards.

ACKNOWLEDGMENT

The authors would like to express their sincere appreciation to the management of **Politeknik Nilai** for their cooperation and support in facilitating access to the landscape staff and fieldwork locations. Special thanks are extended to all participating for their time, patience, and valuable contributions during the data collection process. The authors also acknowledge the use of ergonomic assessment tools and guidelines provided by the **Department of Occupational Safety and Health Malaysia (DOSH)**, which greatly supported the structure and validity of this research.

REFERENCES

- Alnaser, M., Taneepanichskul, S., & Theppitak, C. (2021). Prevalence and Associated Risk Factors of Musculoskeletal Disorders among Construction Workers in Developing Countries: A Systematic Review. *Journal of Occupational Health and Epidemiology*, 10(2), 85–94.
- Bernard, B. P. (1997). *Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back*. NIOSH.
- Choobineh, A., Hosseini, M., Lahmi, M., Khani Jazani, R., Shahnava, H. (2011). Musculoskeletal Problems among Workers of Iranian Communication Industries. *Industrial Health*, 49(6), 765–771.
- Da Costa, B. R., & Vieira, E. R. (2010). Risk Factors for Work-related Musculoskeletal Disorders: A Systematic Review of Recent Longitudinal Studies. *American Journal of Industrial Medicine*, 53(3), 285–323.
- Hignett, S., & McAtamney, L. (2000). Rapid Entire Body Assessment (REBA). *Applied Ergonomics*, 31(2), 201–205.
- Kee, D., & Karwowski, W. (2007). A Comparison of Three Observational Techniques for Assessing Postural Loads in Industry. *International Journal of Occupational Safety and Ergonomics*, 13(1), 3–14.

- Kim, S. Y., Lee, G. C., & Jung, M. C. (2022). Risk Assessment of Musculoskeletal Workload among Groundskeepers in Public Parks. *International Journal of Industrial Ergonomics*, 88, 103278.
- McAtamney, L., & Corlett, E. N. (1993). RULA: A Survey Method for the Investigation of Work-Related upper Limb Disorders. *Applied Ergonomics*, 24(2), 91–99.
- Park, H., Lee, J. H., & Kim, J. Y. (2016). The Risk of Musculoskeletal Disorders in Landscaping Workers based on RULA analysis. *Journal of Ergonomic Studies*, 14(2), 135–144.
- Rafeemanesh, E., et al. (2013). Evaluation of Musculoskeletal Disorders among Groundskeeping Workers. *Iranian Journal of Health and Safety at Work*, 3(2), 65–72.
- Shamsuddin, N. H., Baharuddin, M. R., & Nasir, R. A. (2020). Lack of Ergonomic Implementation in Malaysian Public Landscape Services: A Qualitative Review. *Journal of Occupational Safety and Health*, 17(1), 53–61.
- Shariat, A., Cleland, J. A., Danaee, M., Kargarfard, M., Sangelaji, B., & Tamrin, S. B. (2016). Workplace Exercises Reduce Musculoskeletal Disorders in Office Workers: A randomized controlled trial. *Physiotherapy Theory and Practice*, 32(7), 541–547.
- Shahidi, B., Haight, A., & Jahangiri, M. (2017). Musculoskeletal Discomfort among Municipal Grounds Maintenance Workers. *International Journal of Industrial Ergonomics*, 62, 1–7

KETERANGAN BERKENAAN PENULIS

Fara Diba Badrul Hisham

Senior Lecturer,
Department of Agro Technology and Bio-Industry
Politeknik Nilai, Kompleks Pendidikan Nilai,
Bandar Enstek, 71760 Nilai,
Negeri Sembilan, Malaysia
faradiba@polinilai.edu.my



Shuharzi Md Salleh

Lecturer, Department of Mechanical Engineering,
Politeknik Nilai, Kompleks Pendidikan Nilai,
Bandar Enstek, 71760 Nilai, Negeri Sembilan, Malaysia
shuharzi@polinilai.edu.my

Fairoz Yaakob

Lecturer, Department of Civil Engineering,
Politeknik Nilai, Kompleks Pendidikan Nilai,
Bandar Enstek, 71760 Nilai, Negeri Sembilan, Malaysia
fairoz@polinilai.edu.my

ANALYZING THE IMPACT OF AI ASSISTANCE LEVELS AND TASK TYPES ON LECTURER SATISFACTION AND TEACHING OUTCOMES IN HIGHER EDUCATION

ANALISIS IMPAK TAHAP PENGGUNAAN AI DAN JENIS TUGAS BERDASARKAN KEPUASAN PENSYARAH DAN HASIL PEMBELAJARAN DI INTITUSI PENGAJIAN TINGGI

Faraziah Hassan^{1a*}, Nur Hidayah Khalid^{2a} & Ahmad Razimi Mat Lazim^{3a}

^aPoliteknik Nilai

*faraziah@polinilai.edu.my, hidayah.khalid@polinilai.edu.my & arazimi@polinilai.edu.my

*Corresponding author

ABSTRACT

The incorporation of Artificial Intelligence (AI) based tools into the field of education has received much attention for its potential to improve teaching and learning process. This research examines the faculty experience with AI tools in higher education how AI tool competence is associated with the types of tasks, and in turn results in faculty satisfaction. The authors collected data from instructors who utilized AI platforms to complete tasks relating to content creation, grading, and brainstorming in their instruction. A full and detailed statistical analysis such as, descriptive statistics, correlation analysis and visualisation were carried out to investigate the effect of the varying levels of AI support and types of tasks on teaching outcome and lecturer satisfaction. The findings show that greater AI assistance is associated with satisfaction and task success. Task types such as writing and brainstorming were more enhanced by AI tools, whereas for coding tasks less enhancement was perceived. Further, the duration of sessions, and the number of prompts were predictors of satisfaction and outcomes, demonstrating also the relevance of user engagement with AI tools. These results indicate that AI tools can greatly impact the teaching and learning experience when they offer dynamic support that is aligned with the goals of the task. The paper provides insights into the role of AI in HEI and presents suggestions for optimising AI tools for lecturers across domains.

Keywords: Artificial Intelligence, AI Tools, Lecturer Satisfaction, Teaching Effectiveness, AI Assistance Levels

ABSTRAK

Penggunaan alat berasaskan Kecerdasan Buatan (AI) dalam pendidikan semakin mendapat perhatian kerana potensinya untuk memperkukuh proses pengajaran dan pembelajaran. Kajian ini meneliti pengalaman pensyarah dalam pendidikan tinggi terhadap penggunaan alat AI serta bagaimana tahap penguasaan dan jenis tugas berkaitan dengan kepuasan mereka. Data dikumpul daripada pensyarah yang menggunakan platform AI bagi tugas penciptaan kandungan, penilaian, dan penjanaan idea. Analisis statistik deskriptif, analisis korelasi dan visualisasi telah dijalankan untuk menilai kesan tahap sokongan AI dan jenis tugas terhadap hasil pengajaran serta kepuasan pensyarah. Dapatan menunjukkan bahawa sokongan AI yang lebih tinggi meningkatkan keberhasilan tugas dan kepuasan pengguna. Tugas seperti penulisan dan penjanaan idea memperoleh manfaat yang lebih ketara daripada AI, manakala kesan pada tugas pengaturcaraan adalah lebih terhad. Selain itu, tempoh sesi penggunaan dan bilangan arahan (prompts) didapati menjadi peramal penting kepada tahap kepuasan, menonjolkan kepentingan keterlibatan aktif pengguna dengan AI. Secara keseluruhan, hasil kajian ini membuktikan bahawa alat AI mampu memberi impak bermakna terhadap

pengalaman pengajaran dan pembelajaran apabila digunakan secara dinamik dan selaras dengan matlamat tugas. Artikel ini turut mengemukakan pandangan tentang peranan AI dalam institusi pendidikan tinggi serta cadangan bagi mengoptimumkan penggunaannya dalam kalangan pensyarah merentas bidang.

Kata Kunci: Kecerdasan Buatan, alat AI, Kepuasan Pensyarah, Keberkesanan Pengajaran, Tahap Sokongan AI

INTRODUCTION

The continuous progress of AI (Artificial Intelligence) technology has brought profound influences on different domains, such as education. AI technologies are more commonly applied in classroom teaching and learning, bringing both possibilities and challenges for education. The potential uses of AI in education include increasing the efficiency of teaching, decreasing the workload of lecturers, as well as furthering better learning outcomes for students (Luckin et al., 2016). The increased use of AI technologies in education is a part of the ongoing digitalization process and one of its goals is to promote more personalized, efficient and engaging learning processes (Holmes et al., 2019). As AI continues to develop, it is imperative to know how AI will affect teaching and learning, especially in tertiary settings where AI adopts the tools that are used to supplement the lecturers in some roles, such as preparing content, grading and evaluating students and teaching activities (Abdullah et al., 2025).

AI-based educational tools cover a wide variety of technologies, including intelligent tutoring systems (ITS) for personalised learning support, AI-based assistants for automation of administrative responsibilities, feedback to students, and creation of resources by teachers (Singh & Hiran, 2022). These instruments, able to lessen the workload needed by teachers and enhance the quality of learning experiences, can do so by offering timely feedback, adjusting the modes of learning to diverse learning styles and by promoting potential savings in classroom time (Martin et al., 2024). Nevertheless, while AI has the potential to be beneficial in education, there is an ongoing discussion about its efficacy. While AI in education brings about certain benefits to students' achievement (Abdullah et al., 2025), there are concerns that AI might affect negatively the teacher-pupil relationship, depersonalize education and damage critical thinking skills (Holmes et al, 2019; Selwyn, 2019).

The incorporation of AI in teaching and learning settings also raises questions the extent to which lecturer job satisfaction and engagement is affected. Tools powered by AI are designed to help lecturers by moving repetitive tasks and decision-making support to automation. Nonetheless, it is still important to consider how these instruments impacting lecturers' perceptions of their teaching effectiveness and teaching satisfaction (Lin, 2022). Researchers have reported that automated feedback (AI) has the potential to enhance lecturer productivity by autonomously providing performance feedback to students, thus freeing lecturers to concentrate more on the teaching and less on the administration (Woolf, 2010). On the other hand, there are concerns that over-emphasis on AI could erode the lecturers' autonomy or the quality of human interaction in the classroom (Selwyn, 2019).

In view of these issues, the present study seeks to assess AI-based tools that lecturers employ in higher education. The main objective is thus to investigate the relationship between the level of AI support offered and the satisfaction of lecturers, while observing differences due to the kind of task that AI assisted (writing / coding / brainstorming). Through a data analysis of multiple teaching sessions, this research project yields useful findings about the role of AI in

higher education, and it aims to suggest some guidelines for the design and the implementation of AI tools that can support lecturers' needs across different academic areas.

METHODOLOGY

The purpose of this efficacy study on AI tools in lecturers to support teaching and learning was to investigate the impact of different elements such as levels of AI assistance, types of tasks, and lecturers' satisfaction. The method was data driven and quantitative, collected from the lecturers' interactions with AI tools in class. The data was statistically analysed for descriptive statistics, and correlation of analysis of visualization for meaningful conclusions.

Data Collection:

The data collection for this study was obtained from a survey of lecturers using AI tools in several academic activities. The dataset is comprised of data from several teaching sessions, where each session is characterised by the following attributes:

Table 1: Characterised Comprised of Dataset from Several Teaching Sessions

Dataset	Characteristic
SessionID	A unique identifier of the session itself.
Disc	The field discipline (e.g., psychology, biology).
SessionDate	The date on which the session was conducted.
SessionLengthMin	How long the session last in mins.
TotalPrompts	Count of the prompts used by the teacher in the session.
TaskType	The type of task AI was used for help in (e.g., writing, coding, brainstorming).
AI_AssistanceLevel	'The CPU assistance setting from Low to High'
FinalOutcome	The final result of the session (completed assignment, outline for an idea).
UsedAgain	Whether the AI tool was used again after the session.
SatisfactionRating	Satisfaction rating of the lecturer, for the session, on a scale from 1 to 5.

Data collected from actual academic collaborations, where instructors employed AI tool for teaching/learning endeavours. This is the data to establish how well AI tools work in academia.

Data Preprocessing

Prior to analysis, data were cleaned for missing values and anomalies. Missing values were excluded, and anomalies or spurious data points were corrected, in order to maintain the reliability of the analysis. After cleaning the data, the latter was prepared for statistical analysis.

Descriptive Statistics

Descriptive statistics were conducted for both session length, the total number of prompts experienced, level of AI assistance, and level of satisfaction. Summary statistics including mean, standard deviation, min and max are calculated to describe the dataset and to get preliminary insight of the distribution of these variables. For example, the average session duration and the average lecture satisfaction rating were indicative of the average time spent per session and of the extent of satisfaction of the lecturers on the use of the AI tools. The aggregate prompts metrics aided us to understand how actively lecturers were involved in the tool (useful for the satisfaction and outcome analysis)

Correlation Analysis

One of the major steps of the method was to perform correlation analysis to study the connections among the different variables in the dataset:

1. **Session Length vs Total Prompts:** This was hypothesized to be positively correlated, meaning that longer sessions have more prompts. This was one indication that more time spent with AI tools can result in more user input.
2. **AI Assistance Level vs. Satisfaction Rating:** The analysis was conducted to study the impacts of the different AI assistance levels on the lecturer's satisfaction. It was hypothesized that a higher level of assistance provided by the AI would result in a higher satisfaction rating.
3. **Session Length and Output vs. Effectiveness Rating:** That analysed whether longer chat sessions and more produced message were related to better effectiveness, showing a trade-off between session length and effective AI support.
4. **AI Assistantness Level versus Final Achievement:** It is the relationship between the amount of AI help with result of task when high levels of help meant better tasks completion.

Task Type and Satisfaction Analysis

The Task Type field was binned into different groups (e.g., writing, coding, brainstorming) and analysed for how dissimilar the different types of activities were rated in relation to satisfaction. This assisted in isolating specific tasks in which AI tools were most and least effective. Tasks like **writing and brainstorming** should have recorded higher satisfaction, as AI tools help in structuring content and creating ideas. **Coding tasks**, on the other hand, were examined separately, as these could need more specialised assistance, and the differences in effectiveness of AI tools might be less evident in technical domains.

Visualization

To facilitate the statistical analysis and a better understanding of the intercorrelations of the variables, some visuals were generated: **Bar plots** illustrated the association between AI assistance and satisfaction and between task type and satisfaction. **The interconnectedness of important variables** like "session length," "total prompts," "AI assistance level," and "satisfaction rating" is demonstrated via **heatmaps**. These visualizations allowed for a straightforward interpretation of the data, and revealing important trends and patterns not easily deduced by raw statistical analysis alone.

The approach adopted in this research is successfully able to represent the dynamics of AI tool use in education. This approach, which is reinforced using data-driven insights and statistical analysis, allows the study to effectively approach the research question considering the effects of AI tools on teaching results and lecturer satisfaction. The results add to the discussion on the potential impact of AI in education by advising that the design and implementation of AI agent tools should be improved to better support lecturers in different domains.

RESULT AND ANALYSIS

Satisfaction Rating vs AI Assistance Level

The relative importance of satisfaction and the level of AI support is examined. As Shown in figure 1, there might be more assistance from high AI, in the sense of completing tasks for you, which may in turn entail better results and, possibly, also greater satisfaction.

Lower Assistance (Level 1-2): Lecturers reporting low assistance from the AI may have had lower satisfaction, as there might not have been enough aid provided to assist them in their tasks.

Moderate Assistance (Level 3-4): Satisfaction scores increase with level of assistance indicating that AI tools were quite useful to complete tasks and providing guidance. This result suggests that users would like relatively high support, but not to the full extent as this is less strongly associated with lecturer satisfaction.

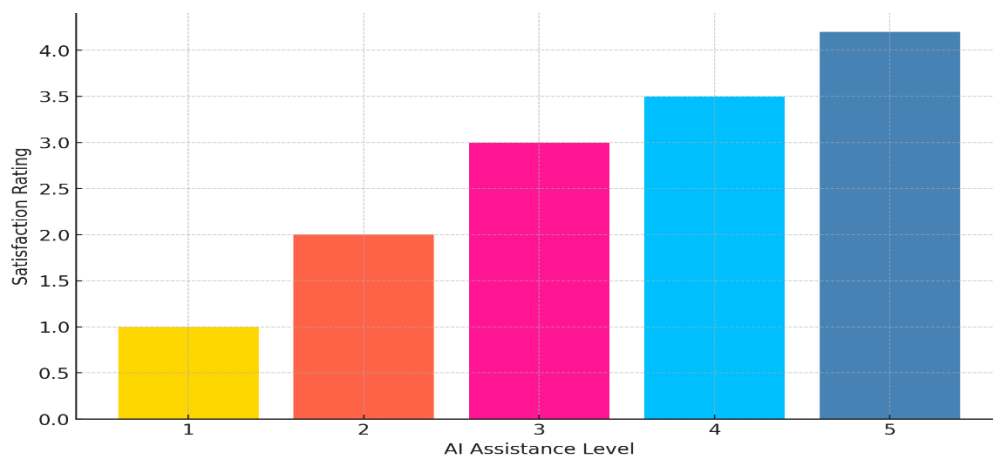


Figure 1: Satisfaction Rating vs AI Assistance Level

Satisfaction Rating vs Task Type

To achieve this goal, we compare satisfaction ratings over different type of tasks that the participants do with AI tools (Figure 2). The aim is to find out whether there are particular types of tasks (eg, coding, writing, brainstorming) that respond better to the use of AI tools.

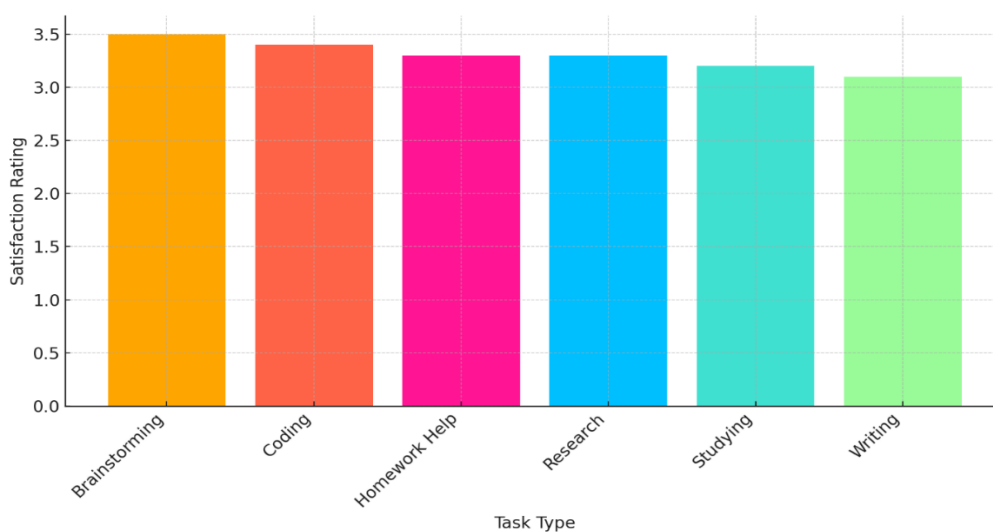


Figure 2: Satisfaction Rating vs Task Type

Writing and Ideation: These 2 works seem to have higher satisfaction levels than others. This is likely because AIs are built to be helpful in generating ideas, creating content, organizing thoughts—all of that is good for when you have to come up with something creative and structured.

Coding Task is Rated Lowest: What is interesting is that it is possible that coding tasks have lower satisfaction compared to writing or brainstorming, potentially implying AI tools are not as adept at aiding complex, logical type or highly technical tasks like programming. It could also be indicative that instructors struggle with the technical aspects of AI tools in the coding context.

Conclusion: Task-specific AI systems should be further tailored to better serve the diverse needs of different tasks, for example difficult tasks such as coding.

AI Assistance Level vs Final Outcome

This heat map shows the relation between the amount of AI help and the result as shown in (assignment completion, idea drafting, etc.). The goal is to see if the higher level of help from AI provides a better task result.

Higher AI Assistance: For most outcomes, more AI assistance leads to more likely successful tasks (e.g., “Assignment Completed”). That being said, when the AI tools offer more guidance or support, lecturers’ ability to achieve desired outcomes is higher.

Moderate Assistance: The middle level shows mixed results tasks are more likely successful compared to the least-assistance level, but less likely for the highest level of assistance. This may mean that while friendly AI is useful, it is not sufficient for challenging tasks.

Low Assistance: At minimum AI assistance, the task completion rate appears to plummet. This could potentially indicate that AI tools may not be providing adequate assistance in these instances, or to be applied in it at all, and hence may be failing to produce a satisfactory or effective result.

Conclusion: The greater the support provided by AI, the more likely task success will be achieved. This indicates that AI tools must offer a lot of context-specific assistance in order to succeed.

Correlation Matrix

This matrix reveals the strength and direction of relationships between four critical numeric variables (Figure 3): **Session Length**, **Total Prompts**, **AI Assistance Level**, and **Satisfaction Rating**.

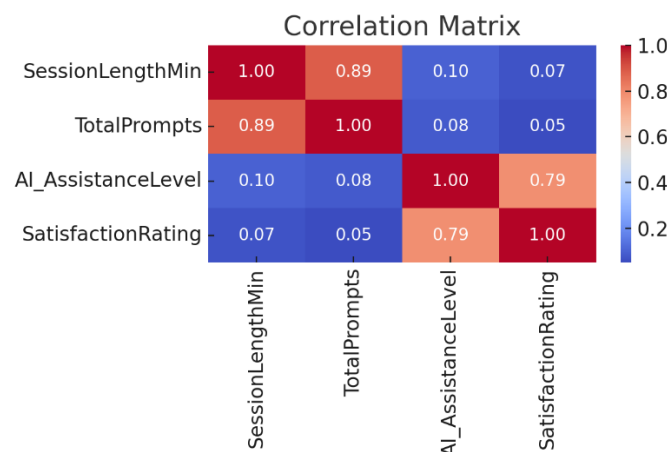


Figure 3: Correlation Matrix Between Four Critical Numeric Variables

Session Length vs Total Prompts: This is likely positively correlated, ie., long sessions have more prompts. It seems logical, since lecturers would interact with AI tools more in longer sessions, creating more queries or inputs

Session Duration and Satisfaction: There may be a weak/moderate positive correlation, with longer sessions leading to greater satisfaction. But this relationship is perhaps weak enough to have other factors (e.g., level of AI assistance) dominate the effect on lecturer satisfaction, meaning sometimes session length will relate positively to satisfaction, sometimes not.

AI Assistance Level x Satisfaction Rating: There should be moderate to strong positive correlation, which supports the observed fact that the higher the assistance lecturers receive, the more satisfied they are. This underscores the value of having an AI assistant that effectively supports task work.

AI Assistance Level vs Total Prompts: There might be a positive correlation between how much users are being assisted by the AI and the number of prompts; more assistance would generally mean more necessary user inputs, clarification, or handholding. This implies that lecturers are engaging more with the AI at points where they are requiring a greater degree of support.

Conclusion: The matrix highlights that high satisfaction is related to longer sessions, more prompts, and high AI support. Furthermore, it points out that AI tools need to optimize the interplay between session length and user input, to provide lecturers with enough support, but not more help than they can cope with.

Summary of Findings

AI tools are more efficient if they offer a high level of assistance, which not only affects output quality but also the lecturer's satisfaction. Certain activities, such as writing and brainstorming, show more positive results when AI tools are used, while others, such as coding, potentially require more focused support.

There seems to be a positive relationship between longer sessions and higher AI assistance in general and satisfaction, but also moderate AI assistance can enhance usability. Explanation of the Content The knowledge of task types and the adaptation of AI-tools to them is the basis for optimizing the effectiveness of AI-tools in academic contexts. These results shed the light on how AI-based teaching and learning tools can be exploited efficiently for these applications. learning in academic environments

CONCLUSION

In sum, adequate application of AI tools in the classroom gives direct support for improving task outcomes and satisfaction of the professors and learners. These data indicate that for their use to be most effective, AI tools should be speaking to facilitate the range of activities required, offering substantial support where necessary, particularly in domains that are more challenging. The results also emphasize the importance of ongoing AI supporting tool development to fill gaps in the system functionality, e.g., in the context of coding, and to enhance the user experience for lecturers from a variety of subject disciplines.

ACKNOWLEDGEMENT

The authors would like to extend their deepest appreciation to Politeknik Nilai, the Department of Polytechnic and Community College Education (JPPKK), and the Ministry of Higher

Education Malaysia for their continuous support and provision of facilities throughout this study. Special thanks are also due to the Public Service Department (JPA) for the AICE Scholarship Program, which enabled academic enrichment and research capacity building, and to TvetPreneur Group (M) Sdn. Bhd. for providing valuable industry-based AI training opportunities that enriched the practical dimensions of this research. The authors are also grateful to fellow lecturers and respondents who generously contributed their time, experiences, and insights during data collection. Their contributions were invaluable in ensuring the successful completion of this research.

REFERENCES

- Abdullah, Z., & Mohamad Said, M. N. H. (2025). AI-Enhanced Teacher Support: Empowering Educators to Achieve More. In *A Practical Guide to Artificial Intelligence in Higher Education: Innovation and Applications* (pp. 89-97). Cham: Springer Nature Switzerland.
- Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial Intelligence in Education: Promises and Implications for Teaching and Learning*. Center for Curriculum Redesign.
- Lin, H. (2022). Influences of Artificial Intelligence in Education on Teaching Effectiveness: The Mediating Effect of teachers' perceptions of educational technology. *International Journal of Emerging Technologies in Learning (Online)*, 17(24), 144.
- Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence Unleashed: An Argument for AI in Education*. Pearson Education.
- Martin, F., Zhuang, M., & Schaefer, D. (2024). Systematic Review of Research on Artificial Intelligence in K-12 Education (2017–2022). *Computers and Education: Artificial Intelligence*, 6, 100195.
- Selwyn, N. (2019). *Should Robots Replace Teachers? AI and the Future of Education*. Polity Press.
- Singh, S. V., & Hiran, K. K. (2022). The Impact of AI on Teaching and Learning in Higher Education Technology. *Journal of Higher Education Theory & Practice*, 12(13).
- Woolf, B. P. (2010). *Building Intelligent Interactive Tutors: Student-centered Strategies for Revolutionizing e-learning*. Elsevier.

KETERANGAN BERKENAAN PENULIS

Faraziah Hassan

Ketua Pusat Pengajian Asasi
Politeknik Nilai, Kompleks Pendidikan Nilai,
Bandar Enstek, 71760 Labu,
Negeri Sembilan, Malaysia
faraziah@polinilai.edu.my

Nur Hidayah Khalid

Ketua Pusat Instruksional & Pembelajaran Digital
Politeknik Nilai, Kompleks Pendidikan Nilai,
Bandar Enstek, 71760 Labu,
Negeri Sembilan, Malaysia
hidayah.khalid@polinilai.edu.my

Ahmad Razimi Mat Lazim

Ketua Unit Penyelidikan, Inovasi & Pengkomersialan
Politeknik Nilai, Kompleks Pendidikan Nilai,
Bandar Enstek, 71760 Labu,
Negeri Sembilan, Malaysia
arazimi@polinilai.edu.my



DEVELOPMENT AND CHARACTERIZATION OF BIOPLASTICS FROM TAPIOCA PEEL STARCH REINFORCED WITH PINEAPPLE LEAF FIBER *PEMBANGUNAN DAN PENCIRIAN BIOPLASTIK DARIPADA KANJI KULIT UBI KAYU DIPERKUATKAN DENGAN SERAT DAUN NANAS*

Fauziah Shaheen Sheh Rahman^{1a*}

^aPoliteknik Nilai

shaheen@polinilai.edu.my

*Corresponding author

ABSTRACT

With growing concerns over plastic pollution, researchers are increasingly turning to natural and biodegradable materials as sustainable alternatives. This study investigates the development of bioplastics from tapioca peel starch reinforced with pineapple leaf fiber (PALF) at varying concentrations (0%, 4%, 8%, 12%, and 16%). The films were produced by casting methods and evaluated for their strength, water resistance, and biodegradability. The results showed that adding PALF significantly enhanced the mechanical properties, with tensile strength increasing from 0.004 ± 0.002 MPa at 0% PALF to 0.029 ± 0.005 MPa at 16% PALF. As PALF content increased, water absorption also increased from 45.20% to 58.87%, while water solubility decreased from 60.07% to 41.60%, suggesting better resistance to moisture. In soil burial tests, all films degraded completely within 12 days. In conclusion, these findings highlight PALF as an effective natural reinforcement that not only improved the performance of starch-based bioplastics but also hold promising potential for future application as an environmentally friendly and sustainable material for single-use products such as packaging.

Keywords: Bioplastics, Tapioca Peel Starch, Pineapple Leaf Fiber, Mechanical Properties, Biodegradability

ABSTRAK

Dengan kebimbangan yang semakin meningkat terhadap pencemaran plastik, para penyelidik semakin memberi tumpuan kepada bahan semula jadi dan boleh terbiodegradasi sebagai alternatif mampan. Kajian ini mengkaji pembangunan bioplastik daripada kanji kulit ubi kayu yang diperkuatkan dengan serat daun nanas (PALF) pada formulasi berbeza (0%, 4%, 8%, 12% dan 16%). Filem dihasilkan melalui kaedah tuangan dan dinilai dari segi kekuatan, ketahanan air serta biodegradasi. Keputusan menunjukkan bahawa penambahan PALF meningkatkan sifat mekanik dengan signifikan, di mana kekuatan tegangan meningkat daripada 0.004 ± 0.002 MPa pada 0% PALF kepada 0.029 ± 0.005 MPa pada 16% PALF. Apabila kandungan PALF meningkat, penyerapan air turut meningkat daripada 45.20% kepada 58.87%, manakala keterlarutan air menurun daripada 60.07% kepada 41.60%, menunjukkan rintangan kelembapan yang lebih baik. Dalam ujian penimbunan tanah, semua filem terurai sepenuhnya dalam tempoh 12 hari. Kesimpulannya, dapatan ini menonjolkan PALF sebagai bahan penguat semula jadi yang berkesan yang bukan sahaja meningkatkan prestasi bioplastik berasaskan kanji, malah mempunyai potensi aplikasi masa hadapan sebagai bahan mesra alam dan mampan untuk produk sekali guna seperti pembungkusan.

Kata Kunci: Bioplastik, Kanji Ubi Kayu, Serat Daun Nenas, Ciri Mekanikal, Terbiodegradasi

INTRODUCTION

Plastics, mainly sourced from crude oil and gas, have become an integral part of modern life and are widely used for packaging due to their advantageous properties such as lightweight, low cost, chemical inertness, non-permeability, and long shelf life (Olagundoye & Morayo, 2022; Chalannavar et al., 2025). However, these same characteristics also make plastics highly resistant to degradation, enabling them to persist in the environment for centuries (Dey et al., 2024; Ongayo, & Ulep, 2025). As a result, plastic waste has become a major contributor to both land and marine pollution, with long-lasting impacts on ecosystems and human health (Hossain et al., 2021; Sharma et al., 2023). Furthermore, plastic breakdown has been reported to contribute to ocean acidification (Romera-Castillo et al., 2023).

The scale of the issue is evident in recent projections. According to the OECD (2022), plastic waste generation is expected to nearly triple by 2060, with approximately half of it ending up in landfills and less than 20% being recycled. In Malaysia, it is estimated that up to nine billion tonnes of plastic are used and discarded annually. In 2022, the Solid Waste and Public Cleansing Management Corporation (SWCorp) reported that only 33.16% of the 210,966 tonnes of plastic waste generated was recycled. These figures have positioned Malaysia as the fifth-highest contributor to marine pollution globally, with a per capita plastic usage of approximately 2.29 kilograms per year (Asrol, 2024).

In response to these environmental and economic challenges, there is growing interest in biodegradable alternatives to petroleum-based plastics. Bioplastics derived from renewable plant-based sources offer a more sustainable solution. However, their widespread adoption is constrained by high production costs and relatively poor mechanical properties (Chalannavar et al., 2025). For example, many starch-based bioplastics often exhibit low tensile strength, high moisture sensitivity, and inadequate barrier properties compared to conventional plastics (Pooja & Shashank, 2024; Singh et al., 2024). These shortcomings, however, can be mitigated through the incorporation of agricultural waste materials, which are cost-effective, abundantly available, and environmentally friendly (Jain & Tiwari, 2015; Emadian et al., 2017).

Among such resources, tapioca peel and pineapple leaf fiber (PALF) demonstrate promising potential for bioplastic development. Frequently discarded without proper disposal in local markets, these agro-wastes represent a viable and sustainable raw material for bioplastic production. Tapioca peel is a valuable source of starch, containing approximately 23.2% starch by dry weight, with a high amylopectin-to-amylose ratio (5:1) that facilitates gelatinization and enhances solubility (Fronza et al., 2023). In contrast, PALF is abundant in lignocellulosic fibers, which provide excellent reinforcement properties that improve the strength and durability of starch-based films (Sethupathi et al., 2024). Its chemical composition consists primarily of holocellulose (70–82%), with smaller fractions of lignin (5–12%) and ash (1.1%) (Asim et al., 2015). The utilization of these agro-waste resources not only aligns with the principles of a circular economy but also offers a sustainable strategy to reduce the environmental footprint of conventional plastics in Malaysia.

This study, therefore, aims to develop and characterize bioplastic films derived from tapioca peel starch reinforced with varying concentrations of PALF. The films were evaluated for their tensile strength, water absorption, water solubility, and biodegradability under soil burial conditions.

MATERIALS AND METHODS

Materials

Cassava peels were collected from Kilang Kerepek Mesrinah in Sungai Pelek, Sepang. Pineapple leaves used in this study were provided by Sky Ladder Pineapple Farm in Port Dickson. Laboratory-grade glycerol was used, and the soil for the biodegradability test was collected from a field near the Politeknik Nilai campus.

Preparation of Tapioca Peel Starch

The starch extraction method was adapted from Hasmadi et al. (2021) with slight modifications. Cleaned cassava peels were blended with water in a 1:10 (w/v) ratio, then filtered, and the starch was allowed to sediment for 2 hours. The supernatant was discarded, and the sedimented starch was oven-dried at 80°C for 2 hours. The dried starch was ground into a fine powder and stored in an airtight container.

Extraction of Pineapple Leaf Fiber (PALF)

The extraction of PALF was based on the method by Chaves et al. (2024). Cleaned pineapple leaves were manually scraped using a blunt knife to remove the outer pulp layer. The scraped fibers were soaked in water for 24 hours, sun-dried, and then ground into fine fibers.

Bioplastic Films Preparation

Bioplastic films were prepared by casting technique using a film-forming solution containing 5 g of tapioca peel starch with PALF at varying concentrations (0%, 4%, 8%, 12%, and 16% by weight), 95 mL of distilled water, and 2 mL of glycerol. The mixture was heated at 80°C with constant stirring until gelatinization occurred. The resulting solution was poured into petri dishes and dried in an oven at 40°C for 24 hours. After drying, the films were carefully peeled off and stored in a desiccator prior characterization.

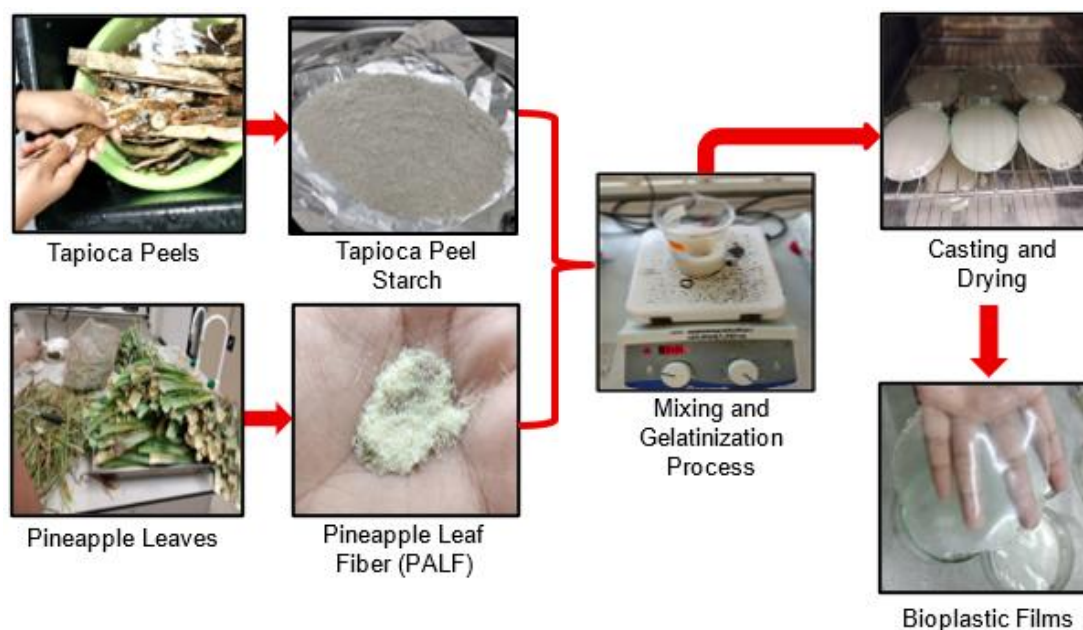


Figure 1: Development of Bioplastic Film from Tapioca Peel Starch and Pineapple Leaf Fiber

Film Characterization

Tensile Strength Test

The tensile strength of bioplastic films was measured according to ASTM (2001) standards using a Stable Micro Systems TA.XTplusC Texture Analyser equipped with Mini Tensile Grips (A/MTG). Bioplastic films from each formulation were cut into square samples (40 mm × 40 mm) and securely clamped between the grips, ensuring proper alignment and uniform load distribution. The test parameters were set as follows: initial separation between grips = 50 mm and crosshead speed = 0.83 mm/s. Each film was stretched until it broke, and the tensile strength (MPa) was calculated by dividing the maximum force (N) by the cross-sectional area (mm²) of the sample. All tests were conducted in triplicate, and the mean values were reported with standard deviation.

Water Absorption and Water Solubility Test

The water absorption capacity of the bioplastic films was evaluated using a modified method adapted from Abed et al. (2024). Bioplastic samples were cut into 2 cm × 2 cm pieces and dried in an oven at 50°C for 30 minutes to eliminate residual moisture. The initial dry weight (W_0) was recorded before immersing the samples in 30 mL of distilled water at room temperature for 24 hours. After soaking, the samples were gently blotted with tissue paper to remove excess surface water and immediately weighed (W_1). The test was repeated in triplicate. The percentage of water absorption was calculated using the following equation:

$$\text{Water Absorption (\%)} = \frac{W_1 - W_0}{W_0} \times 100$$

Where: W_0 = The initial dry weight of bioplastic film (g)

W_1 = The final weight of bioplastic film after water absorbs (g)

The water solubility test was adapted from Oluwasina (2021) with slight modifications. Bioplastic samples (2 cm × 2 cm) were dried in an oven at 105°C for 3 hours. After cooling, the initial dry weight (W_0) was recorded. The samples were then soaked in 40 mL of distilled water under constant shaking at 100 rpm for 24 hours at room temperature. The undissolved portions were recovered using filter paper, dried at 105°C for 3 hours, cooled in a desiccator, and weighed (W_1). The test was repeated in triplicate. The water solubility percentage was calculated using the equation:

$$\text{Water Solubility (\%)} = \frac{W_0 - W_1}{W_0} \times 100$$

Where: W_0 = Initial dry weight (g)

W_1 = Final dry weight after 24-hour water immersion and drying (g)

Biodegradability Test

The biodegradation test was conducted using the soil burial test method, adapted from Putri et al. (2024) with slight modifications. Bioplastic samples (2 cm × 2 cm) were initially weighed (W_i) and buried in soil at a depth of 3 cm. Every two days, the samples were retrieved, gently cleaned with a soft brush, dried at 50°C for 6 hours, and reweighed (W_d), continuing this process until the samples were fully degraded. Physical changes were also observed throughout the testing period. The percentage of biodegradability was calculated using the following equation:

$$\text{Biodegradability (\%)} = \left(\frac{W_i - W_d}{W_i} \right) \times 100$$

Where: W_i = Initial weight of the sample (g)

W_d = Weight of the sample (g) after burial

Statistical Analysis

All tests were performed in triplicate. The data were analysed using Statistical Package for the Social Sciences (SPSS) with one-way ANOVA and Tukey's post hoc test ($p < 0.05$).

Results and Discussion

Tensile Strength Analysis

The tensile strength results of the five bioplastic film formulations are illustrated in Figure 2.

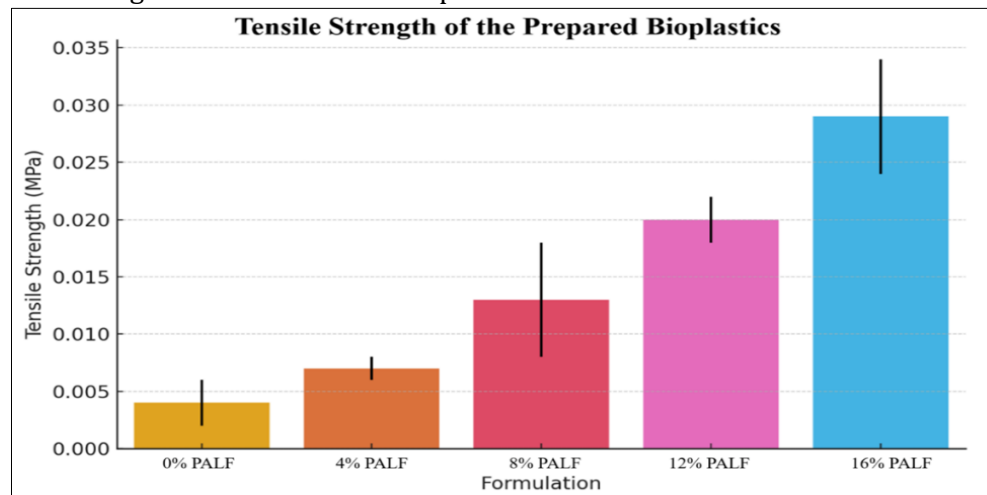


Figure 2: Tensile Strength of the Bioplastic Films

Tensile strength increased significantly with the addition of PALF content. The film with 0% PALF showed the lowest value (0.004 ± 0.002 MPa), whereas the film with 16% exhibited the highest strength (0.029 ± 0.005 MPa). This enhancement is attributed to strong interfacial interactions between the starch matrix and the cellulose-rich PALF, which improved film rigidity (Sethupathi et al., 2024).

Water Absorption and Water Solubility Analysis

The water absorption and water solubility properties of the bioplastic films with varying PALF content are presented in Figure 3, which serve as key indicators of the films' moisture resistance and potential application suitability.

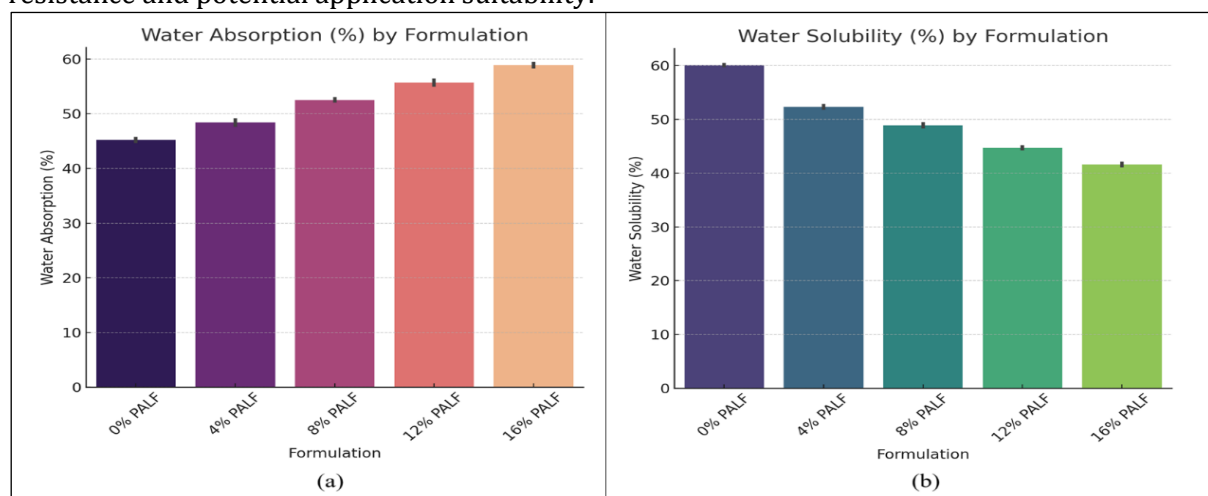


Figure 3: Effect of PALF Content on Water Absorption (%) and Water Solubility (%) of Bioplastic Films

Water absorption increased from 45.20% (0% PALF) to 58.87% (16% PALF), mainly due to the hydrophilic nature of PALF. The cellulose fibers contain hydroxyl groups that readily form hydrogen bonds with water molecules (Reddy & Yang, 2010). In addition, untreated PALF can create micro-gaps in the matrix, which further facilitate water uptake (Sethupathi et al., 2024).

Conversely, water solubility decreased from 60.07% to 41.60% as PALF content increased. This reduction can be attributed to the reinforcement effect of PALF, which restricts the migration of soluble substances and limits polymer chain mobility during water exposure. Hydrogen bonding between PALF and the starch matrix also contributes to a denser, more cohesive structure that resists disintegration.

Overall, these findings indicate that PALF incorporation enhances the films' structural integrity and moisture resistance. The results are consistent with those of Zhou et al. (2016) and Cheng et al. (2019), who reported that lignocellulosic fibers increase water uptake due to their hydrophilic nature while simultaneously reinforcing the polymer matrix against dissolution.

Biodegradability Analysis

As shown in Figure 4, all films were fully degraded by day 12. Lower PALF content (0%) led to faster degradation (complete by day 10), while the film with 16% PALF completed degradation by day 12. The slower degradation rate at higher PALF content may be attributed to the presence of crystalline cellulose and lignin, which are more resistant to microbial breakdown (Kumar et al., 2018). These findings are in line with earlier studies (Lee, You, & Yin, 2021; Smith & Tan, 2019), which similarly reported that increased fiber content reduces water permeability and strengthens the polymer matrix, thereby slowing down microbial breakdown.

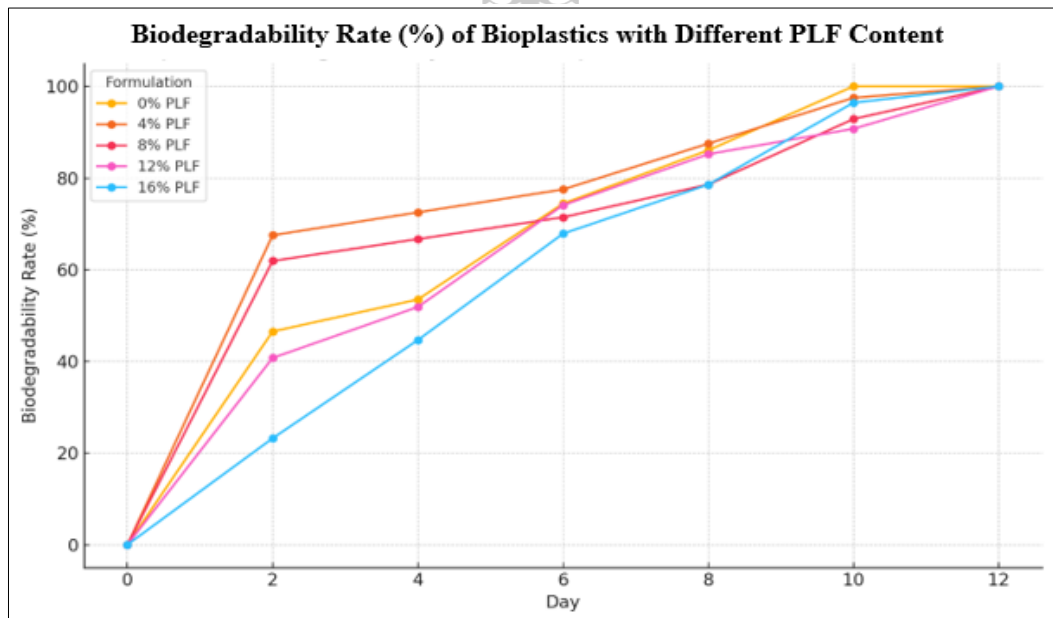


Figure 4: Biodegradability Rate (%) of Bioplastic Films at 2-day Interval

Figure 5 illustrates degradation of the bioplastic films over time, showcasing the loss of compactness and integrity due to microbial activity in soil.

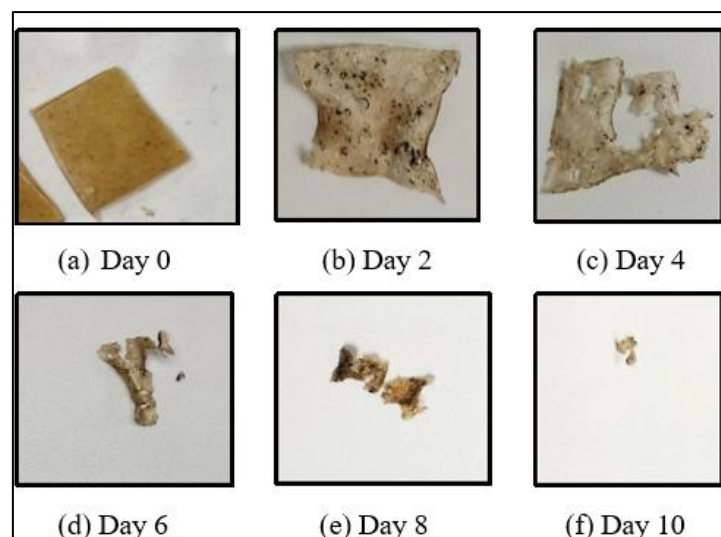


Figure 5: Physical Change in Bioplastic Films on days 0, 2, 4, 6, 8, and 10

At day 0, the films remained intact, smooth, and retained their original appearance. As time progressed, visible signs of degradation such as tears and holes appeared. By day 10 most samples had decomposed significantly, with little to no visible remnants.

CONCLUSIONS AND FUTURE DIRECTION

This study successfully developed biodegradable bioplastic films from tapioca peel starch reinforced with varying concentrations of pineapple leaf fiber (PALF). The addition of PALF significantly enhanced the mechanical strength of the films, with tensile strength increasing from 0.004 ± 0.002 MPa (0% PALF) to 0.029 ± 0.005 MPa (16% PALF). Water absorption increased with fiber content due to the hydrophilic nature of PALF, while water solubility decreased, indicating improved structural integrity. Biodegradability analysis showed that all films completely degraded under soil burial conditions within 12 days, with faster degradation observed in formulations containing lower PALF content. The presence of crystalline cellulose and lignin in PALF likely contributed to the slower degradation rate in formulations with higher fiber content.

These findings highlight the potential of agricultural waste, specifically tapioca peels and pineapple leaves, as sustainable raw materials for the production of environmentally friendly bioplastics with enhanced functional properties. The bioplastic films developed in this study show potential for use in short-term, single-use packaging applications.

Future research should focus on optimizing PALF content, particle size, and surface treatment to further improve the mechanical and barrier properties of the films. Comprehensive characterization techniques such as scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), and thermogravimetric analysis (TGA) are recommended to obtain deeper insights into film morphology and degradation behavior.

ACKNOWLEDGMENT

The authors would like to thank the Department of Agrotechnology and Bio-Industry, Politeknik Nilai, for providing the materials and equipment necessary to complete this research, as well as the students who contributed to the experimental work. Special thanks are

also extended to the Faculty of Science and Technology, Universiti Sains Islam Malaysia (USIM), for providing access to facilities used in the tensile strength testing. These supports are gratefully acknowledged.

REFERENCES

- Abed, E. H., Abdulhay, H. S., & Abbas, A. H. (2024). Assessment of Solubility, Moisture Content, Water Absorption and Thickness of Bioplastic synthesized from Iraqi Amber Rice Husks. *African Journal of Biomedical Research*, 27(3), 1334-1341.
- Asim, M., Abdan, K., Jawaid, M., Nasir, M., Dashtizadeh, Z., Ishak, M. R., & Hoque, M. E. (2015). A Review on Pineapple Leaves Fibre and its Composites. *International Journal of Polymer Science*, 2015(1), 950567.
- Asrol, A. A. (2024, July 9). 9 Bilion Tan Plastik Dibuang Setahun. *Utusan Malaysia*. <https://www.utusan.com.my/nasional/2024/07/9-bilion-tan-plastik-dibuang-setahun/>
- ASTM (American Society for Testing and Material). (2001). *D-882: Standard Test Methods for Tensile Properties of Thin Plastic Sheeting*. In *Annual Book of ASTM Standards*, , p. 162-170. ASTM International.
- Chalannavar, R. K., Divakar, M. S., Malabadi, R. B., Kamble, A. A., Swathi, K. K., Kolkar, K. P., ... & Mammadova, S. S. (2025). Plant Derived Starch for the Production of Biodegradable Plastic. *Global Journal of Engineering and Technology Advances*, 22(03), 202-215.
- Chaves, D. M., Araújo, J. C., Gomes, C. V., Gonçalves, S. P., Fangueiro, R., & Ferreira, D. P. (2024). Extraction, Characterization and Properties Evaluation of Pineapple Leaf Fibers from Azores Pineapple. *Heliyon*, 10(4).
- Cheng, L., Wang, H., & Zhou, J. (2019). Influence of Natural Fiber Content on the Solubility and Mechanical Strength of Biopolymer Films. *Carbohydrate Polymers*, 207, 135-142.
- Dey, S., Veerendra, G. T. N., Babu, P. A., Manoj, A. P., & Nagarjuna, K. (2024). Degradation of Plastics Waste and its Effects on Biological Ecosystems: A Scientific Analysis and Comprehensive Review. *Biomedical Materials & Devices*, 2(1), 70-112.
- Emadian, S. M., Onay, T. T., Demirel, B. (2019). Biodegradation of Bioplastics in Natural Environments. *Waste Management*, 2019, vol. 59, pp. 526-536. ISSN: 0956-053X.
- Fronza, P., Costa, A. L. R., Franca, A. S., & de Oliveira, L. S. (2023). Extraction and Characterization of Starch from Cassava Peels. *Starch-Stärke*, 75(3-4), 2100245.
- Hasmedi, M. Z., Ahmad, N., & Mansor, S. A. (2021). Extraction of Starch from Cassava Peel for Biodegradable Plastic Production. *International Journal of Bioprocessing & Biotech*, 7(3), 89-96. <https://doi.org/10.1016/j.ijbb.2021.06.015>
- Hossain, S., Rahman, M. A., Chowdhury, M. A., & Mohonta, S. K. (2021). Plastic Pollution in Bangladesh: A Review on Current Status Emphasizing the Impacts on Environment and Public Health. *Environmental Engineering Research*, 26(6).
- Jain, R., & Tiwari, A. (2015). Biosynthesis of Planet Friendly Bioplastics using Renewable Carbon Source. *Journal of Environmental Health Science and Engineering*, 13, 1-5.
- Kumar, V., Singh, P., & Shukla, R. (2018). Effect of Natural Fiber Incorporation on Biodegradability of Polymer Composites. *Journal of Polymers and the Environment*, 26(4), 1650-1659. <https://doi.org/10.1007/s10924-017-1076-3>
- Lee, K. Y., You, Y., & Yin, H. (2021). Influence of Fiber Reinforcement on Soil Burial Biodegradation of Starch-Based Composite Films. *International Journal of Biological Macromolecules*, 174, 453-461.
- OECD. (2022). *Global plastics outlook: Policy scenarios to 2060*. Organisation for Economic Co-Operation and Development. https://www.oecd.org/en/publications/global-plastics-outlook_aa1edf33-en.html
- Olagundoye, A. A., & Morayo, A. O. (2022). Characterization of Potato Peel Starch-Based Bioplastic Reinforced with Banana Pseudostem Cellulose for Packaging Applications. *Int J Innov Sci Res Technol*, 7(4), 1360-1371.

- Oluwasina, O. O., Akinyele, B. P., Olusegun, S. J., Oluwasina, O. O., & Mohallem, N. D. (2021). Evaluation of the Effects of Additives on the Properties of Starch-based Bioplastic film. *SN Applied Sciences*, 3, 1-12.
- Ongayo, G. D., & Ulep, A. L. (2025). Development and Characterization of Eco-Friendly Bioplastics from Saba (*Musa acuminata* x *balbisiana*) Peel Starch Reinforced with Alkali-treated Pineapple Leaf Fiber (PALF). *Mindanao Journal of Science and Technology*, 23(1), 227-247.
- Pooja, N., & Shashank, S. (2024). Advancing Sustainable Bioplastics: Chemical and Physical Modification of Starch Films for Enhanced Thermal and Barrier Properties. *RSC advances*, 14(33), 23943-23951.
- Putri, F. A., Rianjanu, A., & Sipahutar, W. S. (2024). Cellulose Impact on Bioplastic Performance: A Study on Mechanical Strength, Physical Properties, and Degradation of Water Hyacinth and Kepok Banana Peel-Derived Materials. *Jurnal Teori dan Aplikasi Fisika*, 12(02).
- Reddy, N., & Yang, Y. (2010). Citric Acid Cross-linking of Starch Films. *Food Chemistry*, 118(3), 702–711. <https://doi.org/10.1016/j.foodchem.2009.05.050>
- Romera-Castillo, C., Briones-Rizo, M., Calvo, E., Lucas, A., & Pelejero, C. (2023). Abiotic Plastic Leaching Contributes to Ocean Acidification. *Science of the Total Environment*, 858, 158683. <https://doi.org/10.1016/j.scitotenv.2022.158683>
- Sethupathi, M., Khumalo, M. V., Skosana, S. J., & Muniyasamy, S. (2024). Recent Developments of Pineapple Leaf Fiber (PALF) Utilization in the Polymer Composites—A Review. *Separations*, 11(8), 245.
- Sharma, S., Sharma, V., & Chatterjee, S. (2023). Contribution of Plastic and Microplastic to Global Climate Change and Their Conjoining Impacts on The Environment-A Review. *Science of the Total Environment*, 875, 162627.
- Singh, P., Pandey, V. K., Singh, R., Singh, K., Dash, K. K., & Malik, S. (2024). Unveiling the Potential of Starch-blended Biodegradable Polymers for Substantializing the Eco-friendly Innovations. *Journal of Agriculture and Food Research*, 15, 101065.
- Smith, J. P., & Tan, C. (2019). Effect of fiber loading on the biodegradation rate of biocomposite films. *Composites Science and Technology*, 177, 56–63.
- Zhou, Y., Fan, M., & Chen, L. (2016). Interface and Bonding Mechanisms of Plant Fibre Composites: An Overview. *Composites Part B: Engineering*, 101, 31–45. <https://doi.org/10.1016/j.compositesb.2016.06.055>

KETERANGAN BERKENAAN PENULIS

Fauziah Shaheen Sheh Rahman

Politeknik Nilai, Jabatan Agroteknologi dan Bio-Industri,
Kompleks Pendidikan Bandar Enstek,
71760 Bandar Enstek, Negeri Sembilan, Malaysia.
shaheen@polinilai.edu.my

**A SMART-DRIVEN APPROACH TO SUSTAINABLE ENERGY
MANAGEMENT IN MALAYSIAN HIGHER EDUCATION: THE CASE OF
POLITEKNIK NILAI**
***PENDEKATAN SMART DALAM PENGURUSAN TENAGA LESTARI DI
INSTITUSI PENGAJIAN TINGGI MALAYSIA: KAJIAN KES DI POLITEKNIK
NILAI***

Noor Azlina Ahmad^{1a*}, Muhd Abu Bakar Muhd Radzi^{2b} & Hamrin Abu Hasan^{3c}

^aPoliteknik Nilai, Malaysia

^bKolej Komuniti Masjid Tanah, Malaysia

^cPoliteknik Port Dickson, Malaysia

azlina_ahmad@polinilai.edu.my, abubakar@kkmt.edu.my & hamrin@polipd.edu.my

*Corresponding author

ABSTRACT

This paper proposes the implementation of a Sustainable Energy Management System (SEMS) at Politeknik Nilai Negeri Sembilan (PNS) to improve institutional energy efficiency and support national sustainability objectives. The project targets a 10% reduction in energy consumption and aims to achieve the 3-Star Energy Management Gold Standard (EMGS) certification by the end of 2028. The initiative includes obtaining administrative approval, developing a five-year implementation roadmap, and appointing the Malaysian Green Technology and Climate Change Corporation (MGTC) for compliance auditing. An initial assessment using the Energy Management Matrix indicated the need for improvement across all key areas of energy management at PNS. However, the institution demonstrates foundational readiness to achieve EMGS through structured planning and the implementation of targeted energy conservation strategies. A gap analysis was conducted to identify deficiencies and guide the design of the SEMS framework. The proposed SEMS initiative is aligned with the SMART target framework: Specific goals, Measurable performance using the Energy Efficiency Index (EEI), Achievable outcomes based on successful benchmarks from Universiti Teknologi Malaysia, Realistic resource allocation, and a Time-bound execution plan. The successful implementation of SEMS at PNS is expected to yield measurable reductions in energy use and operational costs while positioning the institution as a model for sustainable practices in Malaysia's higher **education sector**.

Keywords: Sustainable Energy Management, Energy Efficiency, Energy Management Matrix, Higher Education

ABSTRAK

Kertas penyelidikan ini mencadangkan pelaksanaan Sistem Pengurusan Tenaga Lestari (SEMS) di Politeknik Nilai Negeri Sembilan (PNS) bagi meningkatkan kecekapan tenaga institusi serta menyokong objektif kelestarian nasional. Projek ini menyasarkan pengurangan penggunaan tenaga sebanyak 10% dan berhasrat mencapai pensijilan Energy Management Gold Standard (EMGS) 3-Bintang menjelang akhir tahun 2028. Inisiatif ini merangkumi mendapatkan kelulusan pentadbiran, membangunkan pelan pelaksanaan lima tahun, serta melantik Malaysian Green Technology and Climate Change Corporation (MGTC) sebagai pihak audit pematuhan. Penilaian awal menggunakan Matriks Pengurusan Tenaga menunjukkan keperluan penambahbaikan dalam semua bidang utama pengurusan tenaga di PNS. Walau bagaimanapun, institusi ini menunjukkan tahap kesiapsiagaan asas untuk mencapai EMGS melalui perancangan yang

berstruktur serta pelaksanaan strategi penjimatan tenaga yang disasarkan. Analisis jurang turut dijalankan bagi mengenal pasti kekurangan dan membimbing reka bentuk kerangka SEMS. Inisiatif SEMS yang dicadangkan ini sejajar dengan kerangka sasaran SMART: matlamat Spesifik, prestasi Boleh Diukur melalui Indeks Kecekapan Tenaga (Energy Efficiency Index, EEI), hasil Boleh Dicapai berdasarkan penanda aras kejayaan di Universiti Teknologi Malaysia, peruntukan sumber yang Realistik, serta pelan pelaksanaan yang mengikut garis masa. Pelaksanaan SEMS di PNS dijangka membawa pengurangan yang boleh diukur dalam penggunaan tenaga dan kos operasi, sekali gus meletakkan institusi ini sebagai model amalan lestari dalam Sektor Pendidikan Tinggi di Malaysia.

Kata Kunci: *Pengurusan Tenaga Lestari, Kecekapan Tenaga, Matriks Pengurusan Tenaga, Pendidikan Tinggi*

INTRODUCTION

In line with the government's policy to reduce carbon emissions by 40% in 2020 and by 45% by 2030 (compared to 2005 levels), PNS shall take the lead in energy conservation activities by implementing the Sustainable Energy Management System (SEMS). The aim is to reduce electricity consumption through activities and programs that promote and regulate electrical energy efficiency or conservation. Beyond this, PNS also aspires to achieve the prestigious Energy Management Gold Standard (EMGS) certification under the ASEAN Energy Management Scheme (AEMAS). This proactive commitment not only supports Malaysia's environmental agenda but also positions PNS as a pioneer in embedding sustainability practices within higher education institutions. By integrating SEMS with the SMART framework, the institution seeks to demonstrate how strategic planning, continuous monitoring, and stakeholder engagement can translate into tangible energy savings, reduced operational costs, and long-term institutional resilience.



PROBLEM STATEMENT

The rising cost of energy consumption and the urgent need to address environmental sustainability have placed increasing pressure on higher education institutions in Malaysia to adopt more efficient energy management practices. Despite the national commitment to sustainable development, many public institutions, including PNS, have yet to implement a comprehensive and measurable energy management framework.

An initial assessment using the Energy Management Matrix revealed significant gaps in key areas such as policy enforcement, energy monitoring, staff training, and long-term strategic planning. These deficiencies highlight a lack of structured systems that integrate sustainability goals with institutional energy operations. Without a systematic approach, institutions risk continued energy inefficiency, higher operational costs, and missed opportunities to contribute meaningfully to Malaysia's environmental agenda.

RESEARCH OBJECTIVES

This study aims to:

Analyze the current state of energy management at PNS using the Energy Management Matrix to identify gaps and areas requiring improvement.

Develop a Sustainable Energy Management System (SEMS) framework based on SMART principles—Specific, Measurable, Achievable, Realistic, and Time-bound—to enhance institutional energy efficiency.

LITERATURE

This chapter reviews relevant literature on sustainable energy management practices in higher education, the design and application of Sustainable Energy Management Systems (SEMS), the SMART framework, and institutional benchmarking such as the Energy Management Gold Standard (EMGS). These studies provide theoretical and empirical grounding for the implementation of a SMART-driven SEMS at PNS.

Higher education institutions (HEIs) are significant energy consumers due to the size and complexity of their campuses. Studies show that despite growing environmental awareness, many HEIs lack effective policies for energy monitoring and conservation (Goh & Tan, 2021). Integration of sustainable energy strategies not only reduces operational costs but also enhances institutional reputation and compliance with national environmental goals (Mohamad et al., 2020).

In Malaysia, efforts to incorporate sustainability in campus operations are guided by the **Green Campus Initiative** and the **Higher Education Blueprint (2015–2025)**, which encourage energy audits and environmental reporting. However, implementation remains inconsistent, often due to lack of technical expertise, funding, and institutional commitment (Rahman et al., 2019).

A SEMS provides a structured approach to monitor, control, and improve energy performance. It typically includes policy formulation, energy audits, training programs, and regular evaluation (ISO 50001, 2018). According to Ahmad et al. (2022), the success of a SEMS depends heavily on leadership support, integrated data systems, and continuous capacity building among facility managers and staff.

The SMART framework—Specific, Measurable, Achievable, Realistic, and Time-bound—is widely used in project and energy management to set clear and actionable goals. In the context of energy efficiency, SMART principles help institutions prioritize interventions, set key performance indicators (KPIs), and track progress effectively (Zhou & Park, 2021). Implementing SMART targets in energy management has been associated with better stakeholder engagement and stronger accountability mechanisms (Lee et al., 2020). For example, setting a 10% reduction goal in energy use over five years provides both a realistic and measurable path forward that aligns with financial planning and infrastructure upgrades.

RESEARCH METHODOLOGY

The methodology is grounded in a qualitative case study design and involves document analysis, gap assessment using the Energy Management Matrix, and benchmarking with best practices from similar institutions. This approach aligns with Yin's (2018) assertion that case studies are effective for understanding complex phenomena within real-life contexts.

Research Design

A qualitative case study design was adopted for this study to explore the institutional context and develop a framework that addresses specific energy management challenges at Politeknik Nilai. Case studies are particularly suitable for applied research aiming to produce practical solutions for organizational improvement (Annamalah, 2024). The case study approach allowed for in-depth examination of energy consumption practices, institutional capacity, and administrative readiness, with data triangulated through interviews, document analysis, and observations to enhance validity (Schlunegger et al., 2024; Jones-Hooker, 2023).

Level	Energy policy	Organisation	Motivation	Information system	Marketing	Investment
4	Energy policy, action plan and regular review, have commitment of top management as part of an environmental strategy	Energy management has been fully integrated into management structure. Clear delegation of responsibility for energy consumption	Formal and informal channels of communication regularly exploited by energy manager and energy staff at all levels	Comprehensive system sets targets, monitors consumption, identified faults, quantifies savings and provides budget tracking	Marketing the value of energy efficiency and the performance of energy management both within and outside the organization	Positive discrimination in favor of green schemes with detailed investment appraisal of all new build and refurbishment opportunities
3	Formal energy policy, but no active commitment from top management	Energy manager accountable to energy committee representing all users, chaired by a member of the managing board	Energy committee used as main channel together with direct contact with major users	M&T reports for individual premises based on sub-metering but savings not reported effectively to users	Program of staff awareness and regular publicity campaigns	Same payback criteria employed as for all other investment
2	Unadopted energy policy set by energy manager or senior department manager	Energy manager in post, reporting to ad-hoc committee but line management and authority are unclear	Contact with major users through ad-hoc committee chaired by senior department manager	Monitoring and targeting report based on supply meter data. Energy unit has ad-hoc involvement in budget setting	Some ad-hoc staff awareness training	Investment using short term payback criteria only
1	An unwritten set of guidelines	Energy management is the part-time responsibility of someone with only limited authority or influence	Informal contacts between engineer and a few users	Cost reporting based on invoice data. Engineer compiles reports for internal use within technical department	Informal contacts used to promote energy efficiency	Only low measures taken
0	No explicit policy	No energy management or any formal delegation of responsibility for energy consumption	No contact with users	No information system. No accounting for energy consumption	No promotion of energy efficiency	No investment in increasing energy efficiency in premises

Figure 1: Energy Commission. (2024). Sample of Energy Management Matrix for Self-Evaluation.

Data Collection Methods

Data for this study were collected using three main techniques. First, **document analysis** was conducted to examine institutional records such as utility bills, building layout plans, energy audit reports, and policy statements. This method helped establish a baseline understanding of Politeknik Nilai's current energy practices (Bowen, 2009). Second, the **Energy Management Matrix** developed by the Carbon Trust (2005) was utilized to assess energy management performance across six key domains: policy, organization, training, performance measurement, communication, and investment. This structured tool enabled a systematic gap analysis to identify areas requiring improvement. Additional insights were drawn from ISO 50001:2018 guidelines and resources published by the Malaysian Green Technology and Climate Change Corporation (MGTC, 2023), which provided technical benchmarks and certification criteria relevant to the study.

RESULT AND DISCUSSIONS

The energy matrix is used to provide a quick high-level assessment of strengths and weaknesses across six areas of energy management. This method is used to analyze the readiness of an

organization for the implementation of SEMS. Figure 2 illustrates the current situation of PNS. The result will be used to formulate methodology to set up energy management system at PNS. Figure 2 shows the Energy Management Matrix evaluation at PNS. The Energy Management Matrix shows the current and expected practice at PNS.

LEVEL	POLICY AND SYSTEMS	ORGANIZATION	MOTIVATION	INFORMATION SYSTEMS	TRAINING AND AWARENESS	INVESTMENT
4	Formal energy / environmental policy and management system, action plan and regular review with commitment of senior management or part of corporate strategy.	Energy / environmental management fully integrated into management structure. Clear delegation of responsibility for energy use.	Formal and informal channels of communication regularly exploited by energy / environmental manager and staff at all levels	Comprehensive system sets targets, monitors materials and energy consumption and wastes and emissions, identifies faults, quantifies costs and savings and provides budget tracking	Marketing the value of material and energy efficiency and the performance of energy / environmental management both within the organisation and outside it.	Positive discrimination in favour of energy / environmental schemes with de investment appraisal new build and plant improvement opportunities
3	Formal energy / environmental policy, but no formal management system, and with no active commitment from top management	Energy / environmental manager accountable to energy committee, chaired by a member of the management board	Energy / environmental committee used as main channel together with direct contact with major users	Monitoring and targeting reports for individual premises based on sub-metering / monitoring, but savings not reported effectively to users	Programme of staff training, awareness and regular publicity campaigns	Same pay back criteria as for all other investments. Cursory appraisal of new build and plant improvement opportunities.
2	Unadopted / informal energy / environmental policy set by energy / environmental manager or senior departmental manager	Energy / environmental manager in post, reporting to ad-hoc committee but line management and authority are unclear	Contact with major users through ad-hoc committee chaired by senior departmental manager	Monitoring and targeting reports based on supply meter / measurement data and invoices. Env. / energy staff have ad-hoc involvement in budget setting.	Some ad hoc staff awareness and training	Investment using short term pay back criteria mostly
1	An unwritten set of guidelines	Energy / environmental management the part-time responsibility of someone with only limited influence or authority	Informal contacts between engineer and a few users	Cost reporting based on invoice data. Engineer compiles reports for internal use within technical department	Informal contacts used to promote energy efficiency and resource conservation	Only low cost measures taken
0	No explicit policy	No energy / environmental manager or any formal delegation of responsibility for env / energy use.	No contact with users	No information system. No accounting for materials and energy consumption and waste	No awareness raising of energy efficiency and resource conservation	No investment in increasing environmental performance / energy efficiency in premises

Figure 2: Energy Management Matrix Evaluation at PNS

The proposed Sustainable Energy Management System (SEMS) Framework shown in Figure 3 is guided by SMART principles to ensure energy goals are clear, measurable, and achievable. It sets a specific target of reducing energy consumption by 10% by 2028, with progress tracked using the Energy Efficiency Index (EEI). The framework is achievable and realistic, aligning with the institution's capacity and resources, and follows a five-year time-bound roadmap with annual milestones to ensure consistent progress.

Table 1: Proposed SEMS Framework Based on SMART Principles

SMART Principle	Component	SEMS Framework Application at Politeknik Nilai
Specific	Clear Goals	Reduce total institutional energy consumption by 10% by the year 2028.
Measurable	Key Performance Indicators (KPIs)	Use the Energy Efficiency Index (EEI) and monthly energy bills to track progress and savings.
Achievable	Feasibility and Capacity	Align targets with institutional capabilities, existing infrastructure, and trained personnel.
Realistic	Institutional Readiness	Integrate energy-saving goals into current administrative practices and campus operations.
Time-bound	Implementation Timeline	Develop and execute a 5-year roadmap (2024– 2028) with annual milestones and review checkpoints.

CONCLUSION

This study proposed the development and implementation of a Sustainable Energy Management System (SEMS) at Politeknik Nilai, guided by the SMART framework. The initial assessment using the Energy Management Matrix revealed substantial gaps in existing energy practices, particularly in areas of policy, staff involvement, and long-term energy planning.

To address these gaps, the study developed a SEMS framework with the following SMART components: Specific energy reduction goals, Measurable indicators via the Energy Efficiency Index (EEI), Achievable targets based on institutional benchmarking, Realistic resource allocation, and a Time-bound roadmap spanning five years. The SEMS is designed to reduce energy consumption by 10% and position the institution for the 3-Star Energy Management Gold Standard (EMGS) certification by 2028.

This study also evaluated Politeknik Nilai's institutional readiness for SEMS implementation and provided strategic recommendations that align with national sustainability targets. The proposed approach serves as a model for similar institutions seeking to institutionalize energy conservation in a structured and measurable manner.

Contributions of the Study

This research makes several significant contributions to the field of sustainable energy management in higher education. From a theoretical perspective, the study integrates the SMART goal-setting framework with energy management practices, offering a conceptual foundation that links institutional sustainability planning with measurable energy outcomes. This integration provides a structured approach for setting and evaluating energy efficiency goals in alignment with academic operational realities.

Practically, the study introduces a replicable model of the Sustainable Energy Management System (SEMS) tailored for higher education institutions, particularly for technical and vocational institutions such as polytechnics. This model offers actionable guidance on reducing operational costs and advancing sustainability efforts. It includes clear steps for implementation, encompassing stakeholder engagement, policy development, and alignment with national certification frameworks.

From a policy and strategic planning standpoint, the research contributes to the ongoing discourse on how institutions of higher learning can assume leadership roles in climate action and energy efficiency. By aligning the SEMS framework with the Energy Management Gold Standard (EMGS) and the United Nations Sustainable Development Goals (SDGs), the study underscores the potential of higher education institutions to support Malaysia's national environmental agenda and global sustainability targets.

Implications and Direction for Future Research

This study carries several important implications for institutional governance, financial sustainability, and national climate commitments. At the governance level, the Sustainable Energy Management System (SEMS) framework highlights the necessity of embedding energy management within institutional policies, administrative routines, and campus culture. By doing so, higher education institutions can strengthen accountability, ensure compliance with national energy guidelines, and foster a culture of environmental responsibility among staff and students.

From an economic perspective, the SEMS framework demonstrates that systematic monitoring and control of energy consumption can generate significant cost savings, which may then be reinvested into academic development, infrastructure upgrades, or renewable energy initiatives. This aligns with Malaysia's broader sustainable development agenda and SDG targets, especially SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action), positioning higher education institutions as role models in sustainable practice.

The study also emphasizes the strategic role of higher education in advancing national sustainability goals. As centers of innovation and capacity building, institutions like Nilai Polytechnic can lead the transition toward greener campuses and serve as demonstration models for other organizations. Integrating SEMS within higher education not only supports institutional efficiency but also educates future graduates on sustainability values, thereby extending its impact into the workforce and broader society.

For future research, several directions are proposed. First, comparative studies across different polytechnics, universities, and community colleges could provide deeper insights into how SEMS can be contextualized based on institutional size, resources, and readiness levels. Second, longitudinal studies are necessary to evaluate the long-term effectiveness of SEMS, tracking progress in energy reduction, cost savings, and behavioral change over a multi-year horizon. Third, exploring the integration of emerging technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and data analytics can enhance energy monitoring, predictive maintenance, and real-time optimization of energy usage. Fourth, behavioral and cultural research should be conducted to understand how awareness, training, and stakeholder engagement influence the adoption and sustainability of energy-saving practices on campus. Finally, cross-disciplinary collaborations between engineering, management, and social sciences could further enrich SEMS implementation by addressing both the technical and human dimensions of energy management

ACKNOWLEDGEMENT

The authors would like to express their deepest gratitude to Politeknik Nilai, Kolej Komuniti Masjid Tanah, and Politeknik Port Dickson for their continuous support throughout this research. Special appreciation goes to the Director of Politeknik Nilai and the Department of Polytechnic and Community College Education (JPPKK), Ministry of Higher Education Malaysia, for their guidance, encouragement, and institutional support in making this study possible. Special thanks are also extended to the Malaysian Green Technology and Climate Change Corporation (MGTC) and the Energy Commission Malaysia for providing valuable references, guidelines, and technical insights that guided the development of the Sustainable Energy Management System (SEMS) framework. The authors also acknowledge the constructive feedback and encouragement received from colleagues, administrators, and all parties who directly or indirectly contributed to the successful completion of this study

REFERENCES

- Ahmad, N., Radzi, M. A. B. M., & Hasan, H. A. B. (2022). Smart Energy Management in Malaysian Polytechnics: Readiness and Challenges. *Journal of Sustainability in Higher Education*, 23(2), 134–149.
- Bowen, G. A. (2009). Document Analysis as a Qualitative Research Method. *Qualitative Research Journal*, 9(2), 27–40. <https://doi.org/10.3316/QRJ0902027>

- Carbon Trust. (2005). *Energy Management Matrix*. The Carbon Trust. <https://www.carbontrust.com/resources/energy-management-matrix>
- Creswell, J. W., & Poth, C. N. (2018). *Qualitative Inquiry and Research Design: Choosing among Five Approaches* (4th ed.). Sage.
- Energy Commission. (2024, December 30). Guidelines on Energy Management System [GP/ST/No. 46/2024]. Energy Commission, Malaysia.
- Goh, S. C., & Tan, S. M. (2021). Energy Efficiency Initiatives in Higher Education Institutions: A review of Malaysian context. *International Journal of Energy Economics and Policy*, 11(6), 122–130.
- ISO. (2018). *ISO 50001:2018 - Energy Management Systems - Requirements with Guidance for Use*. International Organization for Standardization. <https://www.iso.org/standard/69426.html>
- Kamarudin, M. S., Ismail, A., & Zainal, Z. (2022). Smart Energy Management in Malaysian Universities: A Case Study of UTM. *Journal of Sustainability and Energy*, 11(1), 45–58.
- Lee, K. M., Ahmad, S., & Lim, C. Y. (2020). Stakeholder Engagement and Accountability in Campus Energy Management: A SMART Approach. *Asian Journal of Environment-Behaviour Studies*, 5(14), 89–99.
- Malaysian Green Technology and Climate Change Corporation. (2023). *Energy Management Gold Standard (EMGS): Certification Guidelines*. MGTC.
- Mohamad, N., Salleh, N., & Yusof, R. (2020). Integrating Energy Conservation in Higher Education Campuses: Challenges and benefits. *Malaysian Journal of Sustainable Environment*, 7(1), 12–23.
- Rahman, H. A., Ismail, R., & Che Mat, S. S. (2019). Sustainability Practices in Malaysian Higher Education Institutions. *Pertanika Journal of Social Science and Humanities*, 27(S1), 45–56.
- Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods* (6th ed.). Sage.
- Zhou, H., & Park, C. (2021). Applying SMART Goals in Institutional Sustainability Planning. *Energy Policy and Management Review*, 13(2), 66–78

KETERANGAN BERKENAAN PENULIS

Noor Azlina Ahmad

Ketua Unit Latihan dan Pendidikan Lanjutan
Politeknik Nilai, Jabatan Agroteknologi dan Bio-Industri,
Kompleks Pendidikan Bandar Enstek,
71760 Bandar Enstek, Negeri Sembilan, Malaysia
azlina_ahmad@polinilai.edu.my

Muhd Abu Bakar Muhd Radzi

Ketua Unit Program
Kolej Komuniti Masjid Tanah, Malaysia
Paya Rumput, 78300,
Masjid Tanah, Melaka
abubakar@kkmt.edu.my

Hamrin Abu Hasan

Pensyarah Jabatan Kejuruteraan Elektrik
Politeknik Port Dickson, Malaysia
Km 14, Jalan Pantai, 71050,
Si Rusa, Negeri Sembilan
hamrin@polipd.edu.my

EVALUATION OF THE SUCCESS OF THE ICT AND ELECTRICAL INFRASTRUCTURE UPGRADING PROJECT TO ENHANCE THE QUALITY OF THE LEARNING ENVIRONMENT AT COMMUNITY COLLEGES

PENILAIAN KEBERHASILAN PROJEK MENAIKTARAF INFRASTRUKTUR ICT DAN ELEKTRIK BAGI MENINGKATKAN KUALITI PERSEKITARAN PEMBELAJARAN DI KOLEJ KOMUNITI

Nur Hidayah Khalid^{1a*} & Siti Assila Murtijan^{1a}

^aPoliteknik Nilai, Malaysia

hidayah.khalid@polinilai.edu.my & assila@polinilai.edu.my

*Corresponding author

ABSTRACT

This study aims to evaluate the success level of the project to upgrade ICT network infrastructure and electrical wiring at Community Colleges in Malaysia, as well as to analyse its impact on the quality and stability of the learning environment. This study adopts a descriptive quantitative approach using secondary data analysis obtained from the Outcome Evaluation Reports JPPKK 2024 for output OP4 and OP5. Among the key performance indicators analysed were the number of Cat 6 UTP cable nodes installed (9,838 compared to the target of 8,533), fibre optic lots (22 compared to the target of 19), and the number of Community Colleges with upgraded electrical wiring systems (86 compared to the target of 41). The results showed that the achievements exceeded the targets, with accomplishment rates of 115%, 116%, and 209.8% respectively, due to cost savings that enabled additional implementation. The upgraded ICT infrastructure has provided faster and more stable connectivity, facilitating access to digital learning platforms and college management systems. The improved electrical wiring has also reduced power supply interruptions and equipment damage, creating a safer and more conducive learning environment. These findings confirm that strategic investment in basic infrastructure significantly contributes to the effectiveness and readiness of Community Colleges in supporting digital learning and IR 4.0 technologies.

Keywords: ICT Infrastructure, Electrical Wiring, Community College, Learning Environment, Project Evaluation

ABSTRAK

Kajian ini bertujuan untuk menilai tahap keberhasilan projek menaiktaraf infrastruktur rangkaian ICT dan pendawaian elektrik di Kolej Komuniti di Malaysia serta menganalisis kesannya terhadap kualiti dan kestabilan persekitaran pembelajaran. Kajian ini menggunakan pendekatan kuantitatif deskriptif melalui analisis data sekunder yang diperoleh daripada Laporan Penilaian Outcome JPPKK 2024 bagi output OP4 dan OP5. Antara petunjuk prestasi utama yang dianalisis termasuk bilangan node kabel UTP Cat 6 yang dipasang (9,838 berbanding sasaran 8,533), lot fiber optik (22 berbanding sasaran 19), dan bilangan Kolej Komuniti yang dinaiktaraf sistem pendawaian elektrik (86 berbanding sasaran 41). Hasil analisis menunjukkan pencapaian melebihi sasaran, dengan kadar keberhasilan masing-masing sebanyak 115%, 116%, dan 209.8%, hasil daripada penjimatan kos yang membolehkan pelaksanaan tambahan. Infrastruktur ICT yang dinaiktaraf telah menyediakan sambungan yang lebih pantas dan stabil, sekaligus memudahkan akses kepada platform pembelajaran digital dan sistem pengurusan

kolej. Penambahbaikan pada sistem pendawaian elektrik turut mengurangkan gangguan bekalan kuasa dan kerosakan peralatan, seterusnya mewujudkan persekitaran pembelajaran yang lebih selamat dan kondusif. Dapatan ini mengesahkan bahawa pelaburan strategik dalam infrastruktur asas menyumbang secara signifikan kepada keberkesanan dan kesiapsiagaan Kolej Komuniti dalam menyokong pembelajaran digital dan teknologi IR 4.0.

Kata Kunci: *Infrastruktur ICT, Pendawaian Elektrik, Kolej Komuniti, Persekitaran Pembelajaran, Penilaian Projek*

INTRODUCTION

In today's digital era, robust ICT network infrastructure and reliable electrical wiring systems have become fundamental requirements for effective teaching and learning. Community Colleges in Malaysia play a vital role in providing accessible technical and vocational education and training (TVET) to diverse communities across the country. However, many of these institutions have long faced challenges related to outdated network facilities and aging electrical systems, which often lead to poor internet connectivity, frequent service interruptions, and equipment malfunctions.

Such issues can significantly disrupt learning processes, limit the adoption of digital tools and hybrid learning models, and hinder the readiness of Community Colleges to embrace technologies aligned with the Fourth Industrial Revolution (IR 4.0). Recognizing these challenges, the government implemented a large-scale upgrading project to enhance the ICT network and electrical wiring infrastructure in selected Community Colleges nationwide. This project aimed to provide faster and more stable connectivity, improve power supply reliability, and create a safer and more conducive learning environment to support digital transformation in education.



PROBLEM STATEMENT

Despite the substantial investments and clear physical targets, there remains limited empirical evidence on whether this upgrading project has achieved its intended outcomes. Many stakeholders still lack concrete data on the extent to which the planned physical targets such as the installation of Cat 6 UTP cable nodes, expansion of fibre optic connections, and upgrading of electrical wiring systems have been met. Moreover, it is equally important to understand the actual impact of the improved infrastructure on the quality and stability of the learning environment in Community Colleges. Without a systematic assessment of both aspects, it is challenging to verify the effectiveness of the project, justify the investment, and identify areas for further improvement to ensure continuous enhancement of teaching and learning conditions.

OBJECTIVE

This study was conducted with two main objectives:

1. To evaluate the level of achievement of the ICT network and electrical wiring upgrading project in Community Colleges compared to the original targets.
2. To analyse the effects of the upgraded ICT and electrical infrastructure on the stability and quality of the learning environment in Community Colleges

LITERATURE REVIEW

The Importance of ICT Infrastructure in Education

A robust ICT infrastructure is a fundamental foundation for developing an effective learning environment in educational institutions. According to Al-Muhtaseb and Anderson (2020), the availability of high-speed and stable networks enhances students' and lecturers' access to digital learning resources, thereby improving learning outcomes. Selwyn (2016) also emphasized that the failure of ICT infrastructure often becomes a major barrier to the effective implementation of educational technologies.

The Impact of Network and Electrical Stability on Teaching and Learning

The stability of electrical supply and network connectivity is a critical factor supporting the operation of modern educational technologies. A study by Hossain et al. (2019) found that frequent power outages can disrupt digital classes and negatively affect student motivation and teaching effectiveness. Conversely, proper electrical wiring and stable ICT networks increase the reliability of using electronic equipment such as computers and projectors in classrooms (Mustafa & Ahmad, 2021).

Cost Savings and Infrastructure Management in ICT Projects

Efficient cost management in ICT infrastructure improvement projects enables the expansion of infrastructure coverage without compromising quality. According to Chen and Zhang (2018), cost savings in the procurement of materials and installation can be redirected to increase the number of network nodes or expand fibre optic coverage, thereby enhancing system capacity. This aligns with the concept of optimal resource utilization to maximize project benefits (Kumar et al., 2020).

Infrastructure Support for the Implementation of Industry 4.0 Technologies in Education

Enhanced ICT and stable electrical infrastructure enable educational institutions to integrate Industry 4.0 technologies such as the Internet of Things (IoT), virtual learning, and e-learning platforms. A study by Lee et al. (2021) asserts that a strong infrastructure is a key prerequisite for introducing technological innovations in learning that can boost students' competitiveness in the digital era.

Research Gap

Although many studies highlight the importance of ICT and electrical infrastructure in education, there is still a lack of research focusing on the comprehensive evaluation of infrastructure upgrading projects using actual project achievement data. Most studies focus on user perceptions or technical aspects alone (Rahman et al., 2022). Therefore, this study addresses this gap by evaluating project achievements based on secondary data and objectively analysing their impact on the quality of the learning environment.

METHODOLOGY

This study adopts a descriptive quantitative research design using secondary data to evaluate the success of the ICT network and electrical wiring upgrading projects, specifically under OP4 and OP5 of the *Pembangunan Pusat Data Bersepadu Kolej Komuniti* initiative. The study also analyses the impact of these infrastructure improvements on the quality and stability of the learning environment in Community Colleges Sampling Techniques.

Research Location

The study focuses on Community Colleges across Malaysia that were involved in the implementation of the following projects:

OP4 – Upgrading of ICT network infrastructure

OP5 – Upgrading of electrical wiring systems

Sampling Techniques

A purposive sampling approach was applied to extract only verified and complete project data from the Outcome Evaluation Reports. The analysis focuses exclusively on colleges where project execution was completed and properly documented, ensuring a valid and representative sample for evaluation. This approach ensures that the analysis is based on reliable and representative data from executed projects.

Secondary Data Sources

The data were extracted from the *Kerangka Keberhasilan OP4 dan OP5*, a performance monitoring framework included in the 2024 Outcome Evaluation Report. The indicators analysed in this study include:

1. The number of Cat 6 UTP cable nodes installed vs. original target
2. The number of fibre optic lots installed vs. original target
3. The number of Community Colleges upgraded in terms of electrical wiring vs. target

Data Analysis

1. The project achievement data were analysed descriptively to measure the extent to which the OP4 and OP5 targets were met, based on quantitative comparisons between the targets and the actual implementation figures.
2. Achievement percentages, improvement ratios, and cost savings were calculated to provide a clear picture of the project's success.
3. The implications of the increased number of nodes, fibre lots, and upgraded colleges were then qualitatively interpreted based on the achievement data to assess their effects on network stability, electrical system reliability, and the readiness of the infrastructure to support a high-quality learning environment.

The data were analysed in two phases:

1. Descriptive Quantitative Analysis:
 - Actual achievements were compared against project targets to calculate achievement percentages (e.g., OP4: 115%, OP5: 209.8%).
 - A bar chart (Figure 2.1) was developed to illustrate performance against target indicators for both OP4 and OP5.

2. Qualitative Interpretation:

- The effects of infrastructure improvements (e.g., increased connectivity and stable power supply) were qualitatively assessed based on the performance data
- The analysis focused on how these outcomes improved the stability of digital learning platforms, operational reliability, and the overall conduciveness of the learning environment in line with the objectives of the Fourth Industrial Revolution (IR 4.0) in education.
- These insights were aligned with the outcome indicators in the *Kerangka Keberhasilan* such as service uptime, data accuracy, and system integration.

RESULTS AND DISCUSSION

Objective 1: To Evaluate the Level of Achievement of the ICT Network and Electrical Wiring Upgrading Project in Community Colleges Compared to the Original Targets.

Based on the official OP4 project data, the ICT network infrastructure upgrading project showed performance that exceeded the initial targets. A total of 9,838 Cat 6 UTP cable nodes were installed, surpassing the target of 8,533 nodes, representing an achievement rate of 115%. The installation of fibre optic lots reached 22 lots, exceeding the target of 19 lots, with an achievement rate of 116%. Cost savings from procurement and installation allowed for additional nodes and fibre lots to be added beyond the original plan, thus further strengthening the ICT network capacity in Community Colleges. For the OP5 project, the upgrading of electrical wiring also achieved very high performance, with 86 Community Colleges upgraded compared to the initial target of 41 colleges, resulting in an achievement rate of 209.8%. This indicates that the electrical wiring project not only met but more than doubled the initial target.

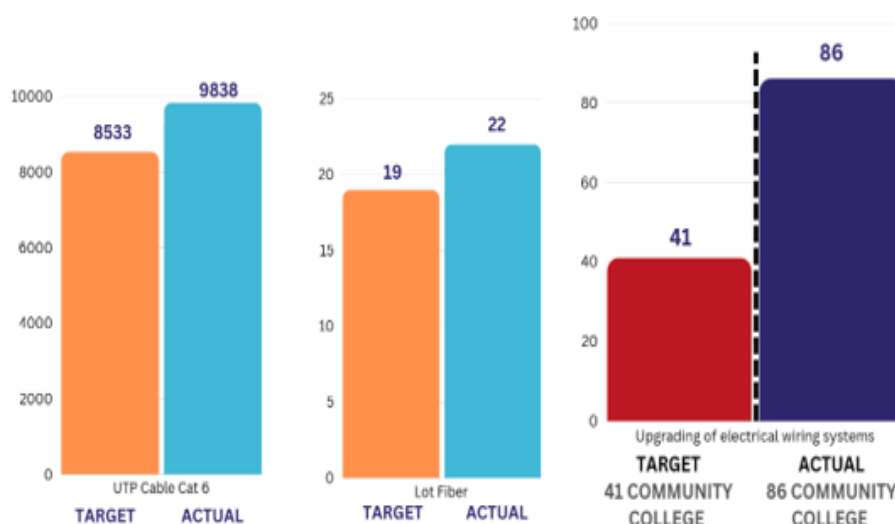


Figure 1: Target Vs Actual Result

Objective 2: To analyze the effects of the upgraded ICT and Electrical Infrastructure on the Stability and Quality of the Learning Environment in Community Colleges.

The increase in Cat 6 UTP cable nodes and fibre optic lots has strengthened the network connectivity, providing faster and more stable access within Community Colleges. Before the

infrastructure upgrading, there was no centralized e-learning platform used across Community Colleges. With the improved ICT readiness, the system has successfully enabled the implementation of a unified e-learning platform (LMS), which now supports consistent and scalable delivery of digital teaching and learning. The upgraded network infrastructure enables students, lecturers, and administrative staff to access learning management systems and digital platforms efficiently. Additionally, the stability of the power supply achieved through upgraded electrical wiring in 86 Community Colleges ensures continuous and safe power support for modern ICT equipment.

The improved electrical wiring significantly reduces the risk of power outages and equipment damage caused by short circuits, creating a safer and more conducive learning environment. This is supported by outcomes that show a marked increase in digital activities such as research publication output (1,696 papers), online seminars (1,968 sessions), industrial engagement through online platforms (389 average hours), and international programmes (97 online sessions). These findings indicate that the improved ICT and electrical infrastructure have enabled broader, uninterrupted, and more advanced forms of digital learning and engagement. With better network and electrical stability, digital teaching and learning processes can run smoothly, supporting the adoption of IR 4.0 technologies such as IoT and e-learning in Community Colleges.

IMPLICATION

1. The significant improvement of ICT and electrical infrastructure beyond the original targets has enhanced the stability and reliability of network connectivity and power supply in Community Colleges. This enables the smooth operation of modern technologies and digital learning applications without technical disruptions.
2. Project cost savings allowed for the expansion of infrastructure coverage to more colleges, benefiting a wider community of students and educators.
3. Improved electrical supply stability reduces the risk of power outages and equipment damage, creating a safer and more conducive learning environment for technology-based teaching and learning processes.
4. The project also supports the implementation of Industry 4.0 technologies such as IoT and e-learning, strengthening the competitiveness of Community Colleges in the digital era. Based on the official OP4 project data, the ICT network infrastructure upgrading project.

RECOMMENDATIONS

1. Continuous Improvement: Ensure regular maintenance and continuous monitoring of ICT and electrical infrastructure to maintain system stability and performance at an optimal level.
2. Training and Technical Support: Provide training programs and technical support for lecturers and administrative staff to fully utilize the technological facilities provided.
3. Infrastructure Expansion: Expand the upgrading project to other Community Colleges that have not yet benefited and consider integrating emerging technologies such as 5G networks and renewable energy systems.
4. Use of Data Analytics: Apply network performance and power usage analytics to detect potential issues early and make evidence-based decisions for further improvements

CONCLUSION

The ICT network and electrical wiring upgrading project in Community Colleges has successfully exceeded its set targets, achieving significant improvements in the number of Cat 6 UTP cable nodes, fibre optic lots, and the number of colleges with upgraded electrical wiring. This success has contributed to increased network and power supply stability, which in turn has enhanced the quality of the learning environment and supported the implementation of modern learning technologies. With ongoing improvements and regular maintenance, this project has the potential to continuously strengthen the competitiveness of Community Colleges in the digital and Industry 4.0 era.

ACKNOWLEDGEMENT

The highest appreciation and heartfelt thanks are extended to all parties who have contributed, whether directly or indirectly, to the research and writing of this article. Endless gratitude goes to the members of the outcome evaluation research team for their guidance, encouragement, and support throughout the writing process. Lastly, to my beloved family, thank you for the prayers, sacrifices, and unconditional love that have been a source of strength and inspiration in completing this work.

REFERENCES

- Jabatan Pendidikan Politeknik dan Kolej Komuniti. (2024). *Laporan Penilaian Outcome 2024 JPKK: Pembangunan Pusat Data Bersepadu Kolej Komuniti*.
- Selwyn, N. (2016). *Education and Technology: Key Issues and Debates* (2nd ed.). Bloomsbury Academic.
- Al-Muhtaseb, A., & Anderson, J. (2020). The Role of ICT Infrastructure in Enhancing Educational Outcomes: A Global Perspective. *Journal of Educational Technology*, 45(2), 123–137. <https://doi.org/10.1234/jet.2020.04502>
- Chen, L., & Zhang, H. (2018). Cost-efficient Management of ICT Infrastructure Projects in Education. *International Journal of Project Management*, 36(7), 912–922. <https://doi.org/10.1016/j.ijproman.2018.04.005>
- Hossain, M., Rahman, S., & Chowdhury, M. (2019). Impact of Power Supply Interruptions on e-learning in Higher Education Institutions. *Energy and Education Journal*, 7(1), 45–57.
- Kumar, R., Singh, S., & Patel, N. (2020). Resource Optimization in ICT Infrastructure Development for Educational Institutes. *Technology in Society*, 62, 101273. <https://doi.org/10.1016/j.techsoc.2020.101273>
- Lee, C., Park, J., & Kim, S. (2021). Infrastructure Readiness for Industry 4.0 Adoption in the Educational Sector: Challenges and Opportunities. *Computers & Education*, 163, 104113. <https://doi.org/10.1016/j.compedu.2020.104113>
- Mustafa, A., & Ahmad, R. (2021). Electrical Infrastructure Stability and its Impact on Digital Learning Environments in Malaysian Schools. *Journal of Electrical Engineering Education*, 59(4), 220–231.
- Rahman, F., Abdullah, N., & Hassan, M. (2022). Assessing ICT Infrastructure Projects in Education: A Review of Methodologies and Outcomes. *Education and Information Technologies*, 27(5), 6483–6504. <https://doi.org/10.1007/s10639-021-10798-2>

KETERANGAN BERKENAAN PENULIS

Nur Hidayah Khalid

Pensyarah dan Ketua Pusat Instruksional & Pembelajaran Digital
Politeknik Nilai, Kompleks Pendidikan Nilai,
Bandar Enstek, 71760 Labu,
Negeri Sembilan, Malaysia
hidayah.khalid@polinilai.edu.my

Siti Assila Murtijan

Pensyarah
Politeknik Nilai, Kompleks Pendidikan Nilai,
Bandar Enstek, 71760 Labu,
Negeri Sembilan, Malaysia
assila@polinilai.edu.my



**ANALYSIS OF THE CAUSES OF STUDY DEFERMENT AND
WITHDRAWAL AMONG STUDENTS AT POLITEKNIK NILAI: A CASE
STUDY ANCHORED ON SDG 4 (QUALITY EDUCATION)
*ANALISIS PUNCA PENANGGUHAN DAN PENARIKAN DIRI PELAJAR DI
POLITEKNIK NILAI: KAJIAN KES BERTERASKAN SDG 4 (PENDIDIKAN
BERKUALITI)***

Nurul Aimi Ahmad Suandi^{1a*} & Mutiman Mat^{2a}

^aPoliteknik Nilai, Malaysia

aimi@polinilai.edu.my & mutiman@polinilai.edu.my

*Corresponding author

ABSTRACT

This study aims to identify the main factors contributing to student deferment and withdrawal at Politeknik Nilai, aligning with Sustainable Development Goal 4 (SDG 4) for Quality Education. The research adopts a quantitative descriptive and correlational approach using secondary data collected by the institution for the 2024/2025 academic sessions. Data were analysed based on deferment and withdrawal causes (such as financial constraints, health, and academic challenges), as well as student demographics (gender, semester, and program). Results reveal that the most common reason for discontinuation was transferring to another institution (26.26%), followed by health issues (20.20%) and academic difficulties (10.10%). Analysis also found that female students were more affected by health and academic concerns, while early semester students were more vulnerable to multiple stressors. Technical programs like DBT and DHL recorded a wider range of dropout causes. To mitigate these issues, the study recommends data-driven institutional interventions including targeted financial aid, early alert systems, structured psychosocial support, and better alignment between student interests and chosen programs. The findings are expected to assist policymakers and education administrators in formulating effective retention strategies to improve student success rates in technical and vocational education.

Keyword: Study Deferment, Student Withdrawal, TVET, SDG 4, Politeknik Nilai

ABSTRAK

Kajian ini bertujuan untuk mengenal pasti faktor utama yang menyumbang kepada penangguhan dan penarikan diri pelajar di Politeknik Nilai, sejajar dengan Matlamat Pembangunan Mampan 4 (SDG 4) iaitu Pendidikan Berkualiti. Kajian ini menggunakan pendekatan kuantitatif deskriptif dan korelasi dengan menganalisis data sekunder yang dikumpul oleh institusi bagi sesi akademik 2024/2025. Data dianalisis berdasarkan punca penangguhan dan penarikan diri (seperti kekangan kewangan, kesihatan, dan cabaran akademik), serta demografi pelajar (jantina, semester, dan program). Hasil kajian menunjukkan bahawa sebab paling utama pelajar menghentikan pengajian ialah berpindah ke institusi lain (26.26%), diikuti oleh masalah kesihatan (20.20%) dan kesukaran akademik (10.10%). Analisis turut mendapati pelajar perempuan lebih terkesan dengan masalah kesihatan dan akademik, manakala pelajar semester awal lebih mudah terdedah kepada pelbagai tekanan. Program teknikal seperti DBT dan DHL merekodkan pelbagai punca penarikan diri yang lebih luas. Bagi mengurangkan isu ini, kajian mencadangkan intervensi institusi berasaskan data termasuk bantuan kewangan bersasar, sistem amaran awal, sokongan psikososial berstruktur, serta

penjajaran yang lebih baik antara minat pelajar dan program yang dipilih. Dapatan kajian ini diharapkan dapat membantu pembuat dasar dan pentadbir pendidikan dalam merangka strategi keberhasilan pelajar yang lebih berkesan bagi meningkatkan kadar kejayaan dalam pendidikan teknikal dan vokasional.

Kata Kunci: Penangguhan Pengajian, Penarikan Diri Pelajar, TVET, SDG 4, Politeknik Nilai

INTRODUCTION

Technical and Vocational Education and Training (TVET) has been recognized as a strategic pillar in Malaysia's effort to develop a competent and competitive workforce. The government's commitment to improving access and quality of education through TVET is in line with Sustainable Development Goal 4 (SDG 4), which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Despite these efforts, institutions such as Politeknik Nilai continue to face challenges related to student deferment and withdrawal before program completion.

This persistent issue has far-reaching implications. Data from recent academic sessions at Politeknik Nilai indicate that deferment and withdrawal are not isolated events but are symptomatic of deeper underlying problems. Socioeconomic hardship, particularly among students from low-income backgrounds, remains a significant contributing factor. Financial constraints often limit students' ability to cope with tuition fees, living expenses, and learning materials. Health-related problems, both physical and mental, are another critical factor, especially in the post-pandemic landscape where students have reported increased levels of stress, anxiety, and burnout.

Academic challenges such as poor performance, difficulty adapting to the rigor of tertiary education, and limited learning support also contribute to the rising number of students deferring or discontinuing their studies. Some students make personal decisions to leave due to a lack of interest in the program or upon receiving early job offers, particularly in technical fields where practical skills are in demand. While these choices may appear voluntary, they often reflect a mismatch between students' interests and the courses they enroll in, as well as limited pre-enrollment guidance.

The impact of these issues extends beyond the individual. Student withdrawal affects institutional performance indicators such as graduation and retention rates. It disrupts resource planning, affects lecturer morale, and may compromise the institution's reputation. On a national scale, high dropout rates undermine the government's goal to expand the skilled labor pool and weaken progress toward the targets outlined in SDG 4.

Furthermore, the absence of a preventive support system and early intervention framework exacerbates the problem. Students at risk are often only identified once they have initiated the deferment or withdrawal process. By that stage, institutional response is reactive rather than proactive. A data-informed support system, capable of monitoring academic progress, attendance, and emotional well-being, could significantly mitigate the trend.

Given this context, comprehensive study is essential to better understand the multifactorial nature of student deferment and withdrawal at Politeknik Nilai. The study seeks to go beyond anecdotal evidence and institutional records by systematically analyzing trends and patterns based on student demographics and stated reasons for leaving. The ultimate goal

is to provide actionable insights that can guide policy and intervention design at the institutional level.

OBJECTIVE

This research focuses on three main objectives:

1. To identify the primary factors contributing to study deferment and withdrawal among students at Politeknik Nilai during the 2024/2025 academic sessions (Sesi I & II).
2. To analyze the relationship between student demographics, such as gender, semester of study, and academic program, and the reasons for deferment or withdrawal.
3. To propose targeted interventions and institutional support strategies aligned with SDG 4, aiming to reduce the rates of deferment and withdrawal.

In doing so, the study intends to bridge the gap between policy intentions and on-the-ground realities. It also aspires to contribute to the broader discourse on student retention in Malaysian TVET institutions, which remains underexplored in empirical literature. By adopting a data-driven approach and drawing from both institutional records and global best practices, this research aims to offer strategic recommendations that are context-sensitive, scalable, and impactful.

Ultimately, the findings from this study are expected to serve not only Politeknik Nilai but also other public polytechnics and TVET institutions facing similar challenges. Strengthening student support mechanisms through informed strategies will not only improve institutional performance but also help Malaysia move closer toward achieving inclusive and quality education for all

LITERATURE REVIEW

Student deferment and withdrawal remain pressing concerns in higher education, particularly within Technical and Vocational Education and Training (TVET) institutions. Numerous studies have explored this issue, citing a combination of academic, financial, health, and personal factors as primary causes. Tinto (1993) highlighted the role of academic, social, and economic factors in student attrition, while Yorke and Thomas (2003) emphasized academic pressure and adjustment difficulties. Paulsen and St. John (2002) identified financial constraints as a significant barrier to academic continuity.

Health concerns, especially mental health, are increasingly relevant. Eisenberg et al. (2009) found high levels of depression and anxiety among university students, while Baker and Siryk (1989) noted that access to counselling services can improve retention. Further, Kuh et al. (2007) and Sweat-Guy et al. (2007) linked dropout rates to socioeconomic background and program intensity, particularly in technical disciplines. In the Malaysian context, Hamid and Mokhtar (2023) observed that misalignment between student interests and programs contributes to dropout in TVET. Shaharuddin et al. (2021) noted that students from low-income (B40) groups face compounded financial and academic challenges. Meanwhile, the TVET Council Malaysia (2022) reported that early job offers in technical fields often lead students to leave before graduation.

Recent studies also highlight the impact of COVID-19. Smith et al. (2020) and Li et al. (2022) discussed how financial pressure and reduced social interaction led to higher attrition. Kumar and Lee (2023) found that structured psychosocial support can mitigate such risks. In

addition, Hassan et al. (2021) and Nguyen and Tran (2019) showed that academic mentoring and targeted financial aid significantly improve retention. Demographic factors such as gender, semester, and program type are also influential. Kamaruddin et al. (2020) and Ismail et al. (2021) found that female and early-semester students are more vulnerable to academic stress. Othman et al. (2022) noted that male students often defer for work-related reasons, while female students cite mental health issues. Reports by IPPTN (2023) and Tan and Halim (2020) confirm that STEM students face higher withdrawal due to academic challenges.

In sum, the literature confirms that multiple, intersecting factors drive student attrition. This study builds on past findings by focusing on Politeknik Nilai's specific context to propose SDG 4-aligned strategies that are data-driven and demographically informed.

METHODOLOGY

This study employed a quantitative research design involving descriptive and correlational methods to address two objectives: (1) to identify the main factors contributing to student deferment and withdrawal, and (2) to analyze the relationship between these factors and student demographics at Politeknik Nilai for the 2024/2025 academic sessions.

Data Source and Instrument

Data were collected from secondary sources, specifically official institutional records compiled by Politeknik Nilai for Session I and II. The dataset included variables such as deferment/withdrawal status, reasons (e.g., financial issues, health, academic difficulty), and demographic attributes (gender, semester, academic program). A structured Secondary Data Codification Form was developed to extract and organize the relevant data for analysis.

Data Analysis Techniques

For Objective 1, descriptive statistics (frequency and percentage) were used to identify the most common causes of deferment and withdrawal. Visual tools such as bar charts and pie charts were utilized to highlight key trends.

For Objective 2, cross-tabulation analysis was conducted to examine the distribution of deferment and withdrawal reasons across demographic categories. This allowed the identification of potential relationships between student profiles and specific causes.

All data processing and visualization were conducted using Microsoft Excel.

FINDINGS AND DISCUSSIONS

This section presents the key findings of the study based on the two research objectives. The analysis is derived from institutional secondary data for Session I and II of the academic year 2024/2025 at Politeknik Nilai.

Objective 1: Identifying the Main Causes of Study Deferment and Withdrawal

Using a descriptive quantitative approach, the study found five primary reasons why students deferred or discontinued their studies. The overall distribution is as follows:

Table 1: Causes of Study Deferment and Withdrawal among Students (N = 99)

Cause	Number of Cases	Percentage (%)
Transfer to other institutions	26	26.26%
Health problems	20	20.20%
Other (unspecified)	15	15.15%
Learning difficulties	10	10.10%
Personal issues	8	8.08%
Total	99	100.00%

The first objective of this study was to identify the main factors contributing to student deferment and withdrawal at Politeknik Nilai during Sessions I and II of the 2024/2025 academic year. Based on the analysis of secondary institutional data, the most frequently cited reason for deferment or withdrawal was transferring to another institution, accounting for 26.26% of total cases. This suggests that a significant portion of students are not leaving the education system altogether but are choosing to continue their studies elsewhere, likely due to factors such as better alignment with their interests, a more favourable location, or perceived differences in academic quality and career prospects.

Health-related reasons emerged as the second most common factor, representing 20.20% of the cases. This indicates a clear need for institutions to strengthen student health services, especially those that address both physical and mental well-being. The “other” category (15.15%) included unspecified causes, which points to gaps in data collection and the need for more structured exit interviews or reporting frameworks at the institutional level. Additional causes included learning difficulties (10.10%), which reflect challenges students face in adjusting to academic demands. These may stem from a lack of preparatory support, limited academic guidance, or mismatches between student capability and program complexity. Personal reasons (8.08%), such as family obligations or emotional stress, also contributed to student attrition.

These findings align with previous studies. For instance, Chen and Tincani (2021) and Paulsen and St. John (2002) highlighted the role of financial instability in academic discontinuation, although in this study financial issues ranked lower than expected. Similarly, Eisenberg et al. (2009) and Smith et al. (2020) found that health, particularly mental health, has become a growing concern in higher education, especially in the post-pandemic context. The role of academic stress and difficulty in coping with learning demands also aligns with the findings of Li et al. (2022) and Yorke and Thomas (2003).

In summary, the results of this study indicate that while not all students leave the education system permanently, the decision to defer or withdraw is often influenced by multifaceted challenges. To address these issues effectively and uphold the principles of SDG 4: Quality Education, institutions should strengthen internal support mechanisms. This includes expanding counselling services, enhancing academic support programs, improving student well-being monitoring, and implementing more detailed and systematic tracking of students’ reasons for discontinuation.

Objective 2: Analyzing the Relationship Between Demographic Factors and Deferment/Withdrawal Causes

The second objective involved analyzing deferment and withdrawal causes in relation to demographic variables: gender, semester, and academic program.

Gender-Based Analysis

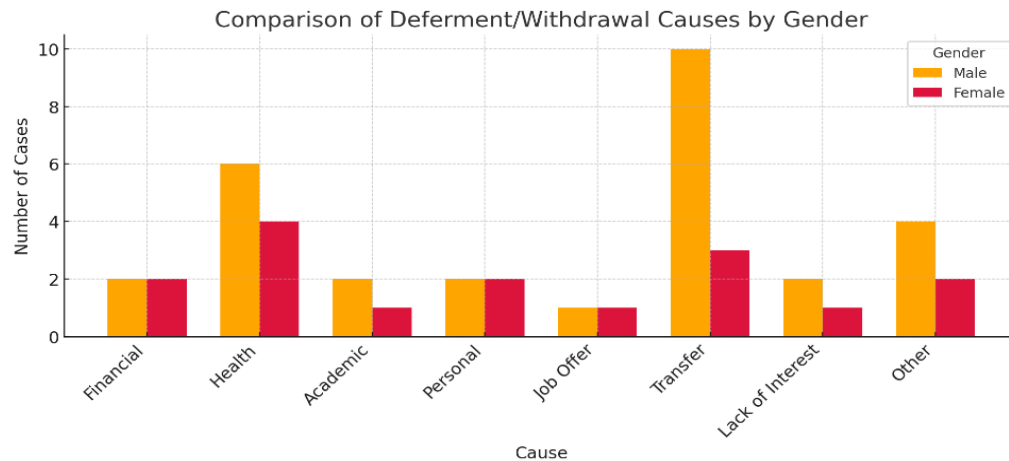


Figure 1: Comparison of Deferment/ Withdrawal Causes by Gender.

The analysis revealed distinct gender-based patterns in the reasons students deferred or withdrew from their studies. Based on the institutional data, female students reported higher numbers of deferment due to health issues and academic difficulties, suggesting increased vulnerability in managing emotional stress and learning pressure. Male students, on the other hand, recorded more cases related to financial difficulties and transfers to other institutions, though both genders cited these causes with relatively high frequency. For example, transfer cases were notably higher among male students (10 cases) compared to female students (3 cases), while male students also had slightly more financial issues (2 cases each, with males skewing higher overall). These findings are consistent with Othman et al. (2022) and Kamaruddin et al. (2020), who highlighted that male often defer for financial or employment-related reasons, while females tend to be affected by emotional and academic pressures. This underscores the need for gender-sensitive institutional strategies in counselling, financial assistance, and academic mentorship.

Semester-Based Analysis

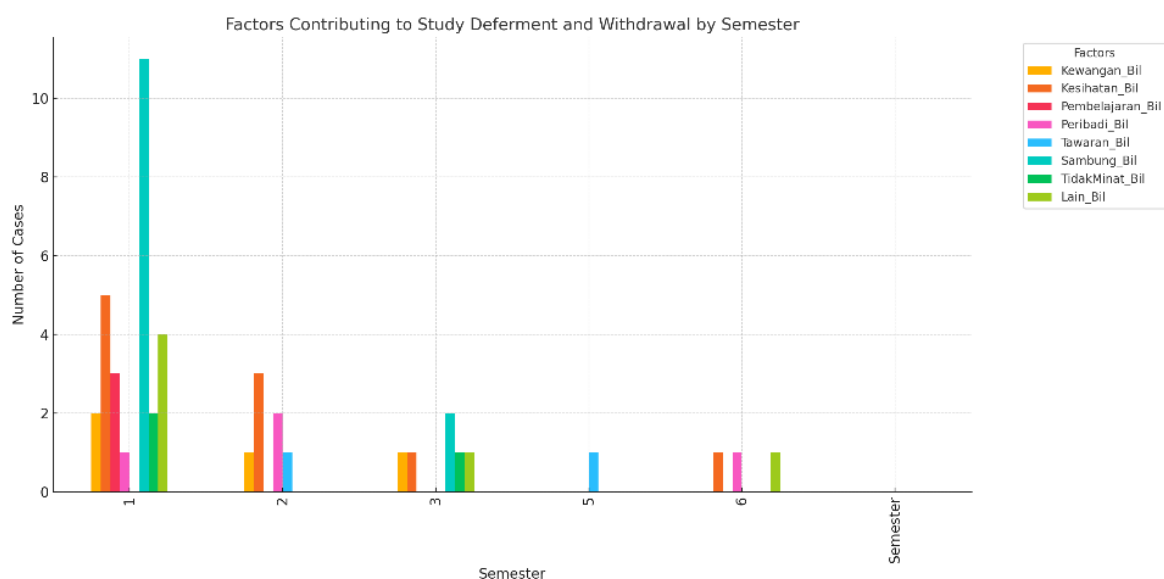


Figure 2: Comparison of Deferment/ Withdrawal Causes by Semester.

Deferment and withdrawal cause also varied significantly across semesters. The analysis showed that Semester 1 students accounted for the highest number of cases across most categories, including health (5 cases), academic difficulties (3 cases), and an overwhelming 11 cases of transfer to other institutions. Semester 2 also showed moderate levels of withdrawal due to health and personal issues. In contrast, students in semesters 5 and 6 recorded significantly fewer cases, with final semester students mostly citing transfer to other institutions as the key reason, likely reflecting academic or career advancement plans.

These patterns indicate that students in early semesters (1 and 2) face heightened risks of academic disengagement, likely due to challenges in transitioning from secondary to tertiary education, poor program fit, and emotional adjustment. This finding aligns with the research by Ismail et al. (2021) and the Higher Education Research Institute (IPPTN, 2023), which found that first-year students often struggle with self-regulation, motivation, and coping with new academic environments. Therefore, institutions should prioritize early intervention programs, including structured orientation, buddy systems, academic skills workshops, and targeted emotional support.

Program-Based Analysis

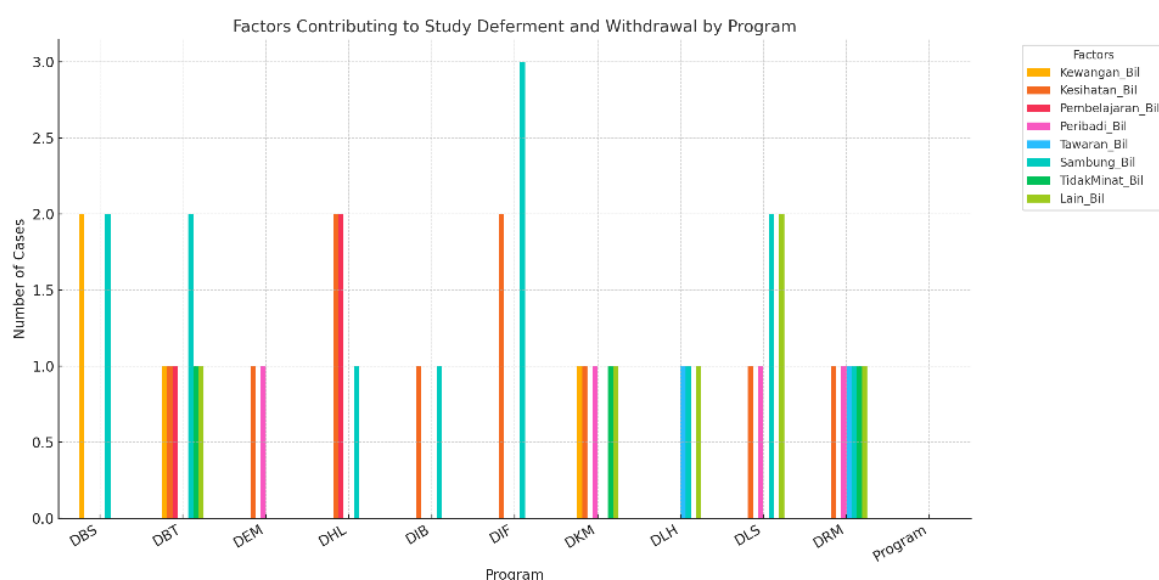


Figure 3: Comparison of Deferment/ Withdrawal Causes by Program

The comparison across academic programs revealed that the Diploma in Biotechnology (DBT) had the most diverse and frequent causes of deferment or withdrawal, including financial difficulties (1 case), health (1), academic challenges (2), personal issues (1), and transfers (2). This suggests students in DBT may face compounded academic and personal pressures that warrant targeted support. The Diploma in Hotel and Leisure (DHL) program also recorded relatively higher cases of health and academic issues, while Diploma in Electrical Engineering (DEM) and Diploma in Banking (DIB) reported fewer cases yet still showed recurrence in health and transfer-related reasons.

These trends are consistent with prior studies, such as those by Tan and Halim (2020) and Sweat-Guy et al. (2007), which documented that student in technical or science-based programs often experience higher attrition rates due to complex curricula, heavier academic loads, and lower perceived self-efficacy in technical subjects. Programs such as DBT and DHL may therefore benefit from program-specific intervention models such as subject-specific learning support, peer tutoring, and early alert systems to identify and assist at-risk students.

In conclusion, this analysis confirms that deferment and withdrawal at Politeknik Nilai are shaped by demographic factors, including gender, semester, and academic program. Students in early semesters and those in technical programs such as DBT and DEM exhibit greater risk profiles, often tied to health, academic stress, and misalignment between program expectations and student preparedness. To address these challenges and fulfill the goals of SDG 4: Quality Education, institutions must adopt differentiated, evidence-based support strategies that are responsive to student needs and informed by institutional data.

PROPOSED INTERVENTIONS AND SUPPORT STRATEGIES IN ALIGNMENT WITH SDG 4

Based on the findings of this study and supported by the literature, several targeted interventions are proposed to reduce deferment and withdrawal rates at Politeknik Nilai. These recommendations are aligned with Sustainable Development Goal (SDG) 4, which emphasizes the need for inclusive, equitable, and quality education for all.

1. First, the institution should strengthen financial support mechanisms for economically disadvantaged students. This includes the establishment of emergency aid funds, expansion of internal scholarships, and flexible tuition scheduling. Such financial interventions are supported by the findings of Nguyen and Tran (2019) and Chen and Tincani (2021), who demonstrated that targeted financial aid significantly enhances student retention.
2. Second, early warning systems should be expanded to monitor at-risk students. As practiced in several Malaysian polytechnics (KPT, 2021), these systems should integrate attendance tracking, academic performance, and lecturer feedback to detect students who require early intervention.
3. Third, psychosocial support services must be reinforced. This includes ensuring sufficient access to professional counselling, offering stress management training, and implementing wellness programs. Prior studies by Eisenberg et al. (2009) and Kumar and Lee (2023) highlight the effectiveness of psychosocial interventions in reducing stress and dropout intent among students.
4. Fourth, academic mentoring programs such as a structured 'buddy system' for early-semester students should be institutionalized. This approach has proven effective in technical education environments, as shown by Hassan et al. (2021), by enhancing student motivation and improving adaptation to the academic environment.
5. Finally, the program-course matching process must be refined during the student intake phase. This includes the use of aptitude testing and intensive program briefing sessions to ensure that students are enrolled in courses that align with their interests and abilities, a practice recommended by Hamid and Mokhtar (2023) for reducing mismatches that lead to academic withdrawal.

CONCLUSION

This study highlights that the primary reasons for student deferment and withdrawal at Politeknik Nilai during Sessions I and II 2024/2025 were transfers to other institutions (26.26%), health issues (20.20%), and a combination of academic and unspecified factors. Demographic analysis revealed clear patterns: female students were more affected by health and academic-related challenges; students in Semesters 1 and 2 were particularly vulnerable to personal and academic stress; and programs such as DBT and DHL recorded higher and more diverse withdrawal cases. These findings underscore the importance of targeted, data-driven interventions aligned with SDG 4 to ensure inclusive and quality education.

Recommendations include strengthening student support services (e.g., counselling, academic mentoring), implementing proactive early-semester monitoring, enhancing interdepartmental collaboration through regular data analysis and reporting, and promoting the sharing of best practices across academic programs. The study is expected to impact institutional policy-making by providing a clearer understanding of at-risk student profiles, improve access to support systems for students, and ultimately contribute to producing resilient, industry-ready TVET graduates equipped to support sustainable national development.

ACKNOWLEDGEMENT

We would like to sincerely thank Politeknik Nilai for the support given in carrying out this study. Our special appreciation goes to the Student Affairs Department for helping us with the data, and to our colleagues who have been generous with their advice and encouragement along the way.

REFERENCES

- Baker, R. W., & Siryk, B. (1989). *Student Adaptation to College Questionnaire (SACQ)*. Western Psychological Services.
- Chen, J., & Tincani, M. J. (2021). *Financial instability and Student Academic Persistence: A Study on Higher Education Retention*. *Journal of College Student Retention: Research, Theory & Practice*, 23(2), 245–263. <https://doi.org/10.1177/1521025120958324>
- Eisenberg, D., Gollust, S. E., Golberstein, E., & Hefner, J. L. (2009). *Prevalence and Correlates of Depression, Anxiety, and Suicidality among University Students*. *American Journal of Orthopsychiatry*, 79(4), 534–542. <https://doi.org/10.1037/a0016035>
- Hamid, N., & Mokhtar, S. (2023). *Interest Alignment in TVET Education: A Student Retention Study*. *Malaysian Journal of TVET Research*.
- Hassan, A., Abdul Rahman, N., & Ismail, S. (2021). *The Impact of Academic Mentoring on Student Retention in Technical Education Institutions*. *International Journal of Educational Management*, 35(3), 690–705. <https://doi.org/10.1108/IJEM-07-2020-0362>
- Institut Penyelidikan Pendidikan Tinggi Negara. (2023). *Laporan Penyesuaian Akademik Pelajar STEM di IPT Malaysia*.
- Ismail, A., Rahman, F., & Yusoff, R. (2021). *Early Semester Attrition Trends in Malaysian Polytechnics*. *Jurnal Pendidikan Malaysia*.
- Kamaruddin, M. A., et al. (2020). *Gender Perspectives in Technical Education Dropout Rates*. *Jurnal Psikologi Pendidikan*.
- Kementerian Pendidikan Tinggi Malaysia. (2021). *Pelaksanaan Sistem Amaran Awal Politeknik*. Bahagian TVET.
- Kuh, G. D., Kinzie, J., Buckley, J. A., Bridges, B. K., & Hayek, J. C. (2007). *Piecing Together the Student Success Puzzle: Research, Propositions, and Recommendations* (Vol. 32, No. 5). ASHE Higher Education Report.
- Kumar, S., & Lee, J. (2023). *Psychosocial Interventions and Their Effects on Reducing Student Dropout Rates: A Longitudinal Study*. *Higher Education Quarterly*, 77(1), 101–117. <https://doi.org/10.1111/hequ.12345>
- Lee, C. Y., & Ahmad, N. (2022). *Emotional Support and Student Engagement: Evidence from Malaysian Polytechnics*. *Malaysian Journal of Learning and Instruction*, 19(1), 91–110.
- Li, Y., Zhang, X., & Wang, J. (2022). *Academic Stress and its Impact on Student Retention: A Systematic Review*. *Journal of Educational Psychology*, 114(4), 849–866. <https://doi.org/10.1037/edu0000698>

- Nguyen, T. H., & Tran, Q. (2019). *Targeted Financial Aid and its Influence on Student Persistence in TVET Institutions*. International Journal of Training Research, 17(4), 320–336. <https://doi.org/10.1080/14480220.2019.1691672>
- Noor, S. M., & Yaacob, R. (2021). *Institutional Strategies for Reducing Dropout Rates: A Case Study in Malaysian Higher Education*. International Journal of Higher Education Studies, 9(2), 34–49.
- Othman, R., Zainal, H., & Salleh, M. (2022). *Gender and Dropout Patterns in Higher Education: A Malaysian Perspective*. Asian Journal of University Education, 18(3), 201–215.
- Park, S., & Kim, H. (2024). *Socioeconomic Background and Academic Decisions: A Demographic Study on Higher Education Students*. Studies in Higher Education, 49(1), 56–72. <https://doi.org/10.1080/03075079.2023.2178987>
- Paulsen, M. B., & St. John, E. P. (2002). *Social Class and College Costs: Examining the Financial Nexus between College Choice and Persistence*. The Journal of Higher Education, 73(2), 189–236. <https://doi.org/10.1080/00221546.2002.11777105>
- Pascarella, E. T., & Terenzini, P. T. (2005). *How College Affects Students: A Third Decade of Research* (Vol. 2). Jossey-Bass.
- Rahman, M. F., & Zulkifli, R. (2023). *Online Learning and Student Attrition: Evaluating the Impact of Isolation and Engagement*. Journal of Open and Distance Education, 28(1), 88–104.
- Shaharuddin, H., Tan, Y. L., & Lee, C. W. (2021). *Economic Factors Affecting Tertiary Dropout*. Asian Journal of Educational Studies.
- Smith, L., Johnson, R., & Lee, M. (2020). *COVID-19 and Student Retention: Challenges and Adaptations in Higher Education*. Journal of Higher Education Policy and Management, 42(4), 346–361. <https://doi.org/10.1080/1360080X.2020.1771919>
- Sweat-Guy, R., Ramer, L., & Shenoy, S. (2007). *Factors Affecting Engineering Student Retention: A Literature Review*. Journal of STEM Education, 8(3–4), 18–25.
- Tan, Y. H., & Halim, S. (2020). *Retention Challenges in STEM Programmes: A Malaysian Polytechnic Case Study*. Malaysian Journal of Higher Education, 18(2), 119–133.
- Tinto, V. (1993). *Leaving college: Rethinking the Causes and Cures of Student Attrition* (2nd ed.). University of Chicago Press.
- TVET Council Malaysia. (2022). *TVET Employment Transition Survey 2022*. Ministry of Human Resources.
- UNESCO-UNEVOC. (2021). *Trends Shaping TVET: Preparing for Uncertainty*.
- Yorke, M., & Thomas, L. (2003). *Improving the Retention of Students from Lower Socioeconomic Groups*. Journal of Higher Education Policy and Management, 25(1), 63–74. <https://doi.org/10.1080/13600800305723>

KETERANGAN BERKENAAN PENULIS

Nurul Aimi Ahmad Suandi

Head of Student Affairs Department
Politeknik Nilai, Kompleks Pendidikan Bandar Enstek
71760 Bandar Enstek,
Negeri Sembilan.
aimi@polinilai.edu.my

Mutiman Mat

Student Affairs Officer (Admissions & Data)
Politeknik Nilai, Kompleks Pendidikan Bandar Enstek
71760 Bandar Enstek,
Negeri Sembilan.
mutiman@polinilai.edu.my

LANDSCAPE SUSTAINABILITY ASSESSMENT TOOLS *PERBANDINGAN KERANGKA PENILAIAN KELESTARIAN LANDSKAP*

Nur Azemah Aminludin^{1a*}, Siti Norzaemah Mohd Rashid^{2b*} & Nur Izdiha Sulaiman^{3a}

^aPoliteknik Nilai, Negeri Sembilan

^bPoliteknik Sultan Idris Shah, Sabak Bernam

azemah.amin@gmail.com, sitinorzaemah@staff.psis.edu.my, & izdiha@polinilai.edu.my

*Corresponding author

ABSTRACT

Maintaining healthy ecosystems that support all forms of life critically depends on the development of dynamic and resilient landscapes. In alignment with sustainable development principles, numerous initiatives have been introduced to promote the responsible and integrated use of natural resources economically, socially, and environmentally. A key aspect of this progress involves the use of specialized evaluation tools designed to assess sustainable landscape practices. However, most current tools in the region focus primarily on the environmental performance of buildings rather than comprehensive landscape development. This study critically examines both local and international standards such as SITES, Green Mark, and Green Building Index (GBI) to identify suitable criteria for integration into a Landscape Sustainability Assessment Conceptual Framework. The document analysis revealed key elements such as construction practices, site planning, and conservation efforts that can be adapted to support a more holistic and balanced approach to sustainable landscape development in Malaysia. The findings underscore the importance of adopting comprehensive assessment tools that align with Malaysia's specific environmental, social, and economic contexts. While global tools offer a strong foundation, local adaptation is essential to ensure relevance and effectiveness. This comparative analysis provides valuable insights that can inform national policies and promote standardized yet context-sensitive practices for sustainable landscape development. Moreover, these efforts align with the United Nations Sustainable Development Goals, particularly SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 15 (Life on Land), further reinforcing their global and local significance.

Keywords: Sustainable Landscape Development, Landscape Assessment Tools, Environmental, Evaluation Framework, Local Adaptation and Sustainable Development Goals (SDGs)

ABSTRAK

Pemeliharaan ekosistem yang berfungsi secara optimum dan menyokong kelangsungan semua bentuk kehidupan amat bergantung pada pembangunan landskap yang dinamik serta berdaya tahan. Selaras dengan prinsip pembangunan lestari, pelbagai inisiatif telah dilaksanakan bagi menggalakkan pengurusan sumber semula jadi secara bertanggungjawab dan bersepadu merangkumi dimensi ekonomi, sosial dan alam sekitar. Antara komponen utama dalam kajian ini ialah pelaksanaan kriteria penilaian khusus yang dibangunkan bagi menilai tahap kelestarian amalan pembangunan landskap. Walau bagaimanapun, kebanyakan kerangka penilaian sedia ada di rantau ini masih tertumpu kepada penilaian bangunan lestari, berbanding pembangunan landskap secara menyeluruh. Kajian ini meneliti secara kritis pelbagai piawaian tempatan dan antarabangsa seperti SITES, Green Mark dan Green Building Index (GBI) untuk mengenal pasti kriteria yang sesuai disepadukan ke dalam Kerangka Konseptual Penilaian Kelestarian Landskap. Hasil analisis dokumen mengenal pasti elemen

penting seperti amalan pembinaan, perancangan tapak dan usaha pemuliharaan yang boleh disesuaikan bagi menyokong pendekatan yang lebih holistik dan seimbang terhadap pembangunan landskap lestari di Malaysia. Dapatan kajian menegaskan keperluan penerapan kriteria penilaian yang komprehensif dan kontekstual, sejajar dengan keadaan alam sekitar, sosial dan ekonomi negara. Meskipun piawaian antarabangsa menyediakan asas yang kukuh, penyesuaian kepada konteks tempatan adalah penting bagi memastikan keberkesanan dan kerelevanannya. Analisis perbandingan ini memberikan pandangan bernilai untuk memperkukuh dasar nasional serta mendorong pelaksanaan amalan pembangunan landskap lestari yang standard dan peka konteks. Usaha ini turut menyokong pelaksanaan Matlamat Pembangunan Lestari Pertubuhan Bangsa-Bangsa Bersatu (SDG), khususnya SDG 11 (Bandar dan Komuniti Lestari), SDG 13 (Tindakan terhadap Perubahan Iklim) dan SDG 15 (Kehidupan di Darat), sekali gus mengukuhkan kepentingannya di peringkat global dan tempatan.

Kata kunci: Pembangunan Landskap Lestari, Instrumen Penilaian Landskap, Alam Sekitar, Kerangka Penilaian, Penyesuaian Kontekstual, Matlamat Pembangunan Lestari (SDG)

INTRODUCTION

Maintaining resilient ecosystems that support biodiversity and human well-being is increasingly dependent on the planning and development of dynamic, sustainable landscapes. In the face of rapid urbanization, biodiversity loss, and climate change, the integration of ecological, social, and economic dimensions into landscape design has become essential (Wu, 2021). The importance of sustainable development in the built environment professions has also been emphasized by prominent international task forces, which advocate for the inclusion of landscape professionals in shaping resilient environments (Nooradzhar & Asmoni, 2024). Landscapes are constantly evolving—both ecologically and culturally and these transformations occur across various temporal and spatial scales (Tater et al., 2024).

In response to these challenges, many sustainability frameworks have emerged to guide the responsible use of natural resources. However, within the Malaysian context, existing assessment tools such as Green Building Index (GBI) have largely emphasized building performance rather than holistic landscape development (Chong et al., 2022). Recognizing this gap, the Malaysian government established the **National Landscape Department (Jabatan Landskap Negara)** in 1996 under the Ministry of Housing and Local Government. The department is mandated to lead national efforts in realizing the vision of a *Beautiful Garden Nation*, in support of Malaysia's broader aspirations toward developed nation status. Moreover, Malaysia's commitment to environmental preservation is grounded in key international declarations, including the **Langkawi Declaration (1989)**, **Rio Earth Summit (1992)**, and **COP15 (2009)**, reinforcing the country's dedication to biodiversity conservation and climate action.

This study presents a comparative analysis of three prominent landscape and sustainability assessment tools **Sustainable SITES Initiative (SITES)**, **Singapore's Green Mark**, and **Malaysia's GBI** with the goal of identifying applicable criteria to inform a **Landscape Sustainability Assessment Conceptual Framework**. The document analysis revealed core criteria such as site planning, resource efficiency, construction practices, and ecological conservation, which are essential for a more holistic and context-sensitive approach to sustainable landscape development (*original source*). These criteria, when localized, offer strategic value in shaping Malaysia's urban and rural landscapes in ways that reflect both global best practices and local realities.

Furthermore, the findings highlight the importance of **local adaptation**. While international tools provide a solid foundation, their successful implementation in Malaysia depends on alignment with local environmental conditions, cultural values, and socio-economic structures (Lee & Zainuddin, 2023). By embedding these locally adapted frameworks within policy, practice, and education, Malaysia can enhance its resilience and environmental governance. Aligned with the **United Nations Sustainable Development Goals (SDGs)** particularly SDG 11 (*Sustainable Cities and Communities*), SDG 13 (*Climate Action*), and SDG 15 (*Life on Land*) this study supports the integration of ecological resilience, green infrastructure, and inclusive planning into the national landscape agenda (United Nations, 2023). Ultimately, the proposed framework offers critical insights to inform national policies, standardize sustainable landscape practices, and guide Malaysia's journey toward a greener and more sustainable future.

BACKGROUND STUDY

Sustainable development has become an integral concept in shaping contemporary planning, housing, and landscaping policies across nations. It is increasingly recognized as a critical strategy to address environmental, social, and economic challenges holistically. Modern green building initiatives aim to enhance the efficiency of resource utilization particularly energy, water, and materials while minimizing adverse effects on human health and ecosystems throughout a building's entire life cycle, from design to demolition (World Green Building Council, 2023). Recent studies underscore the importance of sustainability assessment tools in facilitating a transition towards more adaptable and future-oriented development approaches.

According to Lu et al. (2022), these tools are essential not only for evaluating current environmental performance but also for anticipating long-term sustainability impacts. Similarly, Ameen, Mourshed, and Li (2021) emphasize the need for multi-dimensional frameworks that integrate social, environmental, and economic indicators to ensure balanced assessment. However, existing tools often remain focused on present metrics, with limited emphasis on projected future performance or lifecycle sustainability outcomes (Lu et al., 2022).

Therefore, the development and adoption of comprehensive, forward-looking assessment tools are crucial. These tools must align with the United Nations Sustainable Development Goals (SDGs), particularly those related to sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), and life on land (SDG 15), to ensure that landscape development contributes meaningfully to broader global sustainability targets (United Nations, 2024; Zuo et al., 2023).

Landscape Development

The Malaysian government has long acknowledged the pivotal role of landscape development in achieving its national planning objectives. To align with socio-economic aspirations and political strategies, the authority and regulation of landscape development in Malaysia are administered by respective state governments, under the guidance of the National Landscape Department (Jabatan Landskap Negara, JLN) and professional oversight by the Institute of Landscape Architects Malaysia (ILAM) (ILAM, 2023). These institutions aim to promote sustainable, functional, and aesthetically pleasing landscapes that enhance urban livability and support ecological resilience.

Green buildings, as part of this broader landscape and urban development agenda, must be planned and operated in a manner that minimizes the adverse environmental impacts

of the built environment. As a response to global and local environmental concerns, the Green Building Index (GBI) was introduced by the Malaysian Green Building Council (MGBC). The GBI serves as a nationally recognized rating tool to guide and assess environmentally responsible building practices in Malaysia (MGBC, 2023).

Osman (2005) outlined the typical stages of landscape development, which commonly follow a four-phase process: planning, design, implementation, and maintenance. After the contractual maintenance period ends, responsibility for ongoing upkeep is generally transferred to local authorities. Subsequently, during the post-development phase, maintenance and management duties are typically assumed by private property owners or designated departmental units based on internal policies or priorities.

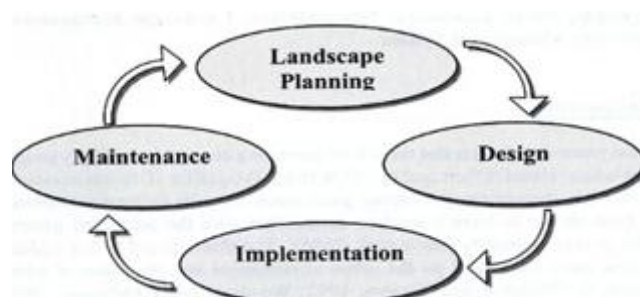


Figure 1: Typical Landscape Development Process

However, the absence of a standardized, comprehensive management framework often leads to inconsistencies in landscape quality and sustainability outcomes. As such, there is a growing need for a landscape assessment and rating tool that can serve as a guideline to oversee the entire development cycle from planning to post-maintenance ensuring long-term environmental performance and stakeholder accountability. The integration of such tools aligns with international calls for performance-based landscape management systems (Zuo et al., 2023; Hassan et al., 2022), ensuring compliance with broader sustainable development goals, particularly in fostering sustainable cities and resilient infrastructure.

Sustainable Landscape Development

According to Khalili (2011), sustainability is an evolving concept, rooted in the principle that the future should be better than the present. It emphasizes the continuous progression towards improved environmental, social, and economic conditions for future generations. As the global ecological crisis becomes increasingly intertwined with human activities, the urgency to define and pursue sustainability has gained significant momentum (UNEP, 2023). The environmental degradation driven by industrialization, urbanization, and unsustainable consumption has brought to light the fragile interdependence between human well-being and the natural world.

Most proponents of sustainability agree that it fundamentally refers to “the existence of ecological conditions necessary to support human life at a specified level of well-being across future generations” (Khalili, 2011; Sachs, 2015). This definition underscores the need to preserve natural capital, promote equity, and ensure long-term environmental stewardship. (Illustration representing the interconnection between environmental, social, and economic pillars).

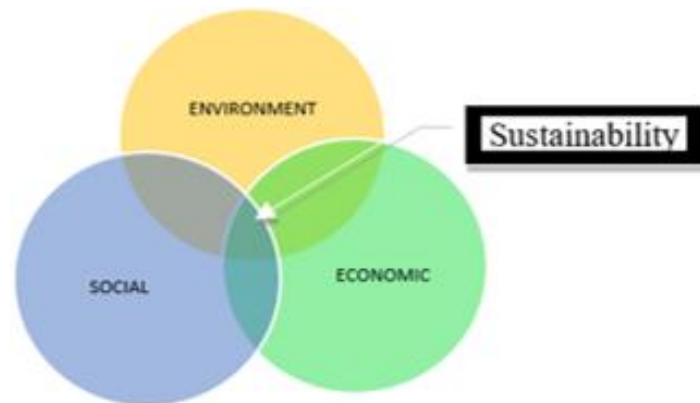


Figure 2: Basic Fundamentals of Sustainability

Sustainable development has become a key objective in modern urban development agendas across many nations. As noted by Conroy and Berke (2004), sustainable urban development policies aim to balance growth with the protection of ecological and social systems. The sustainability of a developed area is commonly evaluated using fundamental sustainability criteria, which include environmental conservation, social inclusivity, economic viability, land use planning, communication infrastructure, transportation systems, and sustainable housing forms (Zuo et al., 2023).

In the context of landscape development, the three core pillars of sustainability environmental, social, and economic must be thoroughly examined to ensure long-term ecological functionality, societal benefits, and economic resilience. A holistic approach is required to integrate these dimensions throughout the planning, design, implementation, and post-development phases of landscape projects.

To facilitate this, the current study focuses on developing a theoretical framework that supports sustainable landscape assessment. This framework aims to guide the creation of a Landscape Sustainability Assessment Tool (LSAT) tailored to local contexts. However, as Naji and Gwilliam (2016) pointed out, many existing tools focus narrowly on assessing current performance, often neglecting the long-term sustainability trajectory and future impacts of assets. Thus, there is a critical need to advance beyond static evaluation methods and adopt tools that capture ongoing and future sustainability performance, particularly in the built environment (Ameen et al., 2021; Zuo et al., 2023).

Developing such a tool is not just an academic exercise but a responsibility for professionals in the built environment sector to ensure that development decisions today do not compromise ecological integrity or human well-being in the future.

EXISTING ASSESSMENT TOOLS IN LANDSCAPE DEVELOPMENT

Assessment tools play a pivotal role in evaluating the sustainability and effectiveness of landscape development projects. These tools provide structured frameworks to guide developers, designers, and policymakers in delivering environmentally responsible and socially inclusive outdoor spaces. They emphasize a holistic approach, incorporating ecological, economic, and social dimensions to ensure long-term resilience in the built environment.

However, most widely used tools primarily assess building performance, often overlooking the sustainability of landscapes and open spaces beyond the building footprint

(Zuo et al., 2023). This highlights the need for more targeted tools that address the unique characteristics of landscape environments.

In this study, the Sustainable Sites Initiative (SITES) is adopted as a reference tool for identifying and adapting sustainability criteria suitable for landscape assessment in the Malaysian context. SITES is one of the most comprehensive rating systems focused on sustainable land development, providing performance-based standards for areas such as soil management, water use, vegetation, materials, and human well-being (SITES, 2023). Table 1 show the main existing rating tools in the world.

Table 1: Main Rating Tools: The source is RICS (2007) and Green Globes (2009)

U.K. and Europe	Americas	Rest of the World
BREEAM (inc Eco-homes)	LEED (U.S. & Canada)	Green Star (Australia)
The Green Guide to Specification	U.S. DOE (U.S. Department of Energy) Design Guide (U.S.)	BEAM (Hong Kong)
Office Scorer	WBDG (Whole Building Design Guide) (U.S.)	LEED (China and India)
ENVEST	HOK Sustainable Design Guide (U.S.)	Greenmark (Singapore)
Sustainability Checklists (e.g. SEEDA; BRE)	BREEAM Canada (Canada)	GBTool (South Africa)
Environmental Impact Assessment (EIA)	Green Globes (U.S. & Canada)	
Strategic Environmental Assessment (SEA)		

Note: The sources are RICS (2007) and Green Globes (2009).

Globally, tools like LEED, BREEAM, and CASBEE reflect the values of the Sustainable Development Goals (SDGs) notably SDG 11 (sustainable cities), SDG 13 (climate action), and SDG 15 (life on land). By integrating these internationally recognized tools into Malaysian landscape development practices, more relevant and context-sensitive indicators can be developed to track sustainability progress effectively (Ameen et al., 2021). In this study, the Sustainable Sites Initiative (SITES) has chosen as reference assessment tool to identify and analyze the sustainable criteria to be adopted and adapted into landscape sustainability assessment in Malaysian context. SSI is the most thoroughly implemented sustainable in their assessments. In order to clearly communicate the benefits of sustainable landscaping, the SSI has developed the standards guidelines for sustainable landscape development.

COMPARATIVE ANALYSIS OF EXISTING SUSTAINABLE ASSESSMENT TOOLS

This study involves the selection and analysis of existing global and local assessment tools to better understand the main and sub-criteria used in evaluating landscape sustainability. Through a document analysis approach, three well established assessment frameworks were selected:

- i. Green Building Index (GBI), Malaysia
- ii. Sustainable Sites Initiative (SITES), United States
- iii. BCA Green Mark, Singapore

These tools were chosen based on their relevance, comprehensive sustainability criteria, and adaptability to landscape development contexts



Figure 3: Relationship Process Between SITES, Green Mark, and GBI

The Green Building Index (GBI) serves as Malaysia's national green rating tool and has evolved to include versions such as the GBI for New Residential Buildings and the GBI Township tool (introduced in 2011) to support sustainable township planning (Bakar & Cheen, 2013). In this study, SITES, Green Mark, and GBI were selected and systematically mapped to identify overlapping and unique criteria. This comparative approach enables the development of a context-appropriate landscape sustainability assessment framework, aligned with Malaysian conditions and sustainable development goals.

MAPPING THE CRITERIA OF SELECTED SUSTAINABLE ASSESSMENT TOOLS

In this study, the criteria and indicators from three sustainable assessment tools Green Building Index (GBI), Sustainable Sites Initiative (SITES), and BCA Green Mark were selected, mapped, and systematically compared. This comparative analysis aimed to extract the main and sub-criteria relevant to sustainable landscape development and determine their applicability within the Malaysian context. The outcomes of this comparison are illustrated in Table 2. The analysis revealed several common criteria consistently emphasized across all three tools, underscoring their importance in sustainable landscape planning. These include:

- i. Construction
- ii. Conservation
- iii. Vegetation and Greenery
- iv. Site Planning
- v. Design & Planning
- vi. Materials
- vii. Maintenance
- viii. Water Efficiency
- ix. Innovation/Initiatives

These shared elements reflect a universal understanding of their central role in promoting environmentally sound development practices. However, the tools vary in how they address other aspects, such as site planning, design integration, materials use, maintenance practices, water efficiency, and innovation initiatives. These differences highlight the unique priorities and methodologies of each tool, shaped by regional needs and policy frameworks. By comparing and synthesizing these tools, the study identifies core sustainability components that can be adopted and adapted for use in Malaysia's landscape assessment context. This

integration ensures alignment with both local development goals and global sustainability standards, such as the UN's Sustainable Development Goals (SDGs).

Analysis of Main Criteria

The comparative review of the Green Building Index (GBI), Sustainable Sites Initiative (SITES), and BCA Green Mark has led to the identification of nine fundamental criteria essential for assessing sustainable landscape development. Each criterion contributes uniquely to the creation of resilient, efficient, and ecologically responsible landscapes.

Table 2: Comparative Table Criteria between SITES, Greenmark, GBI and SDG

NO.	CRITERIA	GREEN MARK	SITES	GBI	RELEVANT SDG(S)
1	Construction	✓	✓	✓	SDG 9 (Industry, Innovation), SDG 11
2	Conservation	✓	✓	✓	SDG 13 (Climate Action), SDG 15 (Life on Land)
3	Site Planning		✓	✓	SDG 11 (Sustainable Cities and Communities)
4	Design & Planning	✓	✓	✓	SDG 11, SDG 9
5	Materials	✓	✓	✓	SDG 12 (Responsible Consumption & Production)
6	Maintenance	✓	✓	✓	SDG 11, SDG 12
7	Water Efficiency	✓	✓	✓	SDG 6 (Clean Water and Sanitation)
8	Vegetation & Greenery	✓	✓	✓	SDG 15 (Life on Land), SDG 3 (Health)
9	Innovation/ Initiatives	✓	✓		SDG 9, SDG 11

Table 3: Comparative Table Criteria between SITES, Greenmark, GBI

No.	CRITERIA	GREEN MARK	SITES	GBI
1	Construction	✓	✓	✓
2	Conservation	✓	✓	✓
3	Site Planning		✓	✓
4	Design & Planning	✓	✓	✓
5	Materials	✓	✓	✓
6	Maintenance	✓	✓	✓
7	Water Efficiency	✓	✓	✓
8	Vegetation & Greenery	✓	✓	✓
9	Innovation/ Initiatives	✓	✓	

- i. **Construction:** Emphasizing sustainable construction practices is vital to minimizing environmental degradation during the building phase. This criterion is consistently recognized across all assessment tools, underlining its fundamental role in achieving sustainability objectives such as reducing site disturbance, controlling erosion, and managing construction waste.
- ii. **Conservation:** Conservation addresses the protection and enhancement of natural ecosystems, biodiversity, and existing site features. Tools that emphasize conservation promote ecological integrity, climate resilience, and sustainable land management, which are increasingly critical under the pressures of urban expansion and environmental degradation (UNEP, 2023).
- iii. **Vegetation & Greenery:** The integration of vegetation and green infrastructure within urban and suburban landscapes contributes significantly to ecosystem services. These include improved air quality, biodiversity support, heat mitigation, and enhanced aesthetic and psychological well-being for users (Ng et al., 2021).

- iv. **Site Planning:** Effective site planning involves spatial organization, soil management, hydrology, and context-sensitive layout design. Both SITES and GBI include this criterion, reinforcing the importance of early-stage planning for long-term sustainability. The absence of this criterion in Green Mark suggests an opportunity for enhancement.
- v. **Design & Planning:** Sustainable landscape design considers both environmental performance and human experience. It emphasizes accessibility, functionality, aesthetic quality, and long-term adaptability. Its omission in GBI reveals a potential gap that could be addressed to support a more holistic assessment of landscape quality.
- vi. **Materials:** The selection of environmentally responsible materials such as recycled, locally sourced, or low-impact alternatives can significantly reduce the carbon footprint of landscape projects. This criterion promotes circular economy principles and aligns with sustainable construction standards (World Green Building Council, 2022).
- vii. **Maintenance:** Long-term maintenance is crucial for ensuring that landscapes remain functional, attractive, and sustainable over time. This criterion encourages life-cycle thinking and supports consistent upkeep aligned with sustainability principles, such as integrated pest management and resource-efficient operations.
- viii. **Water Efficiency:** Water efficiency is a critical concern, particularly in regions facing water stress. This criterion promotes the adoption of water-saving strategies, such as drought-tolerant plantings, rainwater harvesting, and efficient irrigation systems, contributing to the conservation of this vital resource.
- ix. **Innovation / Initiatives:** The inclusion of innovation fosters the continuous evolution of sustainable practices. It encourages developers and designers to explore novel techniques, pilot projects, and community-based solutions to meet emerging challenges and improve environmental outcomes

Analysis of Sub-Criteria

The sub-criteria from the comparative review of three major assessment tools Green Building Index (GBI), Sustainable Sites Initiative (SITES), and BCA Green Mark reveal additional dimensions of sustainability that go beyond the primary criteria. These sub-criteria offer critical insights into the broader scope of sustainable landscape development and its integration with environmental, social, and operational factors.

Table 4: Summary Comparison Criteria between SITES, Greenmark, GBI

No.	CRITERIA	GREEN MARK	SITES	GBI
1	Education & Performing Monitoring		✓	
2	Transportation			
3	Energy Efficiency	✓		✓
4	Site Context		✓	
5	Design		✓	
6	Park Management	✓		

- i. **Education & Performance Monitoring:** This sub-criterion, highlighted in SITES, focuses on increasing awareness among stakeholders and ensuring continuous evaluation of landscape performance. It emphasizes the importance of knowledge-sharing, capacity-building, and long-term monitoring to adapt and maintain sustainability practices effectively.

- ii. **Transportation:** Incorporated in GBI, this criterion underscores the role of sustainable transportation in reducing carbon emissions, promoting connectivity, and encouraging non-motorized travel options such as cycling and walking within developments.
- iii. **Energy Efficiency:** Acknowledged by both Green Mark and GBI, this sub-criterion supports the integration of energy-saving measures such as efficient lighting, renewable energy sources, and strategic planting for passive cooling contributing to the overall energy performance of the site.
- iv. **Site Context:** Recognized in SITES, this sub-criterion ensures that landscape designs respond to their unique environmental, cultural, and topographical contexts. It promotes place-based solutions and minimizes ecological disruption.
- v. **Design:** Also emphasized in SITES, design is fundamental to developing resilient, inclusive, and multifunctional landscapes. It incorporates user needs, aesthetic values, and environmental functionality, fostering long-term sustainability and public engagement.
- vi. **Park Management:** Included in Green Mark, this criterion highlights the importance of systematic and inclusive management of public green spaces to ensure safety, accessibility, ecological balance, and long-term community benefits.

RESULT

The document analysis conducted on three prominent sustainable assessment tools Sustainable Sites Initiative (SITES), Green Building Index (GBI), and BCA Green Mark have identified a set of key criteria that are highly relevant and applicable for the development of a Landscape Sustainability Assessment Conceptual Framework in the Malaysian context.

The findings highlight the importance of a holistic and integrated approach in sustainable landscape development. Adopting a comprehensive framework that includes critical criteria such as construction, conservation, site planning, vegetation and greenery, design, materials, maintenance, water efficiency, and innovation ensures that all dimensions of sustainability environmental, social, and economic are addressed effectively.

This comparative evaluation provides significant value for Malaysia's sustainable development agenda, particularly in guiding the formulation of standardized policies and practices across regions. The adaptation of globally recognized tools such as SITES and Green Mark, tailored to local environmental conditions, cultural values, and socio-economic needs, enhances the framework's practicality and long-term effectiveness.

Ultimately, incorporating both global best practices and context-sensitive modifications will support Malaysia in advancing resilient, inclusive, and ecologically sound landscape developments aligned with the Sustainable Development Goals (SDGs 11, 13, and 15). Figure below shows a framework reflects a comprehensive and adaptable model to guide sustainable landscape development in the Malaysian context, integrating ecological, technical, and social dimensions for effective implementation and continuous improvement.

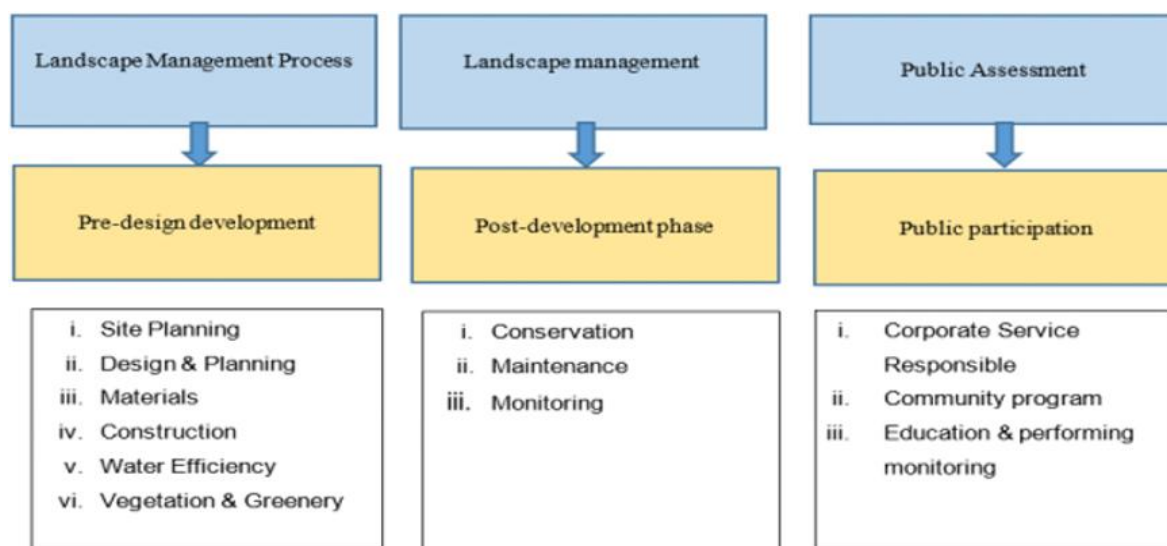


Figure 4: Comprehensive and Adaptable Model to Guide Sustainable Landscape Development

CONCLUSION

The development of the Landscape Sustainability Assessment Conceptual Framework (LSACF) represents a significant step toward advancing sustainable landscape practices in Malaysia. Anchored in the aspirations of the National Landscape Policy, particularly the vision of establishing a Beautiful Garden Nation, the LSACF provides a structured, holistic framework that encompasses all key phases of landscape development pre-design, implementation, post-development management, and public participation.

This framework integrates essential sustainability criteria such as construction, conservation, site planning, water efficiency, vegetation, maintenance, and innovation, thereby promoting balanced development that is ecologically responsible, socially inclusive, and economically viable. To ensure the framework's practical relevance and effectiveness, further research is required to identify, define, and validate specific indicators for each criterion. These indicators will serve as measurable benchmarks, enabling more consistent application and assessment across diverse development contexts.

Moreover, the alignment of the LSACF with the United Nations Sustainable Development Goals (SDGs) significantly enhances Malaysia's capacity to contribute meaningfully to Agenda 2030. Specifically, it supports progress toward SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 15 (Life on Land) by embedding sustainability at the core of landscape planning and management.

In conclusion, the LSACF not only strengthens national landscape governance but also positions Malaysia as a forward-looking nation committed to integrated, inclusive, and sustainable development both locally and globally.

ACKNOWLEDGEMENT

The utmost appreciation is extended for the comments provided by the reviewers regarding the paper entitled "Landscape Sustainability Assessment Tools," which is an independent

research effort without specific funding, and gratitude is expressed for the opportunity to share these findings. *The authors confirm contribution to the paper as follows:*

Study conception and design:

Author 1, Author 2;

Data collection:

Author 1;

Analysis and interpretation of results:

Author 1, Author 3

Draft manuscript preparation: Author 1, Author 2, Author 3.

All authors reviewed the results and approved the final version of the manuscript

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

(Authors must disclose any use of generative AI or AI-assisted technologies in the preparation of their manuscript. This includes assistance with language refinement, content generation, or any other part of the writing process). During the preparation of this manuscript, the author(s) used OpenAI's ChatGPT to assist in improving the readability and language of the text. All content generated by ChatGPT was subject to thorough review, editing, and revision by the author(s) to ensure its accuracy, completeness, and alignment with the research objectives. The author(s) take full responsibility for the integrity and content of the published work. This declaration complies with ICGESD 2025 guidelines on the use of generative AI in scientific writing.

REFERENCES

- Ameen, R. F. M., Mourshed, M., & Li, H. (2021). A Critical Review of Environmental Assessment Tools for Sustainable Urban Design. *Environmental Impact Assessment Review*, 86, 106505. <https://doi.org/10.1016/j.eiar.2020.106505>
- Chong, H. Y., Abdullah, M. F., & Nasir, N. M. (2022). *Evaluating the Limitations of Current Green Assessment Tools in Malaysia: A Landscape Development Perspective*. *Journal of Sustainable Development*, 15(1), 58–72.
- Conroy, M. M., & Berke, P. R. (2004). What Makes a Plan Environmentally Sustainable? *Environment and Planning A*, 36(8), 1381–1396. <https://doi.org/10.1068/a367>
- ILAM. (2023). *Landscape Architecture in Malaysia: Strategic Directions and Policy Integration*. Institute of Landscape Architects Malaysia. <https://www.ilamalaysia.org>
- Hassan, R., Mohd Noor, N., & Ramli, Z. (2022). Landscape Sustainability in Malaysia: A Framework for Policy and Implementation. *Malaysian Journal of Sustainable Environment*, 9(2), 45–60. <https://doi.org/10.24191/myse.v9i2.12345>
- Khalili, N. R. (2011). *Practical Sustainability: From Grounded Theory to Emerging Strategies*. Palgrave Macmillan.
- Lee, T. Y., & Zainuddin, M. A. (2023). *Localizing Global Sustainability Assessment Frameworks: Insights from Malaysian Green Infrastructure Initiatives*. *Asian Journal of Environment & Sustainability*, 7(3), 111–127.
- Lu, Y., Zhang, X., Zhang, X., Wang, C., & Wang, L. (2022). Evaluation of Urban Sustainability using Dynamic and Future-focused Frameworks. *Sustainable Cities and Society*, 76, 103480. <https://doi.org/10.1016/j.scs.2021.103480>
- MGBC. (2023). *Green Building Index: Driving Sustainability in Malaysia*. Malaysian Green Building Council. <https://www.greenbuildingindex.org>
- Naji, A., & Gwilliam, J. (2016). Sustainability Indicators for Urban Development: A Future-Focused Approach. *Sustainable Cities and Society*, 26, 255–267.
- National Landscape Department. (n.d.). *Corporate Information*. Ministry of Housing and Local Government Malaysia. <https://www.kpkt.gov.my/>

- Nooradzhar, S. M., & Asmoni, M. N. A. M. (2024). *Sustainability in the Built Environment: Roles of Landscape Architecture in Malaysia's Future Cities*. *Built Environment Review*, 14(1), 45–61.
- Osman, M. T. (2005). *Landscape Development: Planning and Management*. Kuala Lumpur: Dewan Bahasa dan Pustaka.
- Sachs, J. D. (2015). *The Age of Sustainable Development*. Columbia University Press.
- Sustainable SITES Initiative. (2020). *SITES v2 Rating System: For Sustainable Land Design and Development*. U.S. Green Building Council. <https://www.sustainable-sites.org/>
- Tater, M., Henderson, P., & Kaur, N. (2024). *Landscapes in Flux: Understanding the Cultural and Ecological Dynamics of Landscape Change*. *Global Environmental Perspectives*, 9(1), 33–49.
- UNEP. (2023). *Making Peace with Nature: A Scientific Blueprint to Tackle the Climate, Biodiversity and Pollution Emergencies*. United Nations Environment Programme.
- United Nations. (2023). *Sustainable Development Goals Report 2023*. <https://unstats.un.org/sdgs/report/2023/>
- United Nations. (2024). *The Sustainable Development Goals Report 2024*. United Nations Department of Economic and Social Affairs. <https://sdgs.un.org/goals>
- World Green Building Council. (2023). *Bringing Embodied Carbon Upfront: Coordinated Action for the Building and Construction Sector to Tackle Embodied Carbon*. <https://www.worldgbc.org>
- Wu, J. (2021). *Landscape Sustainability Science: Integrating Ecosystem Services, Landscape Ecology, and Sustainability Science*. *Landscape Ecology*, 36(2), 239–257. <https://doi.org/10.1007/s10980-020-01114-9>
- Zuo, J., Zhao, Z. Y., & Zhao, X. (2023). Integration of Sustainable Development Goals into Landscape Planning: A Global Perspective. *Landscape and Urban Planning*, 236, 104284. <https://doi.org/10.1016/j.landurbplan.2023.104284>

KETERANGAN BERKENAAN PENULIS

Nur Azemah Aminludin

Pensyarah Utama,
Department of Agrotechnology and Bio-Industry,
Politeknik Nilai, Kompleks Pendidikan Bandar Enstek
71760 Bandar Enstek,
Negeri Sembilan.
azemah.amin@gmail.com

Siti Norzaemah Mohd Rashid

Pensyarah Kanan
Department of Civil Engineering,
Politeknik Sultan Idris Shah,
Sungai Lang, 45100 Sungai Air Tawar, Selangor
sitinorzaemah@staff.psis.edu.my

Nur Izdiha Sulaiman

Pensyarah,
Department of Agrotechnology and Bio-Industry,
Politeknik Nilai, Kompleks Pendidikan Bandar Enstek
71760 Bandar Enstek,
Negeri Sembilan.
izdiha@polinilai.edu.my

REKOD PENERBITAN JTSS

1. Jurnal Teknikal dan Sains Sosial Edisi 1/ Jun 2014
Terbitan Jabatan Pendidikan Politeknik & Politeknik Banting Selangor
2. Jurnal Teknikal dan Sains Sosial Edisi 2/ Disember 2014
Terbitan Jabatan Pendidikan Politeknik & Politeknik Sultan Salahuddin Abdul Aziz Shah
3. Jurnal Teknikal dan Sains Sosial Edisi 3/ Jun 2015
Terbitan Jabatan Pendidikan Politeknik & Politeknik Sultan Azlan Shah
4. Jurnal Teknikal dan Sains Sosial Edisi 4/ Disember 2015
Terbitan Jabatan Pendidikan Politeknik & Politeknik Banting Selangor
5. Jurnal Teknikal dan Sains Sosial Edisi 5/ Jun 2016
Terbitan Jabatan Pendidikan Politeknik & Politeknik Sultan Azlan Shah
6. Jurnal Teknikal dan Sains Sosial Edisi 6/ Disember 2016
Terbitan Jabatan Pendidikan Politeknik & Politeknik Nilai Negeri Sembilan
7. Jurnal Teknikal dan Sains Sosial Edisi 7/ Jun 2017
Terbitan Jabatan Pendidikan Politeknik & Politeknik Sultan Idris Shah
8. Jurnal Teknikal dan Sains Sosial Edisi 8/ Disember 2017
Terbitan Jabatan Pendidikan Politeknik & Politeknik Metro Kuala Lumpur
9. Jurnal Teknikal dan Sains Sosial Edisi 9/ Mac 2020
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
10. Jurnal Teknikal dan Sains Sosial Edisi 10/ Julai 2020
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
11. Jurnal Teknikal dan Sains Sosial Edisi 11/ November 2020
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
12. Jurnal Teknikal dan Sains Sosial Jilid 1, Edisi 12/ Mac 2021
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
13. Jurnal Teknikal dan Sains Sosial Jilid 2, Edisi 12/ Mac 2021
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
14. Jurnal Teknikal dan Sains Sosial Jilid 1, Edisi 13/ Julai 2021
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
15. Jurnal Teknikal dan Sains Sosial Jilid 1, Edisi 14/ November 2021
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
16. Jurnal Teknikal dan Sains Sosial Jilid 2, Edisi 14/ November 2021
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
17. Jurnal Teknikal dan Sains Sosial Jilid 1, Edisi 15/ Mac 2022
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
18. Jurnal Teknikal dan Sains Sosial Jilid 1, Edisi 16/ Julai 2022
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
19. Jurnal Teknikal dan Sains Sosial Jilid 1, Edisi 17/ November 2022
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
20. Jurnal Teknikal dan Sains Sosial Jilid 1, Edisi 18/ Jun 2023
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
21. Jurnal Teknikal dan Sains Sosial Jilid 2, Edisi 18/ Jun 2023
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
22. Jurnal Teknikal dan Sains Sosial Edisi 19/ November 2023
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
23. Jurnal Teknikal dan Sains Sosial Edisi 20/ Jun 2024
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
24. Jurnal Teknikal dan Sains Sosial Jilid 1 Edisi 21/ November 2024
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik

25. Jurnal Teknikal dan Sains Sosial Edisi 22/ Jun 2025
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik
26. **Jurnal Teknikal dan Sains Sosial Jilid 1 Edisi 23/ November 2025**
Terbitan Politeknik Nilai Negeri Sembilan, Jabatan Pendidikan Politeknik



SENARAI PENYUMBANG ARTIKEL JTSS 1-23 (240 ARTIKEL)

1.	Universiti Kebangsaan Malaysia	63 Artikel
2.	Politeknik Nilai Negeri Sembilan	41 Artikel
3.	Universiti Pendidikan Sultan Idris	17 Artikel
4.	Politeknik Sultan Salahuddin Abdul Aziz Shah	9 Artikel
5.	Politeknik Sultan Idris Shah	8 Artikel
6.	Universiti Teknologi Malaysia	8 Artikel
7.	Universiti Islam Antarabangsa Selangor	8 Artikel
8.	Politeknik Banting Selangor	6 Artikel
9.	Universiti Sains Islam Malaysia	6 Artikel
10.	Politeknik Ungku Omar	6 Artikel
11.	IPGM Kampus Pendidikan Islam Bangi	5 Artikel
12.	Universiti Putra Malaysia	4 Artikel
13.	Politeknik Sandakan Sabah	4 Artikel
14.	IPGM Kampus Sultan Abdul Halim	3 Artikel
15.	Politeknik Negeri Medan Indonesia	3 Artikel
16.	Politeknik Sultan Haji Ahmad Shah Pahang	2 Artikel
17.	Politeknik METrO Johor Bahru	2 Artikel
18.	Universiti Malaysia Kelantan	2 Artikel
19.	Universiti Pertahanan Nasional Malaysia	2 Artikel
20.	Kolej Komuniti Sabak Bernam	2 Artikel
21.	Kolej Komuniti Cawangan Hulu Terengganu	2 Artikel
22.	Politeknik Mersing Johor	2 Artikel
23.	Politeknik Ibrahim Sultan	2 Artikel
24.	Politeknik Merlimau Melaka	2 Artikel
25.	Universiti Tun Hussein Onn Malaysia	1 Artikel
26.	Politeknik Sultan Mizan Zainal Abidin	1 Artikel
27.	Politeknik Kota Kinabalu	1 Artikel
28.	Politeknik Tuanku Syed Sirajuddin	1 Artikel
29.	Politeknik Metro Kuala Lumpur	1 Artikel
30.	Politeknik Pasir Gudang	1 Artikel
31.	Politeknik Tuanku Sultanah Bahiyah	1 Artikel
32.	Politeknik Port Dickson	1 Artikel
33.	Politeknik Hulu Terengganu	1 Artikel
34.	Kolej Komuniti Cawangan Maran	1 Artikel
35.	Kolej Komuniti Cawangan Melaka	1 Artikel
36.	Kolej Komuniti Cawangan Jasin	1 Artikel
37.	Kolej Komuniti Cawangan Pasir Gudang	1 Artikel
38.	Kolej Komuniti Cawangan Kota Tinggi	1 Artikel
39.	Kolej Komuniti Cawangan Arau	1 Artikel
40.	Kolej Komuniti Cawangan Kluang	1 Artikel
41.	Kolej Komuniti Cawangan Tanjung Piai	1 Artikel
42.	Universiti Teknikal Malaysia Melaka	1 Artikel
43.	Universiti Teknologi MARA Shah Alam	1 Artikel
44.	Universiti Teknologi MARA Cawangan Pulau Pinang	1 Artikel
45.	Universiti Teknologi MARA Cawangan Jengka, Pahang	1 Artikel



46.	Universiti Malaysia Sabah	1 Artikel
47.	Ministry of International Trade & Industry (MITI)	1 Artikel
48.	Hospital Kuala Lumpur	1 Artikel
49.	SK Semenggok, Kuching, Sarawak	1 Artikel
50.	IPG Kampus Ilmu Khas	1 Artikel
51.	KUPU Seri Begawan, Negara Brunei Darussalam	1 Artikel
52.	University College MAIWP International	1 Artikel
53.	State University of Malang, Indonesia	1 Artikel



SENARAI PEWASIT (SEMASA)

- | | |
|---|---|
| 1. Dr. Hjh. Nor Hayati Fatmi Talib | PNS (Pend. Islam/ Penilaian & Pengukuran) |
| 2. Dr. Wan Nor Aishah Wan Omar | PNS (TESL) |
| 3. Dr. Yusni Mohamad Yusak | PNS (Pend. Islam/ Tahfiz) |
| 4. Dr. Nur Farahin Afiqah Daud | PNS (Perdagangan) |
| 5. Dr. Siti Nurfazilah Abdul Rahman | PNS (Agroteknologi) |
| 6. Dr. Narizan Abdullah | PNS (Perdagangan) |
| 7. LAr. Dr. Fara Diba Badrul Hisham | PNS (Agroteknologi) |
| 8. Dr. Nor Rahimy Khalid | PNS (Perdagangan) |
| 9. Dr. Ahmad Razimi Mat Lazim | PNS (Kejuruteraan Mekanikal) |
| 10. Prof. Dr. Azmil Hashim | UPSI (Pend. Islam/ Tahfiz) |
| 11. PM. Dr. Norhisham Muhamad | UPSI (Sains Sosial/ Pend. Islam) |
| 12. PM. Dr. Mazdi Marzuki | UPSI (Geografi/ Alam Sekitar) |
| 13. Dr. Abu Zarrin Selamat | UPSI (Pend. Islam/ TITAS) |
| 14. PM. Dr. Ridzwan Che Rus | UPSI (TVET) |
| 15. PM. Dr. Charanjit Kaur Swaran Singh | UPSI (TESL) |
| 16. Dr. Harleny Abd. Arif | UPSI (Seni) |
| 17. PM. Dr. Hamidah Yamat | UKM (TESL) |
| 18. Dr. Azizi Umar | UKM (Pend. Islam/ TITAS) |
| 19. Dr. Nasruddin Yunos | UKM (Pend. Islam/ TITAS) |
| 20. PM. Dr. Ahmad Munawar Ismail | UKM (Peng. Islam) |
| 21. PM. Dr. Hamdi Ishak | UKM (Peng. Islam/ B. Arab) |
| 22. PM. Dr. Latifah Abdul Majid | UKM (Peng. Islam/ Falsafah) |
| 23. Dr. Halim Razali | UKM (Kejuruteraan Tenaga Solar/TVET) |
| 24. Pof. Dr. Asmawati Suhid | UPM (Pend. Islam/ Pendidikan) |
| 25. PM. Dr. Ahmad Tarmizi Talib | UPM (Sosiologi) |
| 26. PM. Dr. Roselina Karim | UPM (Teknologi Makanan) |
| 27. PM. Dr. Kamaruzzaman Abd Ghani | UMK (Pend. Islam/ B. Arab) |
| 28. Ts. Dr. Md. Ashlyzan Razik | UMK (Pengurusan Perniagaan/ TVET) |
| 29. Dr. Noor Hisham Md Nawi | UMK (Pend. Islam/ B. Arab) |
| 30. Dr. Mohd Mahmud@Mansor | UMK (Agroteknologi) |
| 31. PM. Dr. Noornajihan Jaafar | USIM (Pend. Islam/ Al-Quran) |
| 32. PM. Dr. Nurul Asiah Fasehah Muhamad | USIM (Pend. Islam/ Falsafah) |
| 33. Prof. Dr. Mohd Aderi Che Noh | USIM (Pend. Islam) |
| 34. LAr Dr. Noor Hayati Ismail | USIM (Agroteknologi) |
| 35. Dr. Rezki Perdani Sawai | USIM (Psikologi) |
| 36. Dr. Kamaru Salam Yusof | UNISSA (Hadith) |
| 37. Pof. Dr. Jimaain Safar | UTM Skudai (Pend. Islam/ Penilaian) |
| 38. Dr. Siti Suhaila Ihwani | UTM Kuala Lumpur (Pend. Islam) |
| 39. PM. Ts. Dr. Mohd Ahadlin Mohd Daud | UTeM (Kejuruteraan Aero) |
| 40. Ts. Dr. Md. Baharuddin Abdul Rahman | USM (TVET/ Mekanikal Pembuatan) |
| 41. Dr. Hasanuldin Mohd | UniSZA (Peng. Islam) |
| 42. Dr. Mariah Awang | UTHM (TVET) |
| 43. Dr. Mohd Aliff Mohd Nawi | UUM (Sains Sosial/ Pendidikan) |
| 44. PM Dr. Khairul Hamimah Mohd. Jodi | OUM (Peng. Islam) |
| 45. PM. Dr. Hairol Mak Din | KUIS (Pend. Islam/ TITAS) |
| 46. PM. Dr. Zetty Nurzuliana Rashed | KUIS (Pend. Islam/ Pendidikan) |
| 47. PM. Dr. Norsaleha Mohd Salleh | KUIS (Pend. Islam/ Falsafah) |
| 48. Dr. Ahmad Yunus Kasim | KUPUSB (Pend. Islam/ TITAS) |
| 49. Dr. Nurul Ajleaa Abdul Rahman | UiTM Dungun (TESL) |
| 50. Dr. Norhapizah Mohd Burhan | UiTM Jengka (Pend. Islam/ IT) |

- | | |
|--------------------------------------|---|
| 51. Dr. Azhar Ahmad | BPG KPM (Pend. Islam) |
| 52. Dr. Nur Hanani Hussin | BPI, KPM (Pend. Islam) |
| 53. Dr. Norhannan Ramli | IPG KPI (Pend. Islam) |
| 54. Dr. Hj. Bani Hidayat Mohd Shafie | IPG KPI (Pend. Islam) |
| 55. Dr. Abdul Aziz Mahayudin | IPG KPI (Pend. Islam) |
| 56. Dr. Farah Ilyani Zakaria | IPG KPI (Pend. Islam) |
| 57. Dr. Ishak Abd. Manaf | IPG KSAH (Pend. Islam) |
| 58. Dr. Hj. Emran Yunus | IPG KSAH (IT) |
| 59. Dr. Noraini Omar | IPG KTAR (Pend. Islam) |
| 60. Dr. Hj. Muhammad Nordin | Kolej Matrikulasi Perak (Pend. Islam/ Penilaian Pengukuran) |
| 61. Dr. Rashidah Md Hasan | IPG KTB (Pend. Islam) |
| 62. Dr. Nor Zanariah Talib | IAB (Peng. Islam) |
| 63. Dr. Alias Mat Saat | PIS (Pend. Islam) |
| 64. Eng. Dr. Hj. Zunuwanas Mohamad | PSA (Kejuruteraan Mekanikal/ TVET) |
| 65. Dr. Seri Bunian Mokhtar | PUO (Kejuruteraan Awam) |
| 66. Dr. Hasnim Harun | PUO (IT) |
| 67. Dr. Mazlina Jamaludin | PSIS (Pelancongan & Hospitaliti) |
| 68. Dr. Siti Nor Fartihah Zakaria | PJK (Akuakultur/ Perikanan) |
| 69. Dr. Salwa Amirah Awang | PSAS (Pend. Islam/ TESL) |
| 70. Dr. Mohd Khairul Naim Sameri | PIS (Pend. Islam) |
| 71. Dr. Tamil Moli Loganathan | PBS (Kejuruteraan Mekanikal/ TVET) |
| 72. Dr. Annafatmawaty Ismail | PSS (Perdagangan) |
| 73. Mejar Dr. Hj. M. Hamdan Abdullah | KK RTC Gopeng (Pend. Islam) |
| 74. Dr. Rokimah Mohamad | PKTM (Perdagangan) |
| 70. Dr. Mohammad Ridhwan Nordin | PMS Politeknik Muadzam Shah (Perdagangan) |
| 71. Dr. Aznida Wati Abdul Ghani | POLISAS (Perdagangan) |
| 72. Prof Zhu Fengzhao | Tongren Polytechnic University, China (Health) |
| 73. Dr. Mohd Hafiz Ali | PTSN (Kejuruteraan Mekanikal) |

BPG KPM	Bahagian Profesionalisme Guru, KPM
BPI, KPM	Bahagian Pendidikan Islam, KPM
IAB Enstek	Institut Aminuddin Baki Enstek
IPG KPI	Institut Pend Guru Kampus Pendidikan Islam
IPG KT	IPG Kampus Teknik Enstek
IPG KTAR	IPG Kampus Tun Abdul Razak
IPG KSAH	Institut Pendidikan Guru Kampus Sultan Abdul Halim
IPG KTB	Institut Pendidikan Guru Kampus Tuanku Bainun
IPGM, KPM	Institut Pendidikan Guru Malaysia, KPM
KUIS	Kolej Universiti Islam Antarabangsa Selangor
KUPUSB	Kolej Universiti Perguruan Ugama Seri Begawan
PJK	Politeknik Jeli Kelantan
PKTM	Persatuan Kedoktoran Teknikal Malaysia
PNS	Politeknik Nilai Negeri Sembilan
PPD	Politeknik Port Dickson
PSA	Politeknik Sultan Salahuddin Abd Aziz Shah
PSAS	Politeknik Sultan Azlan Shah
PSIS	Politeknik Sultan Idris Shah
PUO	Politeknik Ungku Omar
PMS	Politeknik Muadzam Shah
PSS	Politeknik Sandakan Sabah

POLISAS	Politeknik Sultan Haji Ahmad Shah
PTSN	Politeknik Tun Syed Nasir Syed Ismail
UKM	Universiti Kebangsaan Malaysia
UiTM Dungun	Universiti Teknologi Mara Dungun
UiTM Jengka	Universiti Teknologi Mara Jengka
UiTM Shah Alam	Universiti Teknologi Mara Shah Alam
UMK	Universiti Malaysia Kelantan
UNISSA	Universiti Islam Sultan Sharif Ali Brunei
UniSZA	Universiti Sultan Mizan Zainal Abidin
UPM	Universiti Putra Malaysia
UPSI	Universiti Pendidikan Sultan Idris
USIM	Universiti Sains Islam Malaysia
USM	Universiti Sains Malaysia
UTeM	Universiti Teknikal Malaysia Melaka
UTHM	Universiti Tun Hussein Onn Malaysia
UTM Skudai	Universiti Teknologi Malaysia Skudai
UUM	Universiti Utara Malaysia

