

K S L 2 0 2 5

ILMU, MUTU DAN BUDI

K O L O K I U M S I S W A Z A H L E S T A R I 2 0 2 5

“Kelestarian Merentas Disiplin,
Seimbang Membina Masa Depan”



15-16 Oktober 2025

8.30 pagi - 5.00 petang



Bilik Kuliah Utama. LESTARI UKM



Institut Alam Sekitar dan Pembangunan (LESTARI)
Universiti Kebangsaan Malaysia
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B U K U A B S T R A K
L A N J U T A N



KATA ALUAN



PROF. ChM. DR. GOH CHOO TA

Pengarah

Institut Alam Sekitar dan Pembangunan (LESTARI)

Universiti Kebangsaan Malaysia (UKM)

Salam Sejahtera,

Institut Alam Sekitar dan Pembangunan (LESTARI), Universiti Kebangsaan Malaysia (UKM), berperanan sebagai pusat penyelidikan termaju yang menumpukan kepada pembangunan lestari melalui pendekatan penyelidikan multidisiplin dan integratif. Sejak penubuhannya pada tahun 1994, LESTARI menjadi perintis dalam menggabungkan aspek sains, dasar dan masyarakat untuk menangani pelbagai isu alam sekitar dan pembangunan. Institut ini turut menekankan kepentingan penyelidikan yang berpaksikan kepada prinsip sains kelestarian serta pelaksanaan Matlamat Pembangunan Mampan (SDG), sejajar dengan aspirasi Universiti Kebangsaan Malaysia sebagai universiti watan yang menjunjung tanggungjawab terhadap kesejahteraan manusia dan alam sekitar.

Kolokium LESTARI diadakan setiap tahun sebagai wadah ilmiah untuk memperkasa wacana akademik dalam kalangan penyelidik, pelajar dan pengamal dasar. Penganjuran kolokium ini bertujuan untuk menyediakan platform bagi pembentangan hasil penyelidikan, pertukaran ilmu serta perbincangan kritikal mengenai pelbagai dimensi kelestarian. Ia bukan sekadar ruang akademik, tetapi juga satu usaha berterusan untuk menyemai budaya ilmu yang menggalakkan pemikiran rentas disiplin dan integrasi pengetahuan antara bidang sains sosial, sains semula jadi, teknologi serta dasar awam.

Tema Kolokium LESTARI 2025, "*Kelestarian Merentas Disiplin, Seimbang Membina Masa Depan,*" amat bertepatan dengan matlamat dan hala tuju LESTARI. Tema ini menyeru seluruh warga akademik dan penyelidik untuk berganding bahu membangunkan pendekatan holistik dalam memahami dan menangani cabaran kelestarian. Dengan mengintegrasikan pelbagai disiplin, kolokium ini diharap dapat melahirkan idea baharu yang menyumbang kepada pembentukan dasar, strategi dan inovasi yang menyokong keseimbangan antara pembangunan manusia dan pemeliharaan alam sekitar.

Akhir sekali, setinggi-tinggi penghargaan dirakamkan kepada semua peserta, penyelia, penilai dan jawatankuasa penganjur atas komitmen dan dedikasi mereka dalam menjayakan Kolokium LESTARI 2025. Diharapkan kolokium ini menjadi pemangkin kepada kolaborasi rentas bidang dan memperkukuh jaringan penyelidikan yang menyumbang kepada pembangunan lestari di peringkat kebangsaan dan global. Semoga usaha ini terus memperkukuh peranan LESTARI sebagai peneraju dalam bidang penyelidikan kelestarian dan tadbir urus alam sekitar di Malaysia dan rantau ini.

Sekian, Terima kasih



PRAKATA

GS. DR. AIDA SORAYA SHAMSUDDIN

Pengerusi Kolokium LESTARI 2025

Institut Alam Sekitar dan Pembangunan (LESTARI)

Universiti Kebangsaan Malaysia (UKM)

Kolokium LESTARI 2025

Tema: Kelestarian Merentas Disiplin, Seimbang Membina Masa Depan

Syukur dan setinggi-tinggi penghargaan dirakamkan atas kejayaan penganjuran Kolokium LESTARI 2025, satu platform ilmiah tahunan anjuran Institut Alam Sekitar dan Pembangunan (LESTARI), Universiti Kebangsaan Malaysia. Kolokium ini diadakan bagi memperkukuh budaya ilmu dan penyelidikan dalam kalangan warga akademik serta pelajar pascasiswazah, selaras dengan hasrat LESTARI untuk terus menjadi peneraju dalam bidang sains kelestarian dan tadbir urus mampan di peringkat nasional dan antarabangsa.

Kolokium ini berfungsi sebagai wahana penting bagi para penyelidik mempersembahkan hasil kajian, bertukar pandangan, dan membincangkan isu semasa berkaitan kelestarian dari pelbagai perspektif disiplin. Seiring dengan tema tahun ini, “Kelestarian Merentas Disiplin, Seimbang Membina Masa Depan,” kolokium ini menggalakkan pendekatan holistik dalam memahami interaksi antara manusia, alam sekitar dan pembangunan. Tema ini amat signifikan kerana ia menekankan keperluan keseimbangan antara kemajuan ekonomi, kesejahteraan sosial, dan pemeliharaan ekologi dalam usaha membina masa depan yang mampan.

Sebagai penganjur, LESTARI terus menekankan kepentingan integrasi ilmu dan kolaborasi rentas bidang dalam setiap inisiatif penyelidikan dan penganjuran ilmiah. Kolokium ini turut menjadi medium untuk memupuk jaringan penyelidikan antara pelajar, penyelia dan rakan akademik, seterusnya memperkukuh ekosistem penyelidikan yang berdaya tahan dan berimpak tinggi. Selain itu, perbincangan yang berlangsung sepanjang kolokium ini diharap dapat menyumbang kepada penjana idea baharu serta cadangan dasar yang menyokong agenda pembangunan lestari negara.

Akhir kata, saya merakamkan setinggi-tinggi penghargaan kepada Pengarah LESTARI, para felo penyelidik yang turut bertindak sebagai penilai, penyelia, ahli jawatankuasa penganjur, serta semua peserta atas komitmen dan dedikasi mereka dalam menjayakan Kolokium LESTARI 2025. Semoga kolokium ini menjadi pemangkin kepada kerjasama strategik serta terus memperkukuh peranan LESTARI sebagai institusi unggul dalam memperkasa ilmu, inovasi, dan amalan lestari di Malaysia.

Sekian, terima kasih.

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KOLOKIUUM SISWAZAH LESTARI 2025
15-16 OKTOBER 2025
BILIK KULIAH UTAMA LESTARI UKM

15 OKTOBER 2025 (RABU)

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8.35 – 8.40 pagi		Taklimat Pengerusi Kolokium Gs. Dr. Aida Soraya Shamsuddin
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Moderator: <ul style="list-style-type: none"> • Dr. Rospidah Ghazali Penilai: <ol style="list-style-type: none"> 1. Prof. Dr. Joy Jacqueline Pereira 2. Prof. Madya Dr. Saiful Arif Abdullah 3. Ts. Dr. Murnira Othman 		
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P2	9.15 – 9.40 pagi	YU BENFENG P120394 Doktor Falsafah <i>An Evolution Governance Framework for Sustainable Urban Wetland in Nanchang City, China</i>
P3	9.40 – 10.05 pagi	AMIRRUDIN BIN ABDUL KADIR P126505 Doktor Falsafah Kerangka Governans Berevolusi bagi Pengurusan Sumber Air Bersepadu di Lembangan Sungai Langat
P4	10.05 – 10.30 pagi	ASVINIDEVI A/P ARUMUGAN P125997 Doktor Falsafah The Evidence, Risk and Sustainable Management of Pharmaceutical Residues as Emerging Micropollutants in Langat River
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10.55 – 11.00 pagi		REHAT

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Moderator: <ul style="list-style-type: none"> • Prof. Madya Dr. Sharina Abdul Halim Penilai: <ol style="list-style-type: none"> 1. Prof. Dr. Muhammad Rizal Razman 2. Prof. Madya Dr. Tanot Unjah 3. Dr. Aziemah Zulkifli 		
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P7	11.25 – 11 .50 pagi	SUN XIAOQIAN P115739 Doktor Falsafah <i>Integrating Sustainable Development Elements into Interaction Design for Ocean Conservation Education in Dalian Natural History Museum, China</i>
P8	11.50 pagi – 12.15 t/hari	ANUSHA A/P MAGENDRAM P106959 Doktor Falsafah <i>Localising Sustainable Development Goals (SDGs) for the Smart Communities of Petaling Jaya, Selangor</i>
P9	12.15 – 12.40 t/hari	GAO MENGHAN P146845 Doktor Falsafah <i>Landscape Approaches for Sustainability Governance of The Yellow River Wetland, Shaanxi, China</i>
P10	12.40 – 1.05 t/hari	SURENTHARAN A/L RAMADAS P117248 Doktor Falsafah <i>Accelerating City Level Climate Action- Case Study of Penang, Malaysia</i>
1.05 t/hari – 2.25 petang		REHAT

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<p>Moderator:</p> <ul style="list-style-type: none"> • Prof. Ts. Dr. Lee Khai Ern <p>Penilai:</p> <ol style="list-style-type: none"> 1. Prof. Dr. Norhayati Ahmad 2. Prof. Dr. Sarah Aziz Abdul Ghani Aziz 3. Gs. Dr. Nurfashareena Muhamad 		
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P12	2.55 – 3.20 petang	ERNI NERINA BINTI AWANG SALLEH P131475 Doktor Falsafah <i>Strengthening the Social and Behavioural Change Communication Framework to Enhance Solid Waste Recycling Practices in Langkawi</i>
P13	3.20 – 3.45 petang	SUZLYNA BINTI ABDUL LATIB P126805 Doktor Falsafah Konsep Integrasi dalam Perancangan Program Perumahan Rakyat (PPR) ke Arah Kesejahteraan Psikologi Komuniti: Kajian Kes PPR Negeri Selangor
P14	3.45 – 4.10 petang	XU WANZHEN P131655 Doktor Falsafah <i>From Flood Prediction to Resilient Road Network Governance Under Extreme Rainfall: A Machine Learning Approach with Multi-Source Data in Central Guangzhou</i>
P15	4.10 – 4.35 petang	MOHAMMED AMRO P120825 Doktor Falsafah <i>Achieving Climate Justice through Adapting the Twin Town Relationship as a Modality to Improve the Resilience of Palestine’s Water Sector</i>
P16	4.35 – 5.00 petang	FAHAD M H KH ALAJMI P114516 Doktor Falsafah <i>Governance Challenges and Influencing Factors in Jointly Operated Cross-Border Oil and Gas Fields in the Arabian Gulf</i>

16 OKTOBER 2024 (KHAMIS)

<p>SESI 4 Tema: Inovasi Digital dan Warisan Slogan: Mengintegrasikan teknologi digital, pendidikan, dan pemuliharaan budaya ke arah masa depan lestari</p>		
<p>Moderator:</p> <ul style="list-style-type: none"> • Dr. Mir Sujaul Islam <p>Penilai:</p> <ol style="list-style-type: none"> 1. Prof. Dr. Ahmad Fariz Mohamed 2. Prof. Madya ChM. Dr. Tan Ling Ling 3. Dr. Nor Diana Mohd Idris 		
P17	8.35 – 9.00 pagi	<p>WANG ZIHAO P127127 Doktor Falsafah <i>Designing an Interactive Education Platform for the Digital Preservation of Intangible Cultural Heritage of Yangjiabu New Year Paintings, China</i></p>
P18	9.00 – 9.25 pagi	<p>LUCHENG LI P132381 Doktor Falsafah <i>Multimodal Virtual Reality for Immersive Learning in Learning Management System in Malaysia</i></p>
P19	9.25 – 9.50 pagi	<p>LIANG SHUANG P120121 Doktor Falsafah <i>Urban Agglomeration-Led Regional Development: Mechanisms and Implementation Strategies in the Jing-Jin-Ji Region</i></p>
P20	9.50 – 10.15 pagi	<p>NURULHUDA MOHAMMAD ISA P112023 Doktor Falsafah Governans Kelestarian Dalam Industri Makanan Dan Minuman di Malaysia: Kajian Kes Baker's Cottage</p>
P21	10.15 – 10.40 pagi	<p>LI XIANG P134170 Doktor Falsafah <i>Sustainable Conservation and Utilization of Religious Property: A Case Study of Longmen Grottoes</i></p>
P22	10.40 – 11.05 pagi	<p>ZHANG KEHUA P116426 Doktor Falsafah <i>A Comparative Study of Classical Chinese Gardens and Thai Gardens - Geographical and Humanistic Factors</i></p>

SESI 5 Tema: Adaptasi, Teknologi dan Kesiapsiagaan Slogan: Membina keupayaan adaptif melalui kesiapsiagaan bencana, penerimaan teknologi, dan kerangka kelestarian		
Moderator: <ul style="list-style-type: none"> Gs. Dr. Nuriah Abd Majid Penilai: <ol style="list-style-type: none"> Prof. ChM. Dr. Goh Choo Ta Dr. Minhaz Farid Ahmed Ts. Dr. Lim Chen Kim 		
P23	11.10 – 11.35 pagi	WAN ANIS AFEEQA BINTI WAN MOHAMMAD AZHAR P144464 Sarjana Sains Penilaian Risiko Banjir di Mukim Hulu Langat, Selangor
P24	11.35 pagi – 12.00 t/hari	MOHAMAD FAIZAL BIN MANSOR P132213 Sarjana Sains Meneroka Jenis-jenis Pelaksanaan Langkah Berjaga-jaga Persendirian (LBP) Secara Langkah Struktur (LS) dalam Kesiapsiagaan Banjir di Mukim Dengkil, Daerah Sepang, Selangor.
P25	12.00 – 12.25 t/hari	LOYOLA OLGA PIUS P145282 Sarjana Sastera Faktor-Faktor yang Mempengaruhi Penerimaan Teknologi Dron dalam Kalangan Petani bagi Penanaman Padi di Lembaga Kemajuan Pertanian Kemubu (KADA), Kelantan
P26	12.25 – 12.50 t/hari	FAIZ UL HASSAN P136858 Sarjana Sains <i>An Integrated Framework for Enhancing Energy Efficiency and Waste Management in Universiti Kebangsaan Malaysia (UKM)</i>
1.00 t/hari – 2.00 petang		REHAT
2.00 – 2.45 petang		Mesyuarat Jawatankuasa Pelajar LESTARI
2.45 – 3.00 petang		Rumusan - Wakil pelajar LESTARI
3.00 – 3.15 petang		Rumusan - Pengerusi Kolokium Gs. Dr. Aida Soraya Shamsuddin
3.15 – 3.40 petang		Penyampaian Hadiah/Sijil <ul style="list-style-type: none"> ➤ Abstrak Lanjutan Terbaik kategori Sarjana ➤ Abstrak Lanjutan Terbaik kategori Doktor Falsafah ➤ Pembentangan Terbaik kategori Sarjana ➤ Pembentangan Terbaik kategori Doktor Falsafah (tempat pertama) ➤ Pembentangan Terbaik kategori Doktor Falsafah (tempat kedua) ➤ Pembentangan Terbaik kategori Doktor Falsafah (tempat ketiga)
3.40 – 3.50 petang		Ucapan penutup oleh Timbalan Pengarah LESTARI Prof. Madya Dr. Sharina Abdul Halim
4.00 petang		Bersurai

**ABSTRAK
LANJUTAN
PEMBENTANG**



PEMBENTUKAN KERANGKA GOVERNANS BEREVOLUSI UNTUK PENGURUSAN SISA PEPEJAL DI PULAU LANGKAWI

Kylie Wang Ching Mun | P103374 | Doktor Falsafah

Penyelia utama: Prof. Ts. Dr. Lee Khai Ern

Penyelia bersama: Prof. Madya Dr. Sharina binti Abdul Halim

1. PENGENALAN

Pulau Langkawi merupakan destinasi pelancongan utama di Malaysia yang mengalami perubahan pesat sejak diisytiharkan sebagai pulau bebas cukai pada tahun 1987 (Langkawi Port Sdn. Bhd. 2017). Perubahan ini disokong oleh penubuhan Lembaga Pembangunan Langkawi (LADA) pada tahun 1990 yang bertanggungjawab dalam merancang pembangunan ekonomi dan pelancongan (Mohd et al. 2014). Usaha ini diperkukuh dengan hasrat kerajaan untuk menjadikan Pulau Langkawi sebagai pulau rendah karbon pertama di Malaysia menjelang tahun 2035 (Kerajaan Negeri Kedah 2022). Namun demikian, visi ini turut menyumbang kepada peningkatan jumlah pelancong yang konsisten, iaitu daripada 3.62 juta pada tahun 2015 kepada 3.92 juta pada tahun 2019, yang telah memberi tekanan kepada sistem pengurusan sisa pepejal (Lembaga Pembangunan Langkawi 2015;2019). Menurut LADA, pada tahun 2024 Langkawi telah mencatatkan kemasukan seramai 2.9 juta pelancong, iaitu jumlah tertinggi sejak pandemik COVID-19, dan dijangka menerima 3.5 juta pelancong pada tahun 2025 (New Straits Times, 2025). Peningkatan ini akan terus menyumbang kepada isu pertambahan sisa pepejal yang menimbulkan cabaran dalam kutipan, pelupusan dan rawatan sisa pepejal (Periathamby & Periaiah 2015). Dengan keadaan infrastruktur pengurusan sisa pepejal yang lemah dan tidak berkesan (Shamshiry et al. 2011), isu ini menuntut penilaian semula terhadap keberkesanan dan kesesuaian governans pengurusan sisa pepejal semasa.

2. PERMASALAHAN KAJIAN DAN SOROTON KAJIAN

Menurut Hettiarachchi et al. (2018) dalam pengurusan sisa pepejal, kemajuan pengurusan sisa pepejal masih dihalang oleh kelemahan sesebuah governans. Kajian di Pulau Langkawi menunjukkan bahawa kelemahan struktur governans telah menyumbang kepada ketidakberkesanan dalam proses kutipan dan pelupusan sisa pepejal yang sedia ada (Shamshiry et al. 2011). Antara cabaran utama yang dikenal pasti adalah tahap kesedaran penduduk yang rendah terhadap isu sisa pepejal dan kurangnya sambutan terhadap kempen kitar semula yang telah dijalankan sejak awal 2000-an (Shamshiry et al. 2012). Masalah turut berpunca daripada kelemahan penguatkuasaan oleh pihak berkuasa tempatan serta pelaksanaan dasar yang tidak berkesan (Shamshiry et al. 2011; Seow et al. 2017; Abas 2014). Dalam Pelan Pembangunan Negeri Kedah 2035, ketiadaan inisiatif pengurusan sisa pepejal menggambarkan ketidakjelasan dalam aspek penyelarasan. Keadaan ini bertambah buruk dengan ketiadaan penekanan terhadap pengurusan sisa pepejal dalam Rancangan Tempatan Daerah Langkawi 2030. Isu-isu ini menunjukkan bahawa terdapat jurang dalam governans dan peranan pihak berkepentingan dalam pengurusan sisa pepejal di Pulau Langkawi. Menurut Assche et al. (2014), susun atur governans dan keterlibatan pihak berkepentingan memberi kesan langsung terhadap keberkesanan sesebuah governans. Sehubungan itu, realiti governans sisa pepejal yang kompleks ini memerlukan penglibatan Teori Pihak Berkepentingan, Teori Penyertaan dan juga Teori Governans Berekolusi. Konfigurasi elemen dalam kerangka yang berasaskan ketiga-tiga teori ini

membolehkan kajian memahami bagaimana interaksi antara pelbagai pelakon, kuasa dan proses penyertaan membentuk landskap governans yang dinamik serta dipengaruhi oleh konteks institusi dan sejarah dasar sedia ada.

3. OBJEKTIF KAJIAN

Kajian ini mempunyai tiga objektif utama yang memfokuskan kepada pembentukan governans berevolusi bagi pengurusan sisa pepejal Pulau Langkawi. Namun begitu, dalam pembentangan kolokium kali ini hanya objektif pertama akan ditumpukan iaitu mengenal pasti halangan dalam governans pengurusan sisa pepejal.

4. KAEDAH KAJIAN

Dalam memenuhi keperluan objektif pertama, analisis kandungan dokumen telah digunakan bagi mengenal pasti halangan dalam governans pengurusan sisa pepejal di Pulau Langkawi. Dokumen rasmi daripada pelbagai peringkat kerajaan yang relevan telah dipilih, iaitu merangkumi dasar di peringkat kebangsaan dan negeri, peraturan pihak berkuasa tempatan, pelan strategik serta laporan institusi. Data dianalisis menggunakan pendekatan analisis deduktif berpandukan kerangka teori kajian. Pengekoden dilakukan secara manual dan berulang dengan catatan memo direkodkan menggunakan perisian Atlas.ti 9 bagi menghuraikan analisis secara interpretif. Bagi mencapai objektif kedua, temu bual separa berstruktur akan dijalankan dengan informan yang mewakili pelbagai peringkat kerajaan dalam governans pengurusan sisa pepejal di Pulau Langkawi. Pemilihan informan dibuat dengan menggunakan kaedah pensampelan bertujuan berdasarkan keterlibatan mereka secara langsung dalam perancangan, pelaksanaan atau pemantauan pengurusan sisa pepejal. Panduan temu bual disediakan mengikut tema utama yang berkait dengan peranan dan interaksi pihak berkepentingan dalam dan antara institusi. Data daripada temu bual dianalisis menggunakan pendekatan analisis tema bagi mengenal pasti peranan dan interaksi antara pelakon dalam governans untuk pengurusan sisa pepejal di Pulau Langkawi.

5. KEPUTUSAN DAN PERBINCANGAN

Bagi objektif pertama, hasil dapatan menunjukkan bahawa halangan governans pengurusan sisa pepejal di Pulau Langkawi boleh dikategorikan kepada lima elemen utama, iaitu peraturan, peranan, organisasi, pengetahuan dan penglibatan. Antara halangan yang didapati daripada kajian adalah pertindihan peraturan antara agensi, ketidakjelasan peranan pihak berkepentingan, pengoperasian silo antara organisasi, kekurangan akses kepada data terkini dan peranan pihak berkepentingan tidak ditakrifkan dengan jelas. Dapatan ini menjelaskan bahawa walaupun terdapat dasar dan garis panduan, pelaksanaannya masih terhalang oleh kelemahan struktur dan penyelarasan antara institusi. Halangan yang dikenal pasti turut menunjukkan bahawa struktur governans semasa terperangkap dalam kebergantungan jalan (*path dependency*) governans, seperti yang dihuraikan dalam kerangka Teori Governans Berevolusi.

6. KESIMPULAN

Daripada objektif 1 kajian dapatlah disimpulkan bahawa governans pengurusan sisa pepejal di Langkawi masih berdepan dengan pelbagai halangan institusi yang kompleks merangkumi elemen peraturan, peranan, struktur organisasi, kekangan pengetahuan dan tahap penglibatan pihak berkepentingan. Halangan ini bukan sahaja menggambarkan kelemahan dalam pelaksanaan dasar, tetapi turut menunjukkan bagaimana kebergantungan jalan dalam sistem

governans sedia ada menghalang perubahan yang lebih progresif dalam pengurusan sisa pepejal di Pulau Langkawi. Dapatan ini memberikan asas penting bagi membentuk kerangka governans yang lebih adaptif, terbuka dan sesuai dengan Pulau Langkawi yang terus berkembang dengan pesat.

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AN EVOLUTIONARY GOVERNANCE FRAMEWORK FOR SUSTAINABLE URBAN WETLANDS IN NANCHANG CITY, CHINA

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1. INTRODUCTION

Urban wetlands provide vital ecosystem services, including flood mitigation, water purification and biodiversity support. However, rapid urbanisation has led to their fragmentation and degradation in major Chinese cities (Wang et al. 2024). Although China has strengthened protection, most notably through the Wetland Protection Law of 2022, effective implementation still relies on multi-level coordination and stakeholder engagement (Deng & Jiang 2023). To address these intertwined ecological and institutional challenges, this study adopts Evolutionary Governance Theory (EGT). EGT offers a co-evolutionary lens to examine the interactions of institutions, actors and policies. Unlike other approaches, such as Adaptive Governance or the Social-Ecological Systems framework, which often encounter difficulties in addressing long-term institutional dynamics or in translating insights into practice, EGT provides a more flexible perspective. It captures cross-scale interactions and supports adaptive, integrated governance (Beunen, Van Assche & Gruezmacher 2022).

2. PROBLEM STATEMENT AND LITERATURE REVIEW

In Nanchang, recent spatial controls and wetland protection measures coexist with persistent governance challenges: institutional fragmentation, an imbalanced policy mix dominated by command-and-control instruments, and weak public participation. National reviews stress that progress since 2022 still depends on effective multi-level integration and implementation capacity (Deng & Jiang 2023). Empirical studies of Chinese coastal and urban wetland policy networks demonstrate that regulatory tools remain central, with limited integration of incentive-based or participatory instruments, thereby constraining adaptability and innovation (Yang et al. 2022). Research on policy integration further indicates that durable solutions require coherent policy mixes and attention to the political processes of integration across sectors and levels (Cejudo & Michel 2021). From a spatial perspective, long-term remote-sensing evidence reveals increasing fragmentation and declining connectivity in Chinese cities, underscoring the need to link ecological change with governance reform (Wang et al. 2024). To address these gaps, this study applies EGT to trace how institutions, actors and instruments co-evolve across spatial, temporal and administrative dimensions, thereby informing a more adaptive and inclusive governance framework for Nanchang.

3. OBJECTIVE

The overall aim of this study is to formulate an evolutionary governance framework for the sustainable management of urban wetlands in Nanchang. In pursuit of this aim, the study sets out three objectives. For this colloquium, however, the focus will be on the following: (i) to identify the governance evolution of urban wetlands in Nanchang City from spatial, temporal and administrative perspectives; and

(ii) to analyse the key issues, challenges and stakeholders involved in the governance of urban wetlands in Nanchang City.

4. METHOD

This study employed a mixed-methods approach integrating spatial–temporal and institutional analyses. For Objective 1, remote sensing imagery (Landsat 1992, 2002, 2012, 2022) and GIS quantified spatial patterns, fragmentation and connectivity, while time-series policy analysis and administrative mapping traced institutional evolution across four governance phases. For Objective 2, policy content analysis was conducted on municipal, provincial and national wetland documents (1992–2024), coded into authoritative, capacity-building and incentive-based categories using ATLAS.ti. Stakeholder mapping identified the roles of government, business, NGOs, communities, researchers and the public. To ensure validity, results were further analysed by cross-checking policy coding with spatial–temporal analyses, compared with existing studies (e.g. Yang et al., 2022), and reviewed through peer and supervisory checks.

5. RESULTS AND DISCUSSION

Spatial Patterns (Objective 1): Between 1992 and 2022, the total wetland area in Nanchang recorded a slight net increase; however, natural wetlands declined by more than 8,000 ha, while artificial wetlands expanded by nearly 9,500 ha. Landscape metrics reveal increasing fragmentation: the number of patches rose from 2,367 to 3,055, and the Largest Patch Index fell by 26.9%. The loss of connectivity and rising ecological risks highlight that rapid urban expansion has resulted in increasingly artificial and fragmented wetland landscapes.

Temporal Evolution (Objective 1): Governance has evolved through four phases: initiation (1992–2001), marked by exploratory regulations; expansion (2002–2011), with ordinances and the establishment of reserves; strengthening (2012–2021), characterised by interdepartmental projects and performance evaluations; and adjustment (2022–present), involving coordination platforms following the Wetland Protection Law. The number of policy documents grew steadily, particularly during the 2010s, alongside more frequent combinations of regulatory and capacity-building instruments.

Administrative Evolution (Objective 1): Institutional responsibilities shifted from a forestry-centred system in the 1990s to a multi-agency structure encompassing water, environment, housing and natural resources. Although this broadened scope, it also generated overlapping mandates and weak vertical coordination. The 2022 law designated the National Forestry and Grassland Administration as the lead authority, yet fragmentation continues at provincial and municipal levels.

Issues and Challenges (Objective 2): Policy analysis reveals a strong reliance on authority-based tools (57.6%), followed by capacity-building instruments (30.6%), while incentive-based mechanisms remain marginal (11.8%). Co-occurrence analysis confirms that regulatory and capacity-building tools are frequently paired, whereas incentives are poorly integrated. This imbalance constrains adaptability and innovation, reflecting a limited policy mix that undermines long-term effectiveness.

Stakeholders (Objective 2): Six categories of stakeholder's shape wetland governance. Government agencies dominate decision-making; businesses balance ecological pressures with green investments; NGOs focus on advocacy and capacity-building; communities link

governance to livelihoods; research institutions provide expertise; and the public influences awareness and participation. Nevertheless, engagement beyond government actors remains secondary. Cross-tabulation shows differentiated priorities: researchers focus on technical concerns, communities on funding and livelihoods, and NGOs and the public on oversight, indicating fragmented collaboration.

Taken together, these results demonstrate that ecological fragmentation (loss of natural wetlands and reduced connectivity) parallels institutional fragmentation (imbalanced tools, overlapping mandates and limited participation). The findings confirm that sustainable urban wetland governance requires rebalancing the policy mix, strengthening cross-sectoral coordination and expanding inclusive stakeholder engagement.

6. CONCLUSION

Wetlands in Nanchang have become increasingly fragmented and artificial, with natural areas shrinking and connectivity declining due to urban expansion. Governance remains imbalanced: authority-based tools dominate, incentives are marginal and multi-agency arrangements lack coordination. These findings reveal a dual challenge of ecological and institutional fragmentation. Addressing this requires rebalancing the policy mix, strengthening cross-sector coordination and enhancing adaptive capacity. By combining spatio-temporal and institutional analysis (Objective 1) with the analysis of governance issues and stakeholders (Objective 2), this study demonstrates the need for an evolutionary governance framework that fosters learning, coordination and inclusive participation.

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KERANGKA GOVERNANS BEREVOLUSI BAGI PENGURUSAN SUMBER AIR BERSEPADU DI LEMBANGAN SUNGAI LANGAT

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1. PENGENALAN

Teori Governans Berevolusi (EGT) melihat governans sebagai proses dinamik dan saling membentuk antara aktor, institusi dan pengetahuan. Sejak abad ke-20, pelbagai model governans seperti hierarki, pasaran dan rangkaian digunakan dalam pengurusan air; namun ketidaktentuan iklim, perbandaran dan tekanan sosio ekonomi menuntut kerangka yang lebih adaptif (Beunen et al. 2015; Van Assche et al. 2015). Pelan Pengurusan Sumber Air Bersepadu (IWRM) diiktiraf meluas tetapi terhalang dengan konteks setempat, jurang penyelarasan dan fragmentasi institusi (Molle 2009; Varady et al. 2016; Watson et al. 2019). Kajian ini menerapkan lensa EGT untuk menilai bagaimana variasi spatial, temporal dan pentadbiran dalam dinamik governans air di Lembangan Sungai Langat (LSL), serta bagaimana kerangka berevolusi dapat memperkukuh keberkesanan pelaksanaan IWRM.

2. PERMASALAHAN KAJIAN DAN SOROTAN

LSL berkeluasan 2,663 km² merangkumi dua sungai utama dan 261 anak sungai, dengan sembilan loji rawatan air serta potensi air bawah tanah 630–690 juta liter/hari serta permintaan diunjurkan mencecah 1,350 juta liter/hari menjelang 2030, manakala guna tanah merangkumi pertanian (44%) dan hutan (23%) (Ahmed et al., 2022; LUAS, 2015, 2019, 2022; Mridha et al., 2019). Pembangunan pesat menambah tekanan ke atas sumber air, menimbulkan isu pencemaran, banjir, kemerosotan zon riparian, kehilangan biodiversiti dan konflik guna tanah. Walaupun pelan pengurusan diperkenalkan sejak 2005, masalah berulang seperti pencemaran yang menyebabkan henti tugas loji rawatan, hakisan dan banjir masih dilaporkan (JPS, 2014; Ranhill, 2015; ASM, 2022; JAS, 2022). Cabaran turut berpunca daripada ketidakselarasan perundangan dan institusi. Selepas pindaan 2005, perkara pembekalan dan perkhidmatan air diletak di bawah Senarai Bersama Persekutuan-Negeri, manakala perkara sumber air kekal di bawah kuasa Negeri (Perlembagaan Persekutuan, 2005). Perkhidmatan air dikawal selia oleh Persekutuan melalui Suruhanjaya Perkhidmatan Air Negara (SPAN) di bawah Akta 654 dan WSIA 2006 (Akta 655), sementara pencemaran sumber air dalam sempadan negeri tertakluk kepada undang-undang negeri (contoh Enakmen LUAS 1999). Kesan praktikalnya adalah penyelarasan rentas bidang kuasa yang kompleks, menyumbang kepada 55 insiden pencemaran yang mengganggu bekalan antara 2016 sehingga 2022. Dalam konteks ini, pendekatan IWRM dan adaptasi kerangka dialog (sains, dasar dan masyarakat) memberi panduan, namun rintangan penyelarasan masih ketara (Mokhtar & Tan, 2011; Pollard et al., 2023; Lukat et al., 2023; Elfithri et al., 2017). Persoalan utama kajian: (i) bagaimana perubahan governans air di LSL difahami melalui dimensi spatial, temporal dan pentadbiran sejak 2001; (ii) apakah peranan aktor (negeri, bukan negeri, hibrid), bentuk pengetahuan (saintifik, teknikal, tempatan, tradisional, pengalaman) dan fragmentasi (institusi, dasar, aktor, wilayah) dalam membentuk dinamik

governans; (iii) apakah jurang kerangka sedia ada yang menjejaskan keberkesanan IWRM; dan (iv) bagaimana kerangka berevolusi untuk masa hadapan dapat dibangunkan.

3. OBJEKTIF KAJIAN

Tiga objektif telah digariskan: 1) Menenal pasti isu dan cabaran governans air di LSL secara spatial, temporal dan pentadbiran; 2) Menganalisis peranan aktor, institusi, kuasa dan pengetahuan serta peraturan formal-tidak formal; 3) Membentuk kerangka governans berevolusi untuk pengurusan sumber air bersepadu yang lebih adaptif, inklusif dan peka konteks setempat (selaras prinsip IWRM).

4. KAEDAH KAJIAN

Bagi menjawab objektif pertama, kajian ini menggunakan pendekatan kualitatif digunakan. Pertama, carian kepustakaan (2000–2022) di SCOPUS dan Web of Science menghasilkan korpus awal yang kemudiannya ditapis kepada sekitar 24 artikel yang relevan dengan sebab akibat isu governans. Pencarian ini bertujuan mengenal pasti isu berkaitan air dalam lembangan sungai merentasi lima dimensi utama dengan menggunakan kata kunci seperti “bekalan air dan sanitasi”, “permintaan air”, “faktor sosio-ekonomi” dan “tadbir urus air”. Kedua, analisis tematik menggunakan ATLAS.ti dilengkapi dengan semakan silang dokumen rasmi Kerajaan IRBM Langat 2022–2030, Pelan Pengurusan LSL 2015–2020, Laporan Kualiti Alam Sekeliling 2022 dan Pelan Transformasi Sektor Air 2040 serta pemetaan secara spatial dan temporal dengan menggunakan GIS. Ketiga, temu bual separa berstruktur secara dalam talian melibatkan 14 informan mewakili PETRA, MOSTI, JPS, JPP, KIMIA, JAS, JMG, LUAS, JPSM, SPAN, IWK, Air Selangor dan MyWP untuk mengesahkan dapatan dan mengenal pasti jurang governans di peringkat dasar, institusi dan pelaksanaan.

5. KEPUTUSAN DAN PERBINCANGAN

Kajian ini dilaksanakan bagi menjawab tiga objektif utama yang saling melengkapi. Bagi objektif pertama, analisis tematik berasaskan kepustakaan dan dokumen rasmi digunakan untuk mengenal pasti isu serta cabaran governans air di Lembangan Sungai Langat dari tahun 2001 hingga kini. Pencarian artikel dalam pangkalan data SCOPUS dan Web of Science bagi tempoh 2000–2022 menghasilkan 75 artikel, namun selepas proses tapisan hanya 24 artikel yang memenuhi kriteria sebab dan kesan dipilih untuk dianalisis menggunakan perisian ATLAS.ti. Analisis ini turut disokong dengan dokumen sah kerajaan, seperti Pelan Pengurusan Lembangan Sungai Langat 2015–2020, IRBM Langat 2022–2030, Laporan Kualiti Alam Sekeliling 2022, serta Pelan Transformasi Sektor Air 2040. Dapatan menunjukkan sebelas cabaran utama berkaitan governans, termasuk fragmentasi pengetahuan (tempatan, peribumi, saintifik, teknikal dan pengalaman), kepelbagaian aktor (negeri, bukan negeri dan hibrid), serta pertembungan institusi, dasar, kapasiti dan pentadbiran.

Selain analisis tematik, penggunaan Sistem Maklumat Geografi (GIS) membolehkan isu dan cabaran divisualisasikan secara spatial dan temporal dalam Lembangan Sungai Langat. GIS digunakan untuk mengenal pasti pola pencemaran, kawasan berisiko banjir serta hubungan antara guna tanah, taburan penduduk dan pembangunan industri dengan tekanan terhadap sumber air. Analisis ini mendapati bahawa kawasan perindustrian dan bandar berketumpatan tinggi di sekitar Hulu Langat dan Kajang mempunyai tahap pencemaran yang lebih tinggi, manakala kawasan tadahan hulu yang pesat diteroka semakin terdedah kepada risiko banjir kilat. Corak ini menegaskan bahawa isu governans air tidak hanya bersifat institusional, tetapi turut

berakar dalam dimensi spatial yang memburukkan lagi cabaran penyelarasan dasar dan pengurusan sumber air. Antara isu kritikal yang berulang adalah pencemaran air yang menyebabkan penutupan loji rawatan berikutan kandungan logam berat, seperti aluminium, arsenik dan plumbum, serta kejadian banjir yang semakin meningkat akibat perubahan iklim dan intensiti hujan yang bertambah.

Bagi objektif kedua, kajian meneliti persepsi dan pandangan pihak berkepentingan melalui temu bual separa berstruktur yang dijalankan secara dalam talian, melibatkan 14 informan daripada agensi utama, seperti PETRA, MOSTI, JPS, JAS, LUAS, SPAN, Air Selangor, IWK dan MyWP. Analisis temu bual dijalankan dengan menggunakan ATLAS.ti dan mengesahkan bahawa pencemaran air dan banjir merupakan cabaran utama yang berulang. Informan turut menekankan bahawa kelemahan program kesedaran awam, latihan kecemasan yang tidak mencukupi, komunikasi yang lemah antara pihak berkuasa tempatan dengan masyarakat, serta kekurangan kepakaran teknologi dalam agensi yang menyebabkan kelewatan dalam pengurusan bantuan banjir. Analisis tematik mendapati cabaran berpunca daripada aktor negeri sebanyak 18.5%, manakala dimensi pengetahuan saintifik dan teknikal mendominasi 54.1%, serta pertembungan undang-undang dan dasar menyumbang 27.4%. Dapatan ini menegaskan bahawa governans air bukan hanya ditentukan oleh aspek teknikal, tetapi turut dipengaruhi oleh kuasa, struktur institusi dan penyelarasan dasar.

Akhir sekali, bagi objektif ketiga, kajian ini mencadangkan penubuhan Pihak Berkuasa Pengurusan Lembangan Sungai Langat sebagai mekanisme penyelarasan berpusat bagi menyatukan sekurang-kurangnya 13 kementerian dan 78 agensi yang kini terlibat dalam pengurusan lembangan. Cadangan ini berlandaskan EGT yang menekankan hubungan antara aktor, pengetahuan dan fragmentasi dalam membentuk peralihan governans. Kerangka yang dicadangkan bertujuan memperkukuh kerjasama rentas agensi, menangani jurang penyelarasan dasar serta pertindihan bidang kuasa, menggalakkan penglibatan aktor hibrid dan memastikan pelaksanaan IWRM dapat dijalankan secara lebih inklusif, adaptif dan berkesan pada masa hadapan.

6. KESIMPULAN

Kerumitan pertembungan undang-undang dan kepelbagaian aktor memerlukan penyelarasan institusi yang jelas, boleh dikuatkuasakan dan responsif. Mengintegrasikan pengetahuan saintifik, teknikal dengan pengetahuan tempatan serta memperluas penglibatan masyarakat dan industri akan memperkukuh legitimasi dan keberkesanan IWRM. Melalui kerangka EGT, LSL berupaya beralih kepada governans yang lebih adaptif, inklusif dan peka; sekaligus meningkatkan daya lestari terhadap risiko pencemaran dan banjir, serta menyokong kesinambungan bekalan air untuk LSL pada masa hadapan.

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THE EVIDENCE, RISK AND SUSTAINABLE MANAGEMENT OF PHARMACEUTICAL RESIDUES AS EMERGING MICROPOLLUTANTS IN LANGAT RIVER

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1. INTRODUCTION

Pharmaceutical residues are increasingly recognized as emerging micropollutants of global concern due to their bioactivity, persistence, and widespread occurrence in aquatic environments. Unlike many conventional pollutants, pharmaceuticals are designed to act at low concentrations and resist degradation, enabling them to persist in rivers, lakes, and treatment systems. Their presence is linked to risks such as antimicrobial resistance, endocrine disruption, and chronic toxicity in aquatic life and potentially in humans (Aus der Beek et al. 2016; Wilkinson et al. 2022). In Malaysia, the Langat River is a critical water source for nearly half of Selangor's population, while also supporting agriculture, industry, and recreation. With over 600 sewage treatment plants (STPs) and 11 water treatment plants (WTPs) in its catchment, the basin is highly vulnerable to contamination. However, the removal efficiency of conventional treatment remains uncertain, raising concerns about the circulation of pharmaceuticals across water matrices.

2. PROBLEM STATEMENT AND LITERATURE REVIEW

Globally, residues of pharmaceuticals such as diclofenac, carbamazepine, sulfamethoxazole, and ciprofloxacin are among the most frequently detected and persistent contaminants in aquatic environments (Kümmerer 2010; Aus der Beek et al. 2016). In Malaysia, compounds including caffeine, diclofenac, and sulfamethoxazole have been reported in rivers and sewage treatment plant effluents (Praveena et al. 2018; Wee et al. 2020). However, existing studies remain fragmented, often focusing on either surface waters or treatment plant effluents without capturing the entire pathway of contamination. This compartmentalized approach obscures the extent to which pharmaceuticals circulate through the water cycle, re-emerge downstream, and potentially return to human exposure pathways. To address this gap, the present study introduces the concept of the "pharmaceutical loop," a framework describing how residues persist through sewage influents, effluents, surface waters, and drinking water sources. Although the loop has been acknowledged in global studies, it has not been explicitly examined in Malaysia, leaving a critical evidence gap. The absence of integrated assessments limits the capacity of regulators and water managers to evaluate risks across multiple water matrices, while also obscuring the contributions of different sources such as domestic wastewater, hospital discharges, and agricultural runoff. Furthermore, the lack of systematic monitoring frameworks for pharmaceuticals in Malaysia means that the issue remains largely invisible in national water policy and governance, despite its growing recognition as a global concern (WHO 2022). By adopting an integrated water cycle perspective, this study seeks to generate cross-compartment

evidence that can improve scientific understanding while also guiding water management and governance in the Langat River Basin.

3. OBJECTIVE

This study consists of three key objectives, addressing pharmaceutical residues in aquatic environments. However, for this colloquium presentation, the focus will be on the first and second objectives: (i) to assess the occurrence and concentration of multiclass pharmaceutical residues in surface waters and effluents from STPs and WTPs in the Langat River; (ii) to evaluate the associated human health and ecotoxicological risks.

4. METHOD

To capture spatial and land-use variability, 29 strategically selected sampling stations were distributed across upstream, midstream, and downstream zones, covering surface waters (SW), STP influents/effluents, and WTP intakes. This ensured representation of minimally impacted headwaters, urbanizing midstream areas, and heavily stressed downstream stretches. Thirteen pharmaceutical active compounds representing six therapeutic classes were selected based on persistence, environmental relevance, and human health risks. Analytical procedures included solid-phase extraction followed by HPLC-MS/MS. QA/QC measures included field blanks, spiked recoveries, triplicate samples, calibration verification, and determination of method detection limits to ensure reliability and reproducibility. Physico-chemical parameters (DO, pH, conductivity, BOD, COD, SS) were measured in situ and in the laboratory to contextualize contamination levels. Human health risks were assessed using Hazard Quotient (HQ) models for adults and children, while ecological risks were evaluated via Risk Quotient (RQ), following internationally recognized methods (US EPA, 2011; Praveena et al., 2018).

5. RESULTS AND DISCUSSION

Of the 13 pharmaceuticals targeted in this study, seven compounds were detected—caffeine (CAF), hydrochlorothiazide (HTZ), chloramphenicol (CMC), ciprofloxacin (CF), diclofenac (DCF), nitrofurazone (NFZ), and amlodipine (AML) across 21 of the 29 sampling sites in the Langat River Basin. Measured concentrations ranged from 1.58 to 907.10 ng/L, with maxima observed in surface waters (907.10 ng/L), STP effluents (698.22 ng/L), and WTP influents (860.50 ng/L). Spatially, contamination was most pronounced in midstream and downstream reaches, reflecting the cumulative impact of dense population centers, industrial activities, and urban wastewater discharges. In contrast, upstream sites (SP1–SP3) showed no detectable pharmaceuticals, consistent with limited anthropogenic influence in forested headwater areas.

Caffeine (CAF) emerged as the most ubiquitous compound, detected in all STP influents and effluents, multiple surface water sites, and even WTP influents. Its persistence and widespread distribution underscore its role as a reliable tracer of domestic wastewater inputs. In contrast, antibiotics were detected less frequently but at environmentally relevant levels: ciprofloxacin (110.71–393.40 ng/L), sulfamethoxazole (24.37–210.77 ng/L), chloramphenicol (12.68–309.96 ng/L), and nitrofurazone (45.56–242.77 ng/L). Detection of nitrofurazone is particularly concerning given its global ban due to carcinogenicity, raising questions about illegal usage, legacy contamination, or inadequate regulatory enforcement. Non-antibiotic pharmaceuticals such as hydrochlorothiazide (mean 103.76 ng/L) and diclofenac (1.58–3.36 ng/L) were also prevalent, reflecting their common therapeutic use and incomplete removal during wastewater

treatment. Risk assessment based on the Hazard Quotient (HQ) approach indicated that all detected compounds had $HQ < 1$, suggesting no immediate health risks under current exposure scenarios. The highest HQ values were observed for hydrochlorothiazide (0.015) and ciprofloxacin (0.0067), while caffeine exhibited comparatively lower risk (0.00016). However, single-compound HQs fail to account for the additive or synergistic risks posed by mixtures of pharmaceuticals, a limitation particularly relevant given the frequent co-occurrence of multiple compounds. Water quality analyses further revealed gradients of anthropogenic impact. Water Quality Index (WQI) values ranged from Class I (Excellent) in pristine upstream areas to Class IV (Polluted) in influents of downstream STPs. This spatial trend, together with the pharmaceutical concentration profiles, supports the concept of a “pharmaceutical loop” whereby compounds introduced into wastewater are incompletely removed, re-emerge in surface waters, and eventually re-enter drinking water treatment systems.

6. CONCLUSION

Pharmaceuticals, intended for therapeutic use, are increasingly recognized as contaminants within aquatic environments, raising concerns for both human and ecosystem health. This study presents the first integrated assessment of pharmaceutical residues across sewage treatment plant (STP) influents and effluents, surface waters, and drinking water intakes in the Langat River Basin, Malaysia. Seven compounds including hydrochlorothiazide, ciprofloxacin, chloramphenicol, sulfamethoxazole, diclofenac, nitrofurazone, and caffeine—were consistently detected, demonstrating the persistence of a “pharmaceutical loop” in which residues bypass treatment barriers, circulate through surface waters, and re-enter potable supplies. While hazard quotient values ($HQ < 1$) indicate limited acute risk, they fail to capture the potential consequences of chronic exposure, mixture toxicity, and ecological effects. The presence of banned substances such as nitrofurazone further reflects regulatory and operational gaps. Findings underscore the need for enhanced wastewater treatment efficiency, strengthened regulatory enforcement, and upstream interventions to mitigate pharmaceutical emissions and safeguard long-term water security.

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ENHANCING WATER SECURITY THROUGH DECENTRALISED RURAL WASTEWATER MANAGEMENT USING PHOTOCATALYTIC WATER TREATMENT IN GUANGXI, CHINA

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1. INTRODUCTION

The management of rural domestic wastewater presents a significant environmental challenge in China, particularly in regions with dispersed populations and complex topography like the Guangxi Zhuang Autonomous Region. The decentralised nature of rural settlements in Guangxi makes conventional, centralised wastewater treatment systems both economically and logistically unfeasible (Chen & Wang 2020). Consequently, a substantial volume of untreated domestic wastewater is discharged directly into the environment, leading to the contamination of surface and groundwater resources, threatening public health and causing severe degradation of the rural aquatic ecosystem (h2o-china.com 2021). This issue has become a primary driver of water pollution and a critical bottleneck in the region's rural environmental remediation and revitalisation efforts (Zhao et al. 2021). Photocatalytic water treatment, an advanced oxidation process (AOP), emerges as a highly promising technology. It leverages abundant solar energy to degrade a wide range of organic pollutants and pathogens without the need for chemical additives, converting them into harmless byproducts, such as CO₂ and H₂O (Science and Technology Daily 2021). This research addresses the urgent need for effective, low-cost and sustainable wastewater treatment solutions tailored to the specific conditions of rural areas in Guangxi, China.

2. PROBLEM STATEMENT AND LITERATURE REVIEW

The core problem addressed in this research is the inadequacy of current wastewater management strategies in rural areas of Guangxi. The region's wastewater treatment rate of 9.2% during the "13th Five-Year Plan" period was significantly below the national average, and persistent challenges, including insufficient funding, a lack of technical expertise and operational difficulties with existing facilities, hindered the progress (Guangxi DEE 2022 ; Liding Environmental 2022). Conventional treatment models are often ill-suited for the variable flow rates and pollutant loads characteristic of rural wastewater, and their high operational costs frequently lead to facilities being underutilised or abandoned (CRRC 2018).

Conventional treatment models have shortcomings, such as high operational costs, large land area requirements, sensitivity to climatic conditions and lower efficiency in removing recalcitrant organic compounds and pathogens. On the other hand, photocatalytic water treatment has been extensively studied for its ability to mineralise a broad spectrum of pollutants, including pesticides, pharmaceuticals and industrial dyes (Zheng et al. 2023). The technology's reliance on semiconductor catalysts, most notably nano-TiO₂ and a light source (preferably solar), makes it an environmentally friendly AOP (MOE 2021).

Despite these advances, a significant research gap exists, whereby there is a lack of comprehensive studies focused on the design, optimisation and field application of systems that couple photocatalysis with ecological engineering (eco-ponds and ecological planting), specifically for treating decentralised rural domestic wastewater. Furthermore, most existing research has been conducted under controlled laboratory conditions, with insufficient data from real-world applications in regions like Guangxi, which possess unique environmental conditions (e.g., high solar irradiation, specific wastewater composition). This study aims to fill this gap by developing and evaluating a tailored, hybrid photocatalytic-ecological system, thereby providing a novel and practical solution to the pressing water pollution issue in the rural areas of Guangxi, China.

3. OBJECTIVE

The specific objectives for this colloquium presentation are: (i) to design and evaluate the performance of a coupled photocatalysis-eco-pond system for rural domestic wastewater in rural areas of Guangxi, China, and (ii) to analyse the synergistic effects of photocatalytic oxidation in enhancing water security in the rural areas of Guangxi, China.

4. METHOD

(i) Research Design. The research was structured around laboratory and pilot-scale experiments, involving a multi-stage treatment process where raw rural wastewater first underwent pre-treatment (screening and sedimentation) before entering the core coupled system. Two main configurations were investigated: (a) Photocatalysis-Eco-Pond, (b) Photocatalysis-Constructed Wetland. The performance of these coupled systems was benchmarked against control groups to quantify the synergistic effects.

(ii) Qualitative Analysis. Systematic Literature Review: A review of academic journals, conference proceedings, patents and government reports were conducted to build a theoretical framework. Case Study Analysis: An analysis of existing rural wastewater treatment projects, such as the “photocatalysis-eco-pond” system implemented in villages in Guangxi, China.

(iii) Quantitative Analysis

Experimental Measurement: Key water quality parameters, including Chemical Oxygen Demand (COD), Ammonia Nitrogen ($\text{NH}_4^+\text{-N}$), Total Nitrogen (TN) and Total Phosphorus (TP), were measured in the influent and effluent of all experimental units. Statistical Analysis: The collected data were analysed using statistical software (e.g., SPSS). Analysis of Variance (ANOVA) was used to determine the statistical significance of different operational parameters (e.g., hydraulic retention time, light intensity) on pollutant removal efficiency.

(iv) Mixed-Methods Analysis

Triangulation: The findings from the qualitative case studies and literature review were used to contextualise and validate the quantitative experimental results. A holistic interpretation was achieved by synthesising quantitative data with qualitative observations.

5. RESULTS AND DISCUSSION

Based on laboratory analysis of the performance of the coupled systems, the findings are presented below:

(i) Performance of the Photocatalysis-Eco-Pond System

Using synthetic rural domestic wastewater (COD~300mg/L, NH₄⁺-N~30 mg/L) and an HRT of 24 hours, the coupled photocatalysis-eco-pond system demonstrated a remarkable improvement in performance compared to a control eco-pond. The system increased the COD reduction efficiency from approximately 60% to 75%. Similarly, NH₄⁺-N removal rose from 50% to 65%.

(ii) Performance of the Photocatalysis-Constructed Wetland System

Using actual rural domestic wastewater, comparing with the control sample, the COD reduction efficiency increased from 80% in the control to 88% in the photocatalytic constructed wetland. And NH₄⁺-N removal improved from 70% to 80%. A modest improvement in TP removal was also noted.

6. CONCLUSION

This study outlines the critical need for advanced, decentralised wastewater treatment solutions in rural areas of Guangxi, China. The research has successfully demonstrated, on a laboratory scale, the feasibility and effectiveness of coupling photocatalytic water treatment with ecological engineering methods (eco-ponds and constructed wetlands). Preliminary results confirm that these hybrid systems achieve significantly higher removal efficiencies for key pollutants like COD and ammoniacal nitrogen compared to standalone ecological systems. The findings highlight the synergistic mechanisms at play, where photocatalysis enhances the biodegradability of wastewater and improves the conditions for subsequent biological treatment. Foundational data have been established, and key pathways for process optimisation have been identified, providing a solid basis for enhancing water security.

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INTEGRATING DUAL-CARBON APPROACH INTO THE GOVERNANCE FOR URBAN STORMWATER MANAGEMENT OF SPONGE CITY IN TONGZHOU, CHINA

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1. INTRODUCTION

As urbanisation accelerates and extreme climate events become more frequent, cities face growing compound water-related risks (Hettiarachchi, Wasko & Sharma 2018). Since being formally incorporated into global climate governance via the 2015 Paris Agreement and the 2030 Agenda, Nature-based Solutions (NbS), such as urban wetlands, green roofs and permeable pavements, harnessing natural processes for water management and co-benefits, have gained prominence for their dual role in ecological restoration and urban flood resilience (Biasin et al. 2023). China, one of the countries most affected by urban flooding, launched the Sponge City initiative in 2015 to address pluvial floods and enhance water resilience (Liu & Fan 2023). Since the 2020 launch of China's dual-carbon strategy (Wang, Xing & Jiang 2022), the initiative has been further aligned with carbon mitigation goals, becoming integral to climate-resilient urban infrastructure (Zheng et al. 2024). As a second-batch Sponge City pilot project and key site for Beijing's expansion, the Tongzhou District plays a leading role in green development (Xu et al. 2025). This underscores the critical importance of governance mechanisms for climate-resilient urban stormwater management.

2. PROBLEM STATEMENT

While the Sponge City initiative in China is gradually being institutionalised at the policy level, significant challenges remain in terms of institutional coordination and evaluation frameworks (Yuan et al. 2024). Firstly, current institutional frameworks lack the flexibility to support dynamic, cross-sectoral governance of evolving urban stormwater systems. Secondly, existing evaluations focus narrowly on engineering outcomes, overlooking the broader ecological, adaptive and carbon mitigation benefits of NbS (Xu et al. 2025; Yuan et al. 2024). Moreover, performance indicators are insufficiently integrated and lack temporal and spatial comparability, limiting their application for policy feedback and cross-regional replication. To address institutional challenges in Tongzhou's Sponge City development, this study proposes the Nature-based Solution for Urban Climate Adaptive Stormwater Management Index (NUCASI) framework, an integrated tool built based on institutional theory (Scott 2014) and evolutionary governance theory (Beunen, Van Assche & Duineveld 2015), to support multi-objective NbS evaluation and guide urban green transition under China's dual-carbon strategy.

3. OBJECTIVE

This study examines governance transitions in urban stormwater management in the context of China's dual-carbon strategy and Sponge City policy, with a focus on Tongzhou District,

Beijing. It focuses on two main objectives: (i) to identify the key issues, challenges and stakeholders in urban stormwater management within the context of dual-carbon goals and Sponge City initiative in Tongzhou City, China, (ii) to analyse the spatial, temporal and administrative evolution of governance for urban stormwater management under the Sponge City initiative in Tongzhou City, China. This study proposes the NUCASI framework, providing a structured basis for addressing Objective 1 and supporting further analysis of governance evolution for Objective 2.

4. METHOD

This study first conducted a systematic literature review to identify the indicators for the NUCASI framework in evaluating the multidimensional performance of urban stormwater management under China's dual-carbon strategy and the Sponge City initiative. Following PRISMA (Page et al. 2021), literature screening via Web of Science and Scopus, covering climate adaptation, stormwater management and Nature-based Solutions. In total, 4,104 records were retrieved; after deduplication, 2,375 remained for initial screening. From the selected literature, policy-relevant indicators were identified and refined against three criteria: data availability, spatiotemporal comparability and cross-scale applicability, yielding five dimensions, 18 primary indicators and nine alternatives. To achieve Objective 1, qualitative content analysis of policy and procurement documents was conducted, and an event timeline from official and public social-media sources was compiled. For Objective 2, the NUCASI framework was applied to map change nodes and responsibility shifts, periodise governance to compute Tongzhou's 2014–2024 NUCAS index and assess trends.

5. RESULTS AND DISCUSSION

The NUCASI framework was built on the five-dimensional NbS framework by IUCN (2020), the European Commission's 12 Societal Challenges (European Commission, 2021) and the City Resilience Framework by Arup and The Rockefeller Foundation (2024). It integrates insights from 63 empirical studies to ensure both theoretical soundness and practical relevance. Each indicator includes defined input variables, normalisation methods and literature-based tipping points, enabling a structured, quantitative assessment of urban stormwater and flood management. The standard procedure involves input collection, indicator calculation, weight assignment, index aggregation and sensitivity analysis. While equal weighting is the default, the framework supports dimension-level adjustment via the Analytic Hierarchy Process (AHP). Coefficient of Sensitivity analysis was applied to evaluate the influence of weighting on outcomes and identify key variables. By setting tipping point thresholds for 18 indicators, the NUCASI framework facilitates early warning and responsive governance. It offers a transparent and adaptable assessment tool for cities like Tongzhou under the dual-carbon agenda, and a methodological basis for institutional and governance pathway studies.

6. CONCLUSION

The NUCASI framework offers a structured and adaptable tool for evaluating Nature-based Solutions in urban stormwater management, addressing key gaps in existing assessment systems by integrating ecological, adaptive and carbon-relevant indicators. Applied to Tongzhou District, an important pilot site in China's Sponge City initiative and a key area for green urban expansion, the NUCASI framework facilitates the identification of governance challenges and supports policy alignment with the dual-carbon strategy. Grounded in institutional theory and

evolutionary governance theory, the framework enables spatiotemporal comparison, early warning through tipping-point thresholds and informed policy feedback. Its flexible design allows for future enhancement through digital technologies and stakeholder participation, making it a valuable contribution to urban climate resilience and sustainable governance.

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INTEGRATING SUSTAINABLE DEVELOPMENT ELEMENTS INTO INTERACTION DESIGN FOR OCEAN CONSERVATION EDUCATION IN DALIAN NATURAL HISTORY MUSEUM, CHINA

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Co-supervisor: Ts. Dr. Lim Chen Kim

1. INTRODUCTION

The ocean provides vital resources and services for the planet, yet it is simultaneously impacted by human activities. Ocean environmental issues pose significant challenges to global sustainable development (Mokos, Realdon & Zubak Čížmek 2020). The concept of ocean conservation education has been recognised by the United Nations as one of the key steps towards achieving ocean sustainability (Runhaar, Dieperink & Driessen 2006). As institutions of environmental education, natural history museums play an essential role in promoting ecological and environmental awareness (Pop & Borza 2016). In the ocean exhibition zone of the Dalian Natural History Museum, visitors can acquire scientific knowledge about the history of ocean development, the evolution of marine flora and fauna, the extinction of endangered ocean species and marine pollution (Hu, Zhang, & Han Han 2023). Since these topics closely align with the content of ocean sustainability, natural history museums are considered ideal venues for delivering ocean conservation education (Hansson & Ohman 2022). With technological advancements, interaction design is increasingly being applied in museums. This interactive approach to the exhibition not only attracts a broader range of visitors but also conveys knowledge more vividly and intuitively, stimulating visitors' interest in the exhibits (Xu et al. 2020). This study primarily investigates how sustainable development elements can be effectively integrated into the ocean exhibition hall of the Dalian Natural History Museum through methods of interaction design, to enhance the museum's educational function in ocean conservation.

2. PROBLEM STATEMENT AND LITERATURE REVIEW

Due to a lack of policy guidance and design management, specifically, the absence of an integrated exhibition policy and systematic design management mechanisms for update cycles, cross-department coordination and sustainability alignment, Dalian Natural History Museum faces several challenges in its exhibition philosophy, display quality and science popularisation activities (Hu, Zhang, & Han Han 2023). These issues are primarily reflected in the following aspects: the exhibition facilities are outdated and slow to be updated, making them less attractive to visitors (Zhong 2008). The current exhibitions rely heavily on specimens, images and textual descriptions, with a strong emphasis on the professional and academic presentation of exhibits. However, sustainable development elements are largely absent, resulting in limited effectiveness in promoting ocean conservation education. Owing to spatial constraints, only around 60% of the ocean exhibits can currently be displayed, with many items remaining in storage. The application of interaction design within exhibition spaces offers the advantage of easily updating information (Bowman & Hodges 1999). Through interaction design approaches, it becomes possible to facilitate communication and dialogue between visitors, exhibits and the

environment, enabling the presentation of more content without spatial limitations (Li & Shu 2024). These diverse forms of display not only attract visitors but also stimulate greater interest in ocean sustainability (Dierking & Falk 1992). Considering the above, the core problem this study addresses is the museum's lack of sustainability education content and clear guidance on design strategy. In this context, the present research aims to formulate a strategic framework for the museum through interaction design, improving update efficiency, enhancing engagement and learning outcomes, and integrating sustainable development elements into the provision and support of diverse learning opportunities, thereby serving the purpose of ocean conservation education.

3. OBJECTIVE

This study has three main objectives, aiming to explore how sustainable development elements can be integrated into ocean exhibitions through interaction design approaches, to enrich visitors' experiences and enhance the educational role of Dalian Natural History Museum in promoting ocean sustainability. This Colloquium will focus primarily on the first two objectives, which are: (i) to identify and categorise the sustainable development elements and interaction design influencing factors that are relevant for ocean conservation education in Dalian Natural History Museum, (ii) to assess the impact of sustainable development elements and interaction design factors on the effectiveness of ocean conservation education in the Dalian Natural History Museum.

4. METHOD

This research was carried out through a mixed-methods approach using an exploratory sequential design. To address objective 1, this research adopted a qualitative approach, whereby a document content analysis was conducted on twenty-six policy documents that are directly or indirectly related to ocean conservation to identify and categorise sustainable development elements relevant to ocean conservation education. Using ATLAS.ti software, a thematic analysis was carried out to extract recurring themes and concepts. To explore the domains influenced by interaction design, through a systematic literature review, forty-five papers related to interaction design were selected and subjected to thematic analysis to identify and categorise the influencing factors of interaction design. To address objective 2, based on these categories and factors, a questionnaire survey was conducted with 384 visitors to the Dalian Natural History Museum. Using SPSS software, through a quantitative approach, the study analysed the interrelationships and synergistic effects among these factors to determine what factors influence the effectiveness of ocean conservation education in the Dalian Natural History Museum, particularly in the context of interaction design.

5. RESULTS AND DISCUSSION

Based on environmental education theory (Awareness / Knowledge / Attitude / Skills / Participation), a thematic analysis was conducted of twenty-six policy documents and searched for topics related to ocean conservation education, five thematic categories (Ocean emotion / Ocean Cognition / Ocean Ethics / Ocean Behaviours / Ocean Volition) and eighteen sustainable development elements were identified (Ecological Crisis Awareness / Global Systems Awareness / Responsibility & Obligation / Social Concern / Ecosystem Principle / Environmental Problem / Sustainable Resource Management / Law and Policy / Global Governance / Scientific Research

& Technology / Emotional Connection / Ecological Value / Problem Identification / Environmental Practice / Voluntary Action / Digital Participation / Community Co-building / Communication & Advocacy). In parallel, a thematic analysis of forty-five academic papers was conducted to examine the factors influencing interaction design within the ocean exhibition spaces of natural history museums. This process focused on paragraphs and sentences addressing the three core topics of “interaction design”, “natural history museums” and “ocean conservation education”, similar topics were summarised and categorised, led to the identification of five categories (Visitors / Content Design / Technical System / Contextual Factors / Interactive Experience) and thirteen key influencing factors (Demographics / Characteristics and Needs / Information Conversion / Display Method / Accessibility / Inclusiveness / Environmental Context / Social Context / Emotional Experience / Sensory Experience / Behavioural Experience / Cognitive Experience / Relational Experience). A questionnaire survey was developed based on these thematic factors and randomly distributed to 384 visitors of the Dalian Natural History Museum. The results showed that 51% of the respondents were female and 49% were male. The majority were aged 18–25 (51%), most were students (56%) and 66% held a university degree. Visitors were mainly accompanied by family members (29%) or classmates (29%), and their primary purpose was leisure and entertainment (38%). Regarding the factors of interaction design, respondents’ overall evaluations ranged from $M = 4.3–4.6$ ($SD = 0.69$, on a 5-point Likert scale). For the elements of sustainable development, the paired-samples t-test results revealed that most items showed significant improvements after the visit ($p < .01$ or $p < .001$). Together, these findings provide a solid foundation for informing the design management of exhibition content and enhancing visitor engagement strategies within the museum context. By aligning sustainable development themes with effective interaction design domains, the research offers valuable insights into how museums can better fulfil their educational role in promoting ocean conservation.

6. CONCLUSION

In response to the challenges faced by the Dalian Natural History Museum, such as outdated exhibition methods, limited spatial capacity and the absence of sustainability themes, this identified and categorised sustainable development elements relevant to ocean exhibition areas through interaction design. By identifying relevant sustainable development elements and analysing interaction design factors, the research provides a foundation for enhancing the museum’s educational role in ocean conservation. The sustainable development elements and interaction design influencing factors were formed into a questionnaire and evaluated in the ocean exhibition area of Dalian Natural History Museum, the findings demonstrate that interactive and engaging exhibition strategies not only overcome spatial and communicative limitations but also enrich visitor experiences and foster deeper awareness of marine environmental issues, thereby supporting the broader goal of promoting ocean sustainability through museum education.

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LOCALISING SUSTAINABLE DEVELOPMENT GOALS (SDGs) FOR THE SMART COMMUNITIES OF PETALING JAYA, SELANGOR

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Co-supervisor: Prof. Emeritus Dato' ChM. Dr. Mazlin Bin Mokhtar

1. INTRODUCTION

The United Nations established the 2030 Agenda for Sustainable Development in 2015, which seeks to accomplish the unrestricted progress of all tiers of economic development, social justice and stability of the environment (United Nations General Assembly 2015). In response, Malaysia has driven the SDGs into national plans like the 12th Malaysia Plan and the Shared Prosperity Vision 2030, organised by the National SDG Council and the Economic Planning Unit. National alignment is evident, but it has still been difficult to localise the SDGs (adapt global targets into actionable work at the city or community level) (Butcher et al. 2021). In this context, localisation should involve more than minimal governance structures, data and technology systems that produce disaggregated real-time information and social outcomes that construct inclusivity, equity and lived realities of communities, whereby there are three interconnected dimensions which are essential to the undertaking (Bonsu et al. 2021; Iyer, 2021). It is against this backdrop that this study seeks to develop a customised localisation model of SDGs in Petaling Jaya, which incorporates the three facets of governance, data systems and social impacts. The framework aims to make smart city infrastructure and initiatives aligned to community needs and enhance digital governance and institutional responsibility (Batty et al. 2012; Lindskog 2004; Beunen et al. 2015).

2. PROBLEM STATEMENT AND LITERATURE REVIEW

Despite Petaling Jaya City Council (MBPJ) possessing a robust ICT infrastructure, several challenges hinder the effective localisation of the Sustainable Development Goals (SDGs). A significant gap lies in the absence of localised SDG indicators that address the specific needs of the community, such as urban poverty and employment among the elderly and the differently abled. Moreover, SDGs implementation efforts are fragmented and often confined within technological initiatives, lacking cohesive governance mechanisms and coordination among federal, state and local authorities. This institutional siloing hampers the integration of the SDG targets into urban planning processes. Compounding these issues is the limited availability of disaggregated data at the city level, as SDG-related data is predominantly collected at broader national or state scales. Consequently, Petaling Jaya faces difficulties in effectively tracking and measuring its local SDGs progress due to insufficient data collection methodologies tailored to its urban context.

3. OBJECTIVE

This research is guided by three main research objectives aimed at localising Sustainable Development Goals (SDGs) for the smart communities of Petaling Jaya, Selangor. For this colloquium presentation, the focus is given on the first objective, which has been completed at

this stage: (i) To identify and map relevant SDG indicators against the conceptual framework's dimensions (institutional governance, data systems and community outcomes), and to determine existing data gaps in Petaling Jaya's Smart Communities.

4. METHOD

The content analysis of a portfolio of strategic and policy documents of importance to the human-environment sustainable urban development and the localisation of a Sustainable Development Goals (SDGs) portfolio in Malaysia was conducted systematically to review and interpret its content. The major sources that will be reviewed are the Strategic Plan (2021-2025) of Petaling Jaya City Council (MBPJ, 2021), the Malaysia Smart City Framework (EPU, MHLG, 2021), the Sustainable Development Goals (SDG) Indicators of Selangor 2022 (DOSM Selangor, 2022), and the Sustainable Development Goals (SDG) Indicators of Malaysia 2022 (DOSM 2022). All of these are significant levels of policy and planning (both local and national), and collectively, they provide a glimpse of the institutionalisation of sustainability agendas within the governance system in Malaysia. The analysis was given by referring to two related tasks: the first one is to map the indicators represented in these documents to the global SDG framework, and the second is to locate gaps and inconsistencies in coverage, measurement and alignment. As an example, the MBPJ Strategic Plan has localised targets connected to infrastructure, mobility and ecological sustainability; however, after reading it more closely, one will find that some social aspects are not thoroughly embedded, including inclusivity and equity, in contrast with the wider SDG agenda (MBPJ, 2021). Likewise, even though the Malaysia Smart City Framework focuses on technological development and digital infrastructure, the connection between it and the SDG indicators addressing the well-being of the communities and participatory governance is not explicitly stated (EPU & MHLG, 2021). The analysis of these documents not only reveals the areas of alignment with the SDGs but also identifies those areas where local and country strategies are lacking in ensuring a comprehensive coverage to inform the further design of a localisation framework, specifically applied to the context of Petaling Jaya.

5. RESULTS AND DISCUSSION

There were critical gaps identified as a result of the strategic documents and indicator mapping in all three dimensions of the conceptual framework: governance, data systems and social outcomes. Objective One is therefore met by structurally identifying the SDG indicators applicable to the smart community agenda in Petaling Jaya, as well as uncovering the major changes and gaps in current data collection procedures. The results indicate that it is still struggling to access disaggregated community-based data that is necessary to realise effective localised monitoring of SDGs. Specifically, in the city of Petaling Jaya, which reflects more national trends, there is clear institutional responsibility bestowed on data collection and management (Butcher et al. 2021; Bonsu et al. 2021). The lack of stewardship supporting evidence-based policymaking, the provision of inaccurate narratives of what is really happening, and the ineffectiveness of transparency and accountability in local governance (Iyer 2021; Pradhan et al. 2017).

i) Institutional Capacity/Governance.

Analysis shows that the priorities of the SDGs in Petaling Jaya are entrenched in the blueprint of Smart, Sustainable and Resilient 2030 (PJSSR 2030), but the institutional frameworks to monitor them have not been established. Even though the national and Selangor state plans align

well with SDGs 1, 3, 4, 7, 8, 9, 10, 11, 16 and 17, localisation of SDGs is not seen throughout because there is no single MBPJ unit of SDG localisation (Ekonomi.gov.my 2024; Majlis Bandaraya Petaling Jaya 2021). Such a lack of ownership of governance will impede accountability and lead to poor integration of SDG targets into local plans. This proposed framework advises the creation of an SDGs and Innovation Unit in MBPJ to internalise the mandate and enhance inter-agency coordination, as well as ensure sustainability of monitoring at the cross-governance levels (Batty et al. 2012; Lindskog 2004).

ii) Data and Technology Systems

There is also a major discrepancy in sources of granular and disaggregated information that would support tracking SDG indicators applied to neighbourhoods. A case in point is housing access (SDG 1.4) and air quality (SDG 11.6), not provide a systematic measurement, and 40% of precincts have air quality readers to date. In the same manner, the method of monitoring SDG 17 (Partnerships for the Goals) is underdeveloped, even though partnerships and MoUs already exist (Majlis Bandaraya Petaling Jaya 2015; Mokhtar & Md Dali 2017). Objective data stewardship ensures that Petaling Jaya has the evidence base to engage in specific interventions or to publish openly without the data on hand. This framework reacts with a focus on data stewardship, which includes the implementation of IoT sensors, integrated data dashboards, regular neighbourhood-wide surveys, and automatic real-time and evidence-based decision-making (Moallemi et al. 2020; Butcher et al. 2021).

iii) Social and Community Outcomes

The results show that they continue to manifest the invisibility of vulnerable groups in existing SDG monitoring platforms. As an example, 45 percent of the responses a community had reveal that a lack of disability-inclusive data is of concern and employment and housing security among the elderly and low-income residents is not effectively monitored. This undermines the inclusivity agenda of the Smart Community of Petaling Jaya, as well as reducing the extent to which the city could address inequality (SDG 10.2). To this end, the framework suggests community-led indicators and formulated alliances with academia and non-governmental organisations in capturing the lived reality of the object of marginalisation. This would help to make social inclusion and equality become part of SDG monitoring, allowing MBPJ to establish trust among its audiences and implement more responsive policies (Iyer 2021; Pradhan et al. 2017).

In this study, the SDG indicators that have the most significant measurement of SDGs aligned with the MBPJ 2021-2025 Strategic Plan to promote Smart Communities in Petaling Jaya are prioritised. SDG 3 (Good Health and Well-being) is highlighted because the national alignment and the relevance of Goal 3 to MBPJ community health programmes focus on four aspects: targeting the improvement of smart medical services, and the formulation of needs in an ageing society. SDG 4 (Quality Education) should be prioritised, and on national/state levels, MBPJ promotes lifelong education, information literacy, and educational facilities in communities. SDG 8 (Decent Work and Economic Growth) is a vital component of economic empowerment that MBPJ is undertaking through fostering entrepreneurship, young employment and innovation centres. SDG 9 (Industry, Innovation and Infrastructure) provides the foundation for developing the digital infrastructure, the innovation ecosystem and smart mobility, which play the primary role in the transformation of Smart Petaling Jaya.

6. CONCLUSION

This study demonstrates that Petaling Jaya's Smart Communities require a comprehensive SDGs localisation framework that incorporates institutional coordination, participatory engagement and robust data systems. Drawing on global best practices, such as Voluntary Local Reviews in Malaysia and Selangor and smart city governance theory, the proposed framework enables local governments and communities to effectively plan, collect and monitor SDGs implementation at the municipal level (Bonsu et al. 2021; Butcher et al. 2021). The model includes baseline mapping, gap analysis, community co-creation of indicators, deployment of open-data dashboards and the formation of a dedicated SDG and Innovation Unit within MBPJ to foster multi-level stakeholder collaboration (Beunen et al. 2015; Batty et al. 2012). This localised, inclusive and data-driven model elevates Petaling Jaya as a leading exemplar of urban SDGs localisation within Malaysia's smart city ecosystem (Moallemi et al. 2020). The study finds that successful SDGs implementation in Petaling Jaya depends on: (i) Customised indicators: Adapting global SDGs to local needs, such as urban poverty, inequality and environmental quality, while reinforcing coordinated governance across federal, state and municipal levels. (ii) Integrated data systems: Establishing a comprehensive SDGs dashboard populated with real-time, disaggregated data to ensure transparent monitoring and public accountability.

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LANDSCAPE APPROACHES FOR SUSTAINABILITY GOVERNANCE OF THE YELLOW RIVER WETLAND, SHAANXI, CHINA

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1. INTRODUCTION

As vital ecosystems, wetlands support environmental and human wellbeing through services like water purification and flood regulation (Gibbs 2000; Jogo & Hassan 2010). In the context of China's ecological civilisation strategy and the global Sustainable Development Goals (SDGs), inland wetlands, such as the Yellow River Wetland in Shaanxi Province, have become central to national restoration efforts (Chen et al. 2018; Mao et al. 2018; Wang et al. 2020). The Yellow River wetland in Shaanxi Province, as a typical inland riverine wetland, is shaped by fluvial processes, seasonal flooding and sediment transport. The landscape includes riparian zones and floodplains that support regionally significant biodiversity while simultaneously sustaining agricultural and rural livelihoods (Xu et al. 2023; Guofu & Shengyan 2004). Historically, this area has experienced a trajectory of farmland encroachment, governance reversal and ecological restoration. Policies, such as "Returning Farmland to Wetlands", have sought to reverse degradation trends and recover key ecosystem functions (Ding 2023; Zhai et al. 2024; Zhu et al. 2022). Landscape approaches provide an essential foundation for sustainable wetland governance by emphasising spatial pattern, ecological connectivity and multifunctionality, and by evaluating the impact of different land uses on ecosystem services to reconcile ecological integrity with human demands. This study adopts an integrated approach to examine the evolution of wetland governance in the Yellow River Basin, focusing on the interactions between ecological policy shifts, landscape pattern dynamics, ecosystem services and the engagement of stakeholders.

2. PROBLEM STATEMENT AND LITERATURE REVIEW

Although national efforts, such as the Wetland Protection Law (2022) and the Yellow River Basin Ecological Protection Strategy have reinforced institutional commitment in this region (Deng & Jiang 2023), their practical effectiveness remains constrained by path-dependent governance structures, sectoral fragmentation and limited participatory mechanisms (Partelow et al. 2020; Van Assche, Gruezmacher & Beunen 2022). Stakeholder engagement, essential for adaptive and inclusive governance, has received insufficient attention in both policy design and empirical research, particularly in inland wetland contexts. At the same time, existing scholarship on wetland systems tends to treat biophysical, spatial and institutional dimensions in isolation. While studies have examined how land use transitions influence ecosystem functions (Huang et al. 2022) and how landscape patterns affect service provision (Wu et al. 2024), few have explored the feedback loops between ecological change and institutional response. These fragmented approaches hinder the development of integrated, sustainability-oriented governance frameworks capable of adapting to dynamic socio-ecological conditions. The fundamental challenge, therefore, lies in developing a framework that can diagnose and respond to the

complex, co-evolutionary relationships between institutional arrangements, landscape patterns and ecosystem service provision.

3. OBJECTIVE

This study is guided by four main research objectives. For this colloquium presentation, the focus is given on the first two objectives, which have been completed at this stage: (i) to identify the evolution of key policies in governing the Yellow River Wetland and analyse how they have responded to environmental and governance changes over time and (ii) to analyse the spatiotemporal dynamics of the Yellow River Wetland landscape and its impact on the ecological functions of wetlands as nature-based solutions.

4. METHOD

This study employs a longitudinal mixed-method design to examine the socio-ecological dynamics of the Shaanxi Yellow River Wetland Nature Reserve from 1992 to 2023. The framework integrates three sequential phases: policy content analysis, remote sensing-based landscape assessment and ecosystem service modelling. First, a content analysis was performed on 179 policy documents to identify governance trends. This involved a dual coding scheme for policy tools and goals, and Latent Dirichlet Allocation (LDA) modelling was applied to reveal underlying discourse patterns. Second, land use change was classified using multi-temporal Landsat and Sentinel-2 imagery within the Google Earth Engine platform, employing a Random Forest algorithm. Landscape metrics representing fragmentation, connectivity, and diversity were calculated using FRAGSTATS and subsequently synthesized via Principal Component Analysis (PCA) into a Integrated Landscape Fragmentation Index (ILFI). Finally, the InVEST Carbon Storage model was used to quantify carbon accumulation. This enabled an analysis of the decoupling between the landscape's structural configuration and its ecological performance.

5. RESULTS AND DISCUSSION

This study's content analysis reveals a distinct three-stage evolution in China's wetland governance from 1992 to 2023. Topic modelling identifies these phases: a “Exploration and Incubation” phase (1992-2003), an “Institutional Building and Coordination” phase (2004-2015), and a “Governance System Deepening” phase (2016-2023) where discourses of “ecological services” became prominent. This evolution is mirrored in policy instruments, which shifted from reliance on regulatory tools to a diversified portfolio including national parks and economic incentives. Social network analysis confirms this transition structurally, showing the governance network evolving from a sparse, sector-dominated structure to a denser, multi-center network after 2016, with new central nodes reflecting a more integrated paradigm. A key finding is the “pattern–function paradox” of cropland. Despite a 14.25% increase in cropland area creating large, continuous patches with low fragmentation indices, their ecological functions—such as habitat availability and carbon sequestration—sharply declined. Conversely, smaller, scattered grassland and wetland patches, though fragmented, retained high ecological value as “stepping stones” for species. This issue was compounded by a 41.92% decrease in exposed sandbars and infrastructure like secondary levees, which further fragmented habitats by decoupling floodplains from natural hydrological pulses. Similarly, a “green fragmentation paradox” was driven by aquaculture. Pond area expanded by 322%, significantly increasing carbon storage but also intensifying fragmentation (Edge Density rose from 15.55 to 32.58). As noted by Barta et al. (2024), they typically rely on independent, controlled water circulation,

which effectively decouples them from surrounding regimes. Our study illustrates the profound landscape-level consequences of this mechanism: while supporting livelihoods, this industry created a dominant and highly connected land-use type that simultaneously isolated natural habitats and disrupted overall wetland connectivity.

6. CONCLUSION

This study's primary contribution is identifying a critical disconnect between the sophisticated evolution of China's wetland governance framework and its paradoxical ecological outcomes. While our analysis of policy texts documents a clear, positive trajectory toward a more systemic and structurally integrated governance paradigm, the corresponding landscape analysis reveals a more complex reality. This reality is defined by profound socio-ecological paradoxes, where seemingly “intact” agricultural landscapes conceal functional degradation and “green” industries like aquaculture intensify habitat fragmentation. The central conclusion, therefore, is that the maturation of a governance framework on paper is insufficient to guarantee true ecological restoration. The persistence of these paradoxes highlights an urgent need to bridge the gap between policy intent and on-the-ground reality. Effective wetland governance must move beyond formulating sophisticated policies to directly address the deeply embedded land-use dynamics and trade-offs that truly shape the landscape.

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ACCELERATING CITY LEVEL CLIMATE ACTION-CASE STUDY OF PENANG, MALAYSIA

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1. INTRODUCTION

Southeast Asia has been identified as among the regions that would be the hardest hit by climate change in the future (IPCC 2018). Among the impacts include rising sea levels, heat waves, tropical storms, wildfires, floods, and droughts. Climate change could result in an additional 14.5 million deaths and USD12.5 trillion dollars' worth of economic losses globally by 2050 (WEF 2024). The current and projected impacts of global warming emphasize the urgency of enhancing governance systems for responding to climate change (IPCC 2018; Hoegh-Guldberg et al., 2019). Climate policy, both mitigation and adaptation, address collective action, sometimes with no clearly identifiable organization or individual responsibility to be steered to solve the problem (Keskitalo et al. 2016). Effective climate action requires coordination among various actors, including governments, businesses, and individuals, which can be complex and challenging. Cities have increasingly become the focus for climate change actions. However, the type of actions and implementation mechanisms have remained largely unexplored. This research aims to examine both current and projected climate conditions and evaluate cities preparedness and policy responses to climate change.

2. PROBLEM STATEMENT AND LITERATURE REVIEW

Penang is among the top five states in terms of its significant contribution to the economy of Malaysia, representing strong economic growth led by its manufacturing and services sectors. Penang is already experiencing the direct and indirect impacts of climate change, such as floods, droughts, storms, heatwaves and a rise in sea levels. It is currently difficult to predict local climate change in Penang due to limited research (Othman et al. 2021). This makes it difficult to predict Penang's local weather patterns and environment, which is expected to evolve over time. There is no denying that climate change will make Penang even more vulnerable to already existing threats such as flooding, food and water scarcity, biodiversity loss, and environmental degradation. Climate change has contributed to increased rainfall in the northern region of Peninsular Malaysia, including Penang over the past decades (Othman et al. 2021). Floods and water-stress are expected to grow increasingly more frequent and could have a detrimental impact on the northern parts of Malaysia, including Penang (Yusuf & Francisco 2009). Temperature variation is also an emerging challenge exacerbating heatwaves and related health issues. Prolonged droughts are expected to hit across Peninsular Malaysia, and these are expected to affect the northeastern region, including Penang (Chan & Ghani 2016). In addition, rising sea levels are an issue that the state government needs to take seriously considering that a significant portion of land in Penang is coastal and low-lying.

As a city, Penang is at the epicentre of the climate disaster and need to accelerate its city level climate action. Climate action, which is included under Goal 13 of the United Nations Sustainable Development Goals (SDGs) is a widely used term that encompasses both mitigation

and adaptation activities to address climate change (UN 2015). Cities are critical to achieving and promoting new climate policies, low-carbon technologies, and sustainable infrastructure (D'Onofrio et al. 2023). A **formal climate change policy** enables a state to coordinate efforts, secure funding, and align with national and global commitments such as the **Malaysia's National Policy on Climate Change** and the **Paris Agreement**. Although Penang has developed several documents and strategies (e.g., **Penang Green Agenda 2030**, **Penang 2030**, and various planning documents), there is no comprehensive document outlining the Penang State Government's approach to addressing the impacts of climate change. Unlike Selangor, which aims to prepare the state for sustainable development while safeguarding the well-being of its residents, **Penang lacks a single, comprehensive climate change policy** that brings together its strategies, goals, and responses in one place. To better address climate impacts in Penang, an effective climate action framework that could accelerate climate actions need to be developed.

3. OBJECTIVE

This research comprises three objectives. The first objective is to identify current and future climate conditions and related policies in Penang. These other two objectives are to assess the effectiveness of current climate policies and practices for sustainable development and design a climate action framework that accelerates effective adaptation and mitigation measures. The focus of this paper and colloquium will be on the first objective.

4. METHOD

Qualitative document analysis design was applied to identify the current climate conditions, analyze future climate projections, and understand associated climate impacts and policy coverage, to delineate key knowledge and policy gaps at the federal, state and local levels. First, relevant documents were **identified** from various credible sources, including government reports and policy documents. Next, the documents were **selected** based on predetermined genres, inclusion criteria, and parameters to ensure alignment with the research objectives. The selected documents were then **assessed** for credibility, relevance, and comprehensiveness. Finally, the information obtained was **synthesized** to identify recurring patterns, key themes, and significant insights that directly inform the study. This qualitative method requires the examination and interpretation of data to extract meaning and build empirical understanding (Corbin & Strauss 2008). The approach entails the examination of a wide range of documents, such as books, newspaper stories, scholarly journal articles, and institutional reports (Morgan, H. 2022). Initial screening yielded about 26 publications relevant to this study. Subsequently, data was collected from 16 official documents of federal, state and local governments. The documents comprise strategic frameworks, policy frameworks, voluntary reviews, spatial plans and roadmaps from federal, state of Penang and local governments in Penang. The documents helped in identifying climate conditions and related policies in Penang for the research. They were selected because they are official, recent, thematically relevant, and represent multiple governance scales in Malaysia's climate policy landscape offering a robust foundation for understanding the policy response to climate change in Penang and Malaysia more broadly.

5. RESULTS AND DISCUSSION

The findings show that Penang will likely face challenges associated with floods, droughts, storms, heatwaves and rising sea levels. Climate change threatens the state's infrastructure,

public health and biodiversity. Based on historical record, the average maximum rainfall per hour has increased six-fold from an average of 31 mm in the 1990s to 180 mm in the 2010s leading to more frequent and severe flooding events. The average annual precipitation of Penang Island is approximately 2,670 mm with an average temperature of 23–32°C (MMD 2009). Both Representative Concentration Pathway (RCP) 4.5 and 8.5 scenarios indicate changes in rainfall distribution, potentially leading to more intense storms and flooding. Temperatures are projected to rise by 1.0–3.5°C in East Malaysia and 1.1–3.6°C in the Peninsular Malaysia until 2095, compared to 2009 (MMD 2009). Penang has already faced a large number of heatwaves and also recorded high frequencies and durations of heatwaves (Suparta and Yatim, 2019). Apart from that, extended periods of drought threaten water security, especially given Penang's reliance on a single water source, Sungai Muda. For Penang, estimations based on projected sea level increases of 0.11 m and 0.68 m for 2030 and 2100 respectively indicate land loss in some area on Penang Island and around the coastline of the state's mainland (NAHRIM 2019). Coastal areas, including George Town, face heightened risks from rising sea levels, threatening infrastructure and livelihoods.

Federal level policies and frameworks provide a strategic direction for integrating climate considerations into development policies at the state and local levels. The state's commitment to sustainable development and climate resilience is aligned with SDG targets, especially SDGs 11 and 13. Federal policies set the national vision, while state and local documents translate it into operational frameworks. Collectively, these policy documents demonstrate a comprehensive approach to addressing climate change across federal, state, and local levels in Malaysia. National and state-level plans emphasize whole of government approaches, though coordination mechanisms are not always clearly defined or institutionalized. The documents emphasize the importance of integrating adaptation and mitigation strategies into development planning, promoting sustainable practices, and enhancing resilience to climate impacts. Policy frameworks show a clear evolution from top-down mandates toward locally driven action plans with measurable goals. However, monitoring and evaluating outcomes and impacts of the climate adaptation and mitigation strategies are lacking. Although these documents collectively reflect a strong policy foundation and growing institutional will, implementation must continue to be scaled up with urgency, coordination, and inclusivity. Despite notable advancements, several challenges persist. These include limited access to localized climate data, fragmented institutional coordination and low levels of public awareness and participation in climate initiatives. Federal and state documents encourage collaboration, but mechanisms are often vague or underdeveloped. Further to that, climate finance support and capacity building are also crucial for addressing climate change. Documents that articulate financing mechanisms for climate actions are limited, while training and institutional support are frequently mentioned but poorly defined. Addressing these gaps is essential for scaling up climate action and ensuring inclusive implementation. A Thematic Diagram will be shown in the presentation slide during the colloquium.

6. CONCLUSION

There are significant climatic shifts in Penang that require a structured, and increasingly holistic approach to climate governance. While policies reflect increasing coherence, ambition, and integration of sustainability across sectors and scales, effective implementation will require greater data availability, institutional synergy, and public engagement. The transition toward a climate-resilient, low-carbon future is underway, but continued effort and investment with proper monitoring and evaluating policies are critical to achieving long-term environmental and

socioeconomic resilience. The result clearly shows that a fully comprehensive and unified climate action strategy is still lacking, despite Penang having frameworks and activities to combat climate change, such as the Penang Green Agenda 2030.

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ANALISIS FAKTOR BAGI ASET KEHIDUPAN DALAM KALANGAN NELAYAN DARAT DAN PENTERNAK IKAN DI SUNGAI PAHANG

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1. PENGENALAN

Matlamat Pembangunan Lestari (Sustainable Development Goals, SDG) menetapkan hala tuju global ke arah pembangunan seimbang dari segi ekonomi, sosial dan alam sekitar. SDG 1 (tiada kemiskinan), SDG 8 (pertumbuhan ekonomi dan pekerjaan) serta SDG 14 (kehidupan di bawah air) menekankan kepentingan melindungi ekosistem perairan serta memperkukuh peluang ekonomi, khususnya di kawasan luar bandar. Malaysia yang kaya dengan sumber perairan termasuk sungai dan tasik menyokong sektor perikanan darat yang berperanan penting dalam menjamin keselamatan makanan, menjana peluang pekerjaan dan menyumbang kepada kesejahteraan masyarakat luar bandar. Ikan air tawar bukan sahaja menjadi sumber protein berkhasiat yang mendapat permintaan tinggi, malah turut membuka peluang ekonomi kepada komuniti nelayan darat dan penternak ikan sangkar. Sungai Pahang, sebagai sungai terpanjang di Semenanjung Malaysia, memainkan peranan penting dalam menyokong aktiviti perikanan darat di kawasan yang dilaluinya. Kajian yang berkaitan dengan aset kehidupan dalam kalangan nelayan darat dan penternak ikan sangkar di Sungai Pahang masih belum diberikan perhatian secara mendalam. Tambahan pula, belum terdapat kajian yang menggunakan analisis faktor bagi mengenalpasti komponen utama bagi setiap kategori aset kehidupan untuk kedua-dua kumpulan ini di Sungai Pahang. Selain itu, kajian ini juga melihat perbandingan dua kumpulan komuniti perikanan darat yang berkongsi sumber yang sama tetapi mempunyai keperluan aset penghidupan yang berbeza. Justeru, usaha ke arah pengurusan lestari sektor ini amat penting bagi memastikan sumber perikanan terus berperanan dalam pembangunan ekonomi dan kesejahteraan komuniti perikanan.

2. PERMASALAHAN KAJIAN

Komuniti nelayan darat dan penternak ikan sangkar di Sungai Pahang, bergantung kepada sumber sungai untuk pekerjaan dan kelangsungan hidup isi rumah. Aktiviti seperti menangkap dan menternak ikan menjadi punca utama mata pencarian di sepanjang Sungai Pahang (Zulkafli et al. 2016). Namun, pergantungan kepada sumber semula jadi seperti stok ikan dan kualiti air mendedahkan mereka kepada ketidaktentuan hasil akibat perubahan cuaca, pencemaran dan gangguan persekitaran lain (Kamsi et al. 2025). Keadaan ini menjejaskan keupayaan mereka untuk meneruskan pekerjaan harian secara konsisten. Oleh itu, keupayaan untuk bertahan dan menyesuaikan diri dengan perubahan, boleh dikaji melalui pemilikan aset-aset kehidupan. Pemilikan aset kehidupan ini membantu komuniti untuk bertindak balas terhadap kejutan dan tekanan, sekali gus mengurangkan tahap kemudahterancam dalam kalangan nelayan darat dan penternak ikan sangkar di Sungai Pahang. Aset kehidupan seperti fizikal, kewangan, modal insan dan semula jadi telah kenalpasti sebagai menyokong strategi daya tahan, tetapi masih terdapat

kekurangan pemahaman tentang aset yang paling kritikal serta bagaimana faktor-faktor yang membentuk aset ini berinteraksi dalam mempengaruhi strategi penghidupan komuniti. Jurang pengetahuan ini menuntut analisis yang lebih mendalam bagi mengenalpasti komponen utama aset kehidupan serta menilai perbezaan aset kehidupan antara nelayan darat dan penternak ikan sangkar di Sungai Pahang.

3. SOROTON KAJIAN

Berdasarkan Kerangka Penghidupan Lestari (SLF) oleh DFID (1999), lima aset utama diperlukan seperti aset fizikal, kewangan, modal insan, sosial dan semulajadi. Kajian ini menilai aset fizikal (seperti bot, jaring, sistem ternakan dan kemudahan asas), aset kewangan (bantuan, pinjaman, simpanan), modal insan (pendidikan, kemahiran, kesihatan), aset sosial (jaringan dan sokongan komuniti), serta aset semulajadi (akses air dan tanah). Menurut Kamsi et al. (2025), komuniti nelayan kecil di Malaysia berdepan kekangan dalam pemilikan aset kehidupan, khususnya dalam aspek kewangan, sosial dan fizikal. Ketidakseimbangan ini menyukarkan mereka merancang penghidupan yang mampan serta menghadapi kejutan luar, ini termasuk komuniti nelayan darat dan penternak ikan sangkar. Lindenberg (2002) dan Moser (2006) menjelaskan bahawa tahap kemudahterancaman komuniti sangat bergantung kepada jumlah dan kepelbagaian aset yang dimiliki iaitu semakin kurang aset, semakin tinggi risiko keterdedahan. Kajian oleh Kapembwa et al., (2021) menunjukkan bahawa pemilikan aset yang mencukupi mampu meningkatkan daya tahan nelayan kecil. Mengikut Prayitno et al. (2025) membuktikan bahawa di Indonesia, gabungan aset modal insan, semula jadi, fizikal dan sosial memperkukuh keupayaan komuniti menghadapi cabaran. Sementara itu, Roslina (2018), menekankan bahawa modal insan dan kewangan amat penting bagi kelangsungan penternak ikan kecil di Malaysia.

4. OBJEKTIF KAJIAN

Objektif kajian ini mengenalpasti dan menganalisis aset-aset kehidupan dalam kalangan komuniti nelayan darat dan penternak ikan sangkar di Sungai Pahang.

5. KAEDAH KAJIAN

Kajian ini menggunakan pendekatan kuantitatif melalui kaedah tinjauan iaitu soal selidik berstruktur, bagi mendapatkan data berkaitan profil responden dan aset kehidupan komuniti nelayan darat dan penternak ikan sangkar di Sungai Pahang. Lima komponen aset yang diteliti ialah aset fizikal, kewangan, modal insan, sosial dan semulajadi. Kajian ini menggunakan pensampelan secara rawak berstrata iaitu dibahagikan mengikut daerah dan jenis pekerjaan. Seramai 521 responden terlibat, terdiri daripada 261 nelayan darat dan 260 penternak ikan sangkar, mewakili lima daerah utama iaitu Jerantut, Temerloh, Bera, Maran dan Pekan. Data dikumpul dalam bentuk skala ordinal menggunakan skala likert, dan dianalisis menggunakan perisian SPSS versi 26. Analisis pertama melibatkan statistik deskriptif bagi menerangkan profil responden. Seterusnya, analisis faktor penerokaan (Exploratory Factor Analysis, EFA) digunakan dalam kajian ini bagi mengenalpasti faktor-faktor dimensi yang terbentuk daripada item soal selidik, ini membolehkan struktur aset kehidupan bagi komuniti nelayan darat dan penternak ikan sangkar di Sungai Pahang dikenalpasti dengan lebih jelas dan sistematik. Langkah awal EFA melibatkan ujian Kaiser-Meyer-Olkin (KMO) untuk mengukur kecukupan persampelan (minima 0.50) dan Bartlett's Test of Sphericity bagi memastikan korelasi antara item signifikan ($p < 0.05$). Seterusnya, Rotated Component Matrix dengan putaran Varimax

digunakan bagi mengenal pasti bilangan dimensi serta item yang membentuk setiap dimensi dalam komponen aset.

6. KEPUTUSAN

Data bagi analisis ini diperoleh daripada soal selidik yang dijawab oleh 521 responden daripada komuniti nelayan darat dan penternak ikan sangkar di kawasan Sungai Pahang. Kajian ini dimulakan dengan analisis deskriptif bagi menerangkan profil asas responden, merangkumi daerah tempat tinggal, jantina, umur, agama, status perkahwinan, dan tahap pendidikan. Hasil analisis ditunjukkan dalam jadual 1 berikut di lampiran. Hasil analisis deskriptif berdasarkan data soal selidik menunjukkan bahawa majoriti responden daripada kedua-dua komuniti adalah beragama Islam, dengan 100% nelayan darat dan 98.5% penternak ikan sangkar. Dari segi status perkahwinan, sebahagian besar responden telah berkahwin, iaitu 85.4% bagi nelayan darat dan 80.4% bagi penternak. Dalam aspek jantina, kedua-dua komuniti didominasi oleh lelaki, namun penyertaan wanita lebih ketara dalam kalangan penternak ikan sangkar (10.4%) berbanding nelayan darat (1.5%). Bagi kategori umur, majoriti nelayan darat berumur antara 50 hingga 59 tahun, manakala penternak ikan sangkar berada dalam lingkungan umur 30 hingga 39 tahun. Perbezaan ini mencerminkan jurang generasi dalam penglibatan ekonomi serta peranan dalam menyara isi rumah. Dalam aspek pendidikan, kedua-dua kumpulan menunjukkan tahap pendidikan tertinggi pada peringkat sekolah menengah dan SPM. Namun begitu, penternak ikan sangkar menunjukkan latar pendidikan yang lebih pelbagai, dengan 17.3% daripada mereka memiliki kelulusan STPM, diploma atau ijazah, berbanding hanya 2.7% bagi nelayan darat.

Analisis kedua, melibatkan Analisis Faktor Penerokaan (EFA) ke atas lima kategori aset penghidupan (fizikal, kewangan, modal insan, sosial dan semula jadi) bagi komuniti nelayan darat dan penternak ikan sangkar, bagi mengenal pasti faktor komponen setiap kategori aset. Langkah awal EFA melalui nilai Kaiser-Meyer-Olkin (KMO) dan Bartlett's Test of Sphericity ditunjukkan dalam jadual 2 di bahagian lampiran. Hasil analisis menunjukkan bahawa nilai KMO bagi semua aset kehidupan nelayan darat dan penternak ikan sangkar adalah tinggi, iaitu melebihi 0.500, dan Bartlett's Test of Sphericity juga nilai yang signifikan ($p < 0.001$). Dapatan ini membuktikan bahawa aset kehidupan (aset fizikal, kewangan, modal insan, sosial dan semulajadi) bagi kedua-dua kumpulan responden adalah sesuai untuk ke peringkat analisis seterusnya.

Langkah seterusnya, kaedah Principal Component Analysis (PCA) dengan putaran Varimax telah digunakan bagi mengenalpasti faktor bagi setiap aset kehidupan. Hasil analisis bagi kedua-dua komuniti dapat dilihat di jadual 3 (nelayan darat) dan jadual 4 (penternak ikan sangkar) seperti yang ditunjukkan bahagian lampiran. Hasil analisis faktor bagi komuniti nelayan darat menunjukkan, aset kewangan mempunyai nilai kumulatif yang tertinggi iaitu 79.53 peratus diikuti dengan aset fizikal iaitu 76.48% yang merupakan nilai yang paling dominan. Manakala bagi penternak ikan sangkar menunjukkan bahawa aset semulajadi yang paling dominan dengan nilai kumulatif iaitu sebanyak 79.47% diikuti dengan aset fizikal dengan nilai kumulatif 74.05% dan aset sosial 71.9%

7. PERBINCANGAN

Tujuan utama analisis faktor penerokaan (EFA) dengan PCA dan putaran Varimax dijalankan adalah untuk mengenalpasti dimensi utama setiap aset kehidupan berdasarkan item dalam soal selidik. Hasil kajian ini dapat memperjelaskan struktur aset kehidupan yang perlu dibentuk

dalam strategi penghidupan nelayan darat dan penternak ikan sangkar di Sungai Pahang serta mengenalpasti aset yang paling dominan dalam menyumbang daya tahan kedua-dua komuniti.

Hasil dapatan nelayan darat menunjukkan aset kewangan (pengurusan kredit) merupakan aset dominan dengan nilai kumulatif 79.53% ($\alpha = 0.742$) dan aset fizikal (kelengkapan peralatan) varian 44.08% ($\alpha = 0.816$) serta (kemudahan penyimpanan) varian 32.40% ($\alpha = 0.744$), mencatatkan kumulatif 76.48%. Dapatan ini menunjukkan bahawa aset penghidupan yang utama bagi nelayan darat adalah bergantung pada aset kewangan (pinjaman) dan aset fizikal (peralatan, kemudahan stor penyimpanan). Ini selari dengan dapatan Kamsi et al. (2025) bahawa nelayan kecil berdepan dengan kekangan dalam kewangan dan fizikal yang menjejaskan daya tahan mereka. Hasil ini membuktikan bahawa nelayan darat di Sungai Pahang lebih bergantung pada aset kewangan dan aset fizikal untuk mengatasi masalah ketidaktentuan hasil tangkapan ikan darat. Ini menunjukkan bahawa kelangsungan penghidupan mereka lebih terjamin melalui sokongan kredit dan peralatan pekerjaan. Sementara itu, aset modal insan, aset sosial dan aset semulajadi menjadi aset kehidupan sokongan kepada nelayan darat di Sungai Pahang.

Hasil dapatan menunjukkan aset semulajadi (akses persekitaran) merupakan aset dominan kepada penternak ikan sangkar dengan nilai kumulatif tertinggi 79.47% iaitu $\alpha = 0.674$ diikuti dengan aset fizikal (kelengkapan peralatan) varian 42.38%, $\alpha = 0.731$ dan (kemudahan kediaman) varian 31.67% $\alpha = 0.751$ dengan nilai kumulatif 74.05%. Dapatan ini menunjukkan bahawa kehidupan penternak ikan sangkar amat dipengaruhi oleh kualiti alam persekitaran bersih dengan bekalan air yang bersih. Aset sosial juga menunjukkan nilai kumulatif yang tinggi iaitu 71.93% dengan (hubungan dengan agensi pelaksana) varian sebanyak 39.58% $\alpha = 0.707$ dan (hubungan dengan komuniti) varian sebanyak 32.35% $\alpha = 0.526$. Hubungan dengan agensi pelaksana seperti agensi kerajaan turut penting, mencerminkan pergantungan kepada kerajaan bagi dasar, permit dan sokongan teknikal. Aset modal insan pula menyumbang kepada 68.08% nilai kumulatif dan aset kewangan pula menyumbang 65.08% menjadi aset kehidupan sokongan bagi komuniti ini. Penternak ikan sangkar terdedah dengan risiko alam sekitar seperti pencemaran, perubahan suhu dan penyakit ikan. Mengikut Prayito et al., (2025) menekankan bahawa daya tahan komuniti bergantung kepada interaksi antara aset kehidupan dengan keupayaan mereka untuk menghadapi kejutan alam sekitar dan pasaran. Oleh itu, penternak ikan sangkar perlu memanfaatkan modal insan dan aset sosial bagi imbangkan pergantungan terhadap persekitaran sumber sungai. Dapatan ini juga menyokong pandangan Kapembwa et al., (2021) bahawa strategi penghidupan komuniti kecil tidak hanya berasaskan satu bentuk aset, tetapi memerlukan kombinasi pelbagai aset untuk menjamin daya tahan dan kelangsungan penghidupan.

Hasil dapatan kajian menunjukkan bahawa keperluan aset kehidupan adalah berbeza mengikut keperluan komuniti. Aset fizikal penting bagi kedua-dua kumpulan komuniti kerana keperluan memerlukan peralatan fizikal seperti bot, enjin, jaring, sangkar dan lain-lain untuk tujuan pekerjaan mereka. Aset kewangan pula, lebih dominan untuk nelayan darat kerana lebih bergantung kepada pinjaman dan bantuan kerajaan untuk menampung kos operasi. Manakala, aset modal insan lebih dominan di kalangan penternak ikan sangkar kerana tahap pendidikan membantu keupayaan mereka memahami lebih tinggi. Aset sosial lebih menonjol di kalangan penternak ikan sangkar kerana mempunyai hubungan rapat dengan agensi kerajaan dan institut sokongan bagi mendapatkan maklumat, bantuan teknikal dan akses peluang pasaran. Akhir sekali aset semulajadi menunjukkan dominan di kalangan penternak ikan sangkar kerana mereka sangat bergantung kepada kualiti air sungai, lokasi sangkar, serta kestabilan persekitaran untuk menjamin pertumbuhan ikan. Sebarang perubahan seperti pencemaran air, perubahan suhu, atau penyakit ikan memberi kesan langsung terhadap hasil penternakan mereka.

7. KESIMPULAN

Komuniti perikanan darat bergantung kepada sumber sungai seperti stok ikan dan kualiti air, yang mendedahkan mereka kepada ketidakpastian hasil akibat cuaca, pencemaran dan gangguan persekitaran. Keadaan ini menjejaskan kelangsungan pekerjaan harian. Oleh itu, pemilikan aset kehidupan diperkenalkan sebagai asas daya tahan komuniti perikanan darat dengan objektif kajian ini bagi mengenal pasti dan menganalisis aset kehidupan nelayan darat dan penternak ikan sangkar di Sungai Pahang melalui analisis faktor penerokaan (EFA). Hasil kajian ini mendapati bahawa nelayan darat lebih bergantung kepada aset kewangan dan fizikal, manakala penternak ikan sangkar lebih bergantung kepada aset semulajadi, fizikal dan sosial. Perbezaan ini menunjukkan bahawa walaupun kedua-dua komuniti berkongsi sumber sungai yang sama, tetapi strategi penghidupan mereka adalah berbeza mengikut keperluan aset dominan masing-masing. Dapatan ini menyokong kerangka Penghidupan Lestari (DFID 1999; Scoones 1998) yang menegaskan gabungan aset kehidupan berfungsi secara berbeza mengikut daya ketahanan komuniti dalam menghadapi cabaran. Kajian ini juga mengisi jurang pengetahuan analisis menggunakan pendekatan EFA untuk mengenalpasti aset kehidupan nelayan darat dan penternak ikan sangkar di Sungai Pahang. Secara keseluruhan, kajian membuktikan bahawa perbezaan pemilikan aset mempengaruhi strategi penghidupan dan daya tahan komuniti, manakala keseimbangan aset kehidupan merupakan kunci kelangsungan hidup serta pengurangan kerentanan.

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LAMPIRAN

Jadual 1: Profil Responden

Pembolehubah Demografi	Kategori	Bil Nelayan Darat (N=261)	Peratus (%)	Bil Penternak Ikan (N=260)	Peratus (%)
Daerah	Jerantut	62	23.8 %	32	12.3%
	Temerloh	62	23.8 %	70	26.9%
	Bera	35	13.4 %	20	7.7%
	Maran	75	28.7 %	9	3.5%
	Pekan	27	10.3 %	129	49.6%
Jantina	Lelaki	257	98.5 %	233	89.6%
	Perempuan	4	1.5 %	27	10.4%
Umur	15-19	-	0.0 %	4	1.5%
	21-29	15	5.7 %	37	14.2%
	30-39	43	16.5%	75	28.8%
	40-49	61	23.4%	53	20.4%
	50-59	82	31.4%	57	21.9%
	60-64	29	11.1%	17	6.5%
Agama	65 dan keatas	31	11.9 %	17	6.5%
	Islam	261	100%	256	98.5%
Status Perkahwinan	Buddha	-	0.0	4	1.5%
	Berkhawin	223	85.4%	209	80.4%
	Belum Berkhawin	30	11.5%	47	18.1%
Tahap Pendidikan Tertinggi	Lain-Lain	8	3.1%	4	1.5%
	Sek Rendah	78	29.9%	48	18.5%
	Sek Menengah (tanpa kelulusan SPM)	83	31.8%	47	18.1%
	SPM	85	32.6%	98	37.7%
	STPM/Diploma	7	2.7%	35	13.5%
	Ijazah/Master/PhD	-	0.0	10	3.8%
	Tidak Bersek	5	1.9%	10	3.8%
Lain-lain (Sijil, Sek Pondok)	3	1.1%	12	4.6%	

Jadual 2: Analisis KMO dan Bartlett's Test

Komuniti	Kategori Aset	Nilai KMO	Bartlett's Test (P-value)
Nelayan Darat	Aset Fizikal	0.672	0.000
	Aset Kewangan	0.500	0.000
	Modal Insan	0.858	0.000
	Aset Sosial	0.646	0.000
	Aset Semulajadi	0.694	0.000
Penternak Ikan Sangkar	Aset Fizikal	0.600	0.000
	Aset Kewangan	0.566	0.000
	Modal Insan	0.854	0.000
	Aset Sosial	0.513	0.000
	Aset Semulajadi	0.500	0.000

Jadual 3: Analisis Faktor bagi Komuniti Nelayan Darat

Aset	Kumulatif %	Komponen	% Varian	Cronbach's Alpha
Fizikal	76.48%	Kelengkapan Peralatan	44.08%	0.816
		Kemudahan penyimpanan	32.40%	0.744
Kewangan	79.53%	Pengurusan Kredit	79.53%	0.742
Modal Insan	58.53%	Latihan & Kemahiran	40.97%	0.928
		Pengalaman & Kesejahteraan	17.56%	0.641
Sosial	57.40%	Hubungan Keluarga & Komuniti	57.40%	0.617
Semula Jadi	47.01%	Kualiti Persekitaran & Sumber	47.01%	0.588

Jadual 4: Analisis Faktor Komuniti Penternak Ikan Sangkar

Aset	Kumulatif %	Komponen	% Varian	Cronbach's Alpha
Fizikal	74.05%	Kelengkapan Peralatan	42.38%	0.731
		Kemudahan Kediaman	31.67%	0.751
Kewangan	65.08%	Perlindungan & Perancangan	33.84%	0.589
		Keupayaan Kewangan	31.24%	0.697
Modal Insan	68.08%	Latihan & Kemahiran	34.73%	0.942
		Kesejahteraan Kesihatan	12.23%	0.598
		Pengalaman	11.68%	0.592
		Tahap Pendidikan	9.44%	0.532
Sosial	71.93%	Hubungan dengan Agensi	39.58%	0.707
		Hubungan Komuniti	32.35%	0.526
Semula Jadi	79.47%	Akses Persekitaran	79.47%	0.674

STRENGTHENING THE SOCIAL AND BEHAVIOURAL CHANGE COMMUNICATION FRAMEWORK TO ENHANCE SOLID WASTE RECYCLING PRACTICES IN LANGKAWI

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1. INTRODUCTION

Langkawi Island, located in the northwestern region of Peninsular Malaysia, holds the distinction of being the first UNESCO Global Geopark in Southeast Asia since 2007. Renowned for its ecological richness and geodiversity, Langkawi is a prominent ecotourism destination that faces mounting waste diversion to landfill challenges in balancing tourism growth with environmental sustainability. With tourists generating nearly twice the waste of local residents with an average of 1.34 kg per capita daily and up to 150 tonnes per day of solid waste during peak seasons (EPR Feasibility Study Report 2022). Langkawi's landfill at Kampung Belanga Pechah is nearing unsustainable limits (Reezal Marican 2021). Despite the implementation of numerous sustainability programmes and awareness campaigns intended to promote recycling in Langkawi, the actual level of recycling practice remains critically low compared to national benchmark. While Malaysia's has achieved recycling of 37.9% in 2024, Langkawi lags significantly behind at just 8.6% (EPR Feasibility Study Report 2022). With tourism driven waste generation continuing to rise, recycling efforts remain weak as waste policies and blueprint priorities on infrastructure solutions rather than behavioural and communication change. This study aims to formulate a context-specific approach to strengthening the Social and Behavioural Change Communication (SBCC) framework by leveraging tourism stakeholders as influencer to promote recycling among local communities and tourists. Stakeholder tourism in this study is referring to local communities, tour agents, tour guides, hotels managers and government authorities and non-governmental organizations (NGOs). This is significant to closing the gaps and offers not only a strategic response to Langkawi's waste crisis but also a replicable model for other tourism-dependent, ecologically sensitive regions seeking sustainable, community-driven solutions.

2. LITERATURE REVIEW

Research in waste management increasingly acknowledges behavioural factors are as influential as infrastructural systems in shaping recycling outcomes (Ramayah 2012). Ajzen's Theory of Planned Behaviour (2021) has been instrumental in explaining pro-environmental intentions through attitudes, social norms, and perceived behavioural control, though intention-behaviour gaps persist, particularly in socialist contexts where institutional trust and shared norms play a central role (Bachmann & Inkpen 2011). A well-documented "knowledge-action gap" further complicates behaviour change, with studies by Kollmuss and Agyeman (2022), and Zhang et al. (2019) emphasizing the need for social reinforcement, and psychological engagement to move

beyond awareness alone. Social and Behavioral Change Communication (SBCC) entails addressing issues that impact people behaviour directly or indirectly at the individually, societal national and international levels (Livingston White 2023). Globally, SBCC has proven effective in health campaigns, especially in low-trust environments (UNICEF 2005), while McKenzie-Mohr's Community-Based Social Marketing (CBSM) approach applies similar principles to environmental contexts through tools such as social modelling and behavioural prompts. Regardless of its potential, SBCC and CBSM remains underutilised in municipal waste management systems. In Malaysia, although policy frameworks such as the National Solid Waste Management Policy and SDG 12 support recycling, their effectiveness is often undermined by top-down messaging that lacks community relevance and cultural nuance (Mokhtar & Sopian 2021).

3. RESEARCH OBJECTIVE

For the purpose of this colloquium this study aims to evaluate the effectiveness of Social and Behavioural Change Communication (SBCC) in promoting sustainable waste management through recycling practices. First objective is to determine the effectiveness of sustainability awareness campaign in promoting sustainable discard behaviour and practice. This will focus on previous sustainability programmes reachability, and behavioural impact, especially in addressing the low recycling rates and public disengagement. Second, is to identify the gaps within the existing national, local policies and blueprints on promoting sustainability waste management especially in addressing the behavioural change in mobilizing stakeholder tourism. Ultimately, the study seeks to contribute toward mitigating Langkawi's overreliance on landfill and incineration as the dominant waste disposal methods, by offering insights into how context-specific, theory-informed SBCC strategies can enhance recycling behaviours and support a more sustainable, community-driven waste management system.

4. METHOD

This study adopts a qualitative approach to formulate a context-specific in strengthening the Social and Behavioural Change Communication (SBCC) framework grounded in the Theory of Planned Behaviour (TPB:1991, 2021) for tourism stakeholders' knowledge, roles and rights in driving communication for behavior change and social change (Fyall & Garrod 2005). Aimed at enhancing recycling awareness and promoting environmental sustainability in Langkawi in three core elements communication, behaviour change and social change. For the first objective which to determine the effectiveness of the previous sustainability awareness campaign, this study employs three case study which are Low Carbon Island, Green City Action Plan and Extended Producer Responsibility Feasibility Study. While for second objectives, is to identify the gaps within the existing national and local policies and blueprints on sustainability waste management especially in addressing the behavioural change for recycling participation. The study will be supported by document analysis of ten national, local policies and blueprints to trace the evolution of waste management strategies and communication approaches. The ten documents analysed include: (1) the 13th Malaysia Plan (2026–2030), (2) the National Solid Waste Management Policy (2007), (3) the Solid Waste and Public Cleansing Management Act 2007 (Act 672), (4) the SWCorp Malaysia Strategic Plan, (5) the National Recycling Rate Roadmap 2020–2030, (6) the Blueprint Ekonomi Kitaran Sisa Pepejal Malaysia 2025–2035,

(7) the National Policy on the Environment (2002), (8) the Malaysia Plastics Sustainability Roadmap 2023–2030, (9) the Langkawi UNESCO Global Geopark Management Plan, and (10) the Langkawi Tourism Blueprint 2016–2025. These documents were selected as they collectively represent the policy, regulatory, and strategic landscape shaping recycling and waste minimization in Langkawi. The case study method enables an in-depth exploration of Langkawi's tourism-driven waste management challenges, while document analysis provides insights into policy frameworks and blueprints as well as the role of tourism stakeholders as communicators of recycling to both local communities and tourists.

5. RESULTS AND DISCUSSION

Langkawi, despite being a UNESCO Global Geopark, struggles with a low recycling rate of just 8.6% far below the national average of 37.9% due to systemic challenges including weak public participation, fragmented awareness efforts, and a lack of culturally tailored communication in promoting recycling. Outcome from three case studies further highlights that existing initiatives such as the case study of Low Carbon Island, Green City Action Plan and Extended Producer Responsibility Feasibility Study fall short in embedding Social and Behavioural Change Communication (SBCC) principles that could bridge the inclusivity, knowledge-action, and promote sustained behavioural shifts. Also, this study reveals a significant disconnect between existing solid waste management policies and the behavioural realities on the ground in the island due to lack of right communication plans and medium for community engagement. The urgent need to adapt the push and pull awareness models to promote tourism stakeholder participatory as the sustainability communicator and community-driven communication strategies. While through documents analysis reveals that existing policies and blueprint prioritize physical infrastructure over psychological and behavioral sustainable strategies that are essential for fostering long-term recycling practices. They also show limited integration of local cultural values and weak engagement of tourism stakeholders, despite their pivotal role in sustainable waste management in Langkawi. Moreover, awareness initiatives are narrowly framed around waste reduction and cleanliness, without explicitly linking recycling to the broader planetary crisis. In addition, the policies and blueprints are not well integrated, resulting in fragmented approaches that undermine their capacity to instill the urgency and shared responsibility. The absence of impact assessments and limited data collected and sharing further constraints evidence-based decision making, leaving policies and blueprints not well integrated and fragmented, thereby weakening their potential as coherent way forward for better recycling behavior.

6. CONCLUSION

This study underscores the urgent need for a paradigm shift in Langkawi's waste management strategy is the one that moves beyond infrastructure and policy rhetoric to actively engage behavioural drivers through Social and Behavioural Change Communication (SBCC). Despite the existence of robust national and local frameworks, Langkawi continues to face persistent recycling challenges, characterised by the limited inclusion of tourism stakeholders in planning and development, their underutilisation as sustainability communicators, weak communication and educational outreach, and a lack of shared responsibility among stakeholders. The comprehensive document analysis of ten policies and blueprints reveals a consistent and critical gap: the absence of culturally contextualised, community-driven communication strategies that can effectively support long-term behavioural change (Snyder et al. 2004). Current top-down approaches often fail to resonate with local values, resulting in limited behavioural impact

despite increased awareness. This reinforces the necessity for a tailored SBCC framework that not only informs but transforms community and tourist attitudes and recycling practices. By integrating behavioural theories such as the Theory of Planned Behaviour (TPB) with participatory communication approaches rooted in Communication for Development (C4D), the proposed framework presents a strategic, locally grounded solution to enhance recycling performance. It aims to reduce Langkawi's dependency on landfill and incineration, while supporting the island's vision of a more sustainable, inclusive, and community-empowered waste management system that aligns meaningfully with both national aspirations and global sustainability goals.

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KONSEP INTEGRASI DALAM PERANCANGAN PROGRAM PERUMAHAN RAKYAT (PPR) KE ARAH KESEJAHTERAAN PSIKOLOGI KOMUNITI: KAJIAN KES PPR NEGERI SELANGOR

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1. PENGENALAN

Perancangan bandar merupakan asas penting pembangunan negara kerana setiap keputusan yang dibuat dalam susun atur pembangunan akan memberikan kesan jangka panjang terhadap kesejahteraan masyarakat setempat. Dalam proses ini, pelbagai konsep perancangan diaplikasikan bagi memastikan pembangunan memenuhi objektif yang ditetapkan, sekali gus menjamin kualiti dan kelestarian hidup penduduk yang bakal menghuni kawasan tersebut. Penilaian daripada perspektif psikologi wajar diintegrasikan dalam reka bentuk dan perancangan bandar bagi membentuk komuniti yang sejahtera dan berdaya tahan. Program Perumahan Rakyat (PPR), sebagai salah satu inisiatif kerajaan untuk menyediakan kediaman kepada golongan berpendapatan rendah, pada asasnya masih mengamalkan pendekatan berasingan yang memisahkan komuniti ini daripada golongan berpendapatan lebih tinggi. Pendekatan sebegini dilihat memberi kesan terhadap kesejahteraan psikologi penduduk, sekali gus berpotensi mencetuskan implikasi sosial yang lebih luas. Dalam konteks tersebut, konsep integrasi perumahan pelbagai kategori pendapatan dalam satu komuniti berpotensi menjadi strategi alternatif bagi mengatasi pengasingan sosial, memperkukuh hubungan komuniti, dan menyokong kesejahteraan psikologi. Sehubungan itu, kajian ini bertujuan meneroka potensi konsep integrasi ini serta peranannya dalam meningkatkan kesejahteraan psikologi komuniti, di samping menilai dasar dan polisi kerajaan yang berkaitan bagi melihat kebolehlaksanaannya dengan memberi tumpuan khusus kepada PPR di Negeri Selangor.

2. PERMASALAHAN KAJIAN DAN SOROTON KAJIAN

Pengasingan sosial yang terhasil daripada pembangunan berasingan bukan sahaja menjejaskan imej komuniti PPR, malah turut menyumbang kepada tekanan psikologi, stigma sosial, dan ketidakpuasan hidup (Phys.org 2023; Yang & Yuan 2022). Kajian Hee Jung Jun dan Han (2020) menunjukkan bahawa perumahan berkonsep sosial berintegrasi berupaya mengurangkan tahap diskriminasi dan tekanan berbanding model perumahan segregasi. Arthurson (2002, 2010) pula menegaskan bahawa integrasi komuniti pelbagai pendapatan merupakan pendekatan strategik untuk membentuk komuniti inklusif. Di Malaysia, meskipun terdapat dokumen seperti Garis Panduan Perancangan Kawasan Perumahan (PLANMalaysia 2016), aspek kesejahteraan psikologi dan integrasi sosial masih belum dijadikan elemen teras dalam reka bentuk perumahan awam. Penekanan sedia ada lebih bersifat kuantitatif, iaitu pembangunan PPR berasingan mengikut kategori sosioekonomi, yang seterusnya meningkatkan risiko pengasingan sosial, stigma komuniti, dan keterbatasan mobiliti sosial. Sebaliknya, model *mixed-income housing* di negara maju terbukti mengurangkan stigma serta meningkatkan kesejahteraan psikologi penghuni. Isu kesejahteraan psikologi dan Kesihatan mental dalam kalangan komuniti

berpendapatan rendah di Malaysia kini semakin mendapat perhatian, khususnya apabila penerapan konsep berasingan PPR secara berterusan menimbulkan kesan seperti rasa terasing, rendah diri, dan terpinggir. Keadaan ini mempengaruhi sikap serta tingkah laku penduduk, termasuk kelemahan disiplin sosial, sikap kurang bertanggungjawab, dan kurangnya penghargaan terhadap persekitaran penempatan. Oleh itu, terdapat keperluan mendesak untuk menilai tahap ketersediaan dasar semasa, mengenal pasti jurang pelaksanaan yang menghalang penerapan konsep integrasi, serta membangunkan model PPR yang lebih inklusif dan berdaya tahan bagi menghadapi cabaran kesejahteraan psikologi komuniti pada masa hadapan.

3. OBJEKTIF KAJIAN

Kajian ini mempunyai empat objektif namun untuk tujuan pembentangan kolokium, kajian memfokuskan kepada dua objektif iaitu objektif pertama dan kedua. Objektif pertama ialah untuk mengenal pasti ciri-ciri konsep integrasi bagi pembangunan PPR dan kepentingannya dalam mewujudkan kesejahteraan psikologi komuniti; dan objektif kedua pula meneliti ketersediaan polisi perancangan serta potensi pembangunan PPR berkonsep integrasi dengan komponen rumah mampu milik (RMM) yang lain di Malaysia. Persoalan kajian yang cuba diuraikan melalui objektif-objektif ini ialah apakah ciri-ciri yang diterapkan dalam pembangunan penempatan PPR konsep integrasi; bagaimana ia dapat menyokong peningkatan kesejahteraan psikologi komuniti; bagaimanakah senario semasa konsep perancangan PPR di Malaysia; dan potensi untuk membangunkan PPR dengan konsep integrasi dengan RMM yang lain dari sudut ketersediaan polisi.

4. KAEDAH KAJIAN

Pengumpulan maklumat dan analisis dalam kajian ini dilaksanakan melalui kajian kepustakaan yang melibatkan eksplorasi terhadap jurnal, penulisan ilmiah, dan dokumen rasmi kerajaan, merangkumi sumber media cetak dan elektronik. Bagi mencapai objektif pertama, pendekatan analisis kandungan dan analisis tematik digunakan, di mana analisis kandungan berperanan mengumpulkan maklumat serta mengkategorikan elemen berkaitan konsep integrasi perumahan dan kesejahteraan psikologi komuniti. Ia merangkumi ciri-ciri pembangunan penempatan PPR berkonsepkan integrasi; elemen kesejahteraan psikologi; serta perkaitannya dengan ciri-ciri PPR Integrasi. Seterusnya, analisis tematik dilaksanakan bagi mengenal pasti serta mentafsir tema-tema utama daripada bahan bacaan yang diperolehi. Kedua-dua kaedah ini saling melengkapi untuk memberikan tafsiran yang mendalam dalam membentuk kerangka ciri-ciri konsep integrasi yang menyokong kesejahteraan komuniti. Bagi objektif kedua, analisis kandungan dan analisis perbandingan diaplikasikan terhadap dokumen kerajaan melalui semakan ke atas dasar perancangan dan pembangunan perumahan negara seperti Dasar Perumahan Negara, Dasar Perumahan Mampu Milik Negara, Dasar Perbandaran Negara, Rancangan Fizikal Negara dan Garis Panduan Perancangan. Analisis perbandingan turut dilakukan dengan meneliti amalan antarabangsa (contoh: Singapura, Korea Selatan, Eropah) untuk melihat potensi adaptasi ke dalam konteks Malaysia. Pendekatan ini membolehkan kajian menilai tahap ketersediaan polisi semasa berkaitan PPR di Malaysia serta potensi untuk membangunkan model PPR berkonsepkan integrasi pada masa hadapan.

5. KEPUTUSAN DAN PERBINCANGAN

Kajian kepustakaan mengenal pasti tiga tema utama yang membentuk ciri-ciri konsep integrasi perumahan awam, iaitu kepelbagaian sosial dan ekonomi; kualiti reka bentuk serta persekitaran

fizikal; dan kemudahan sosial yang berfungsi sebagai ruang interaksi. Konsep ini menekankan penggabungan unit kediaman berpendapatan rendah dengan komuniti berpendapatan berbeza dalam satu pembangunan, disokong oleh reka bentuk yang berupaya mewujudkan jaringan ekonomi dan sosial merentas kelas masyarakat. Kemudahan komuniti dikongsi bersama tanpa segregasi, dengan penyediaan ruang khusus yang dapat menggalakkan interaksi dan memperkukuh sokongan sosial. Dari sudut kesejahteraan psikologi, analisis yang dibuat berasaskan teori psikologi humanistik, psikologi sosial, dan psikologi alam sekitar, menemukan lapan dimensi utama iaitu memenuhi keperluan asas dan keselamatan; kesejahteraan emosi dan mental; perhubungan dan sokongan sosial; penghargaan serta identiti sosial; aktualisasi diri dan harapan masa depan; pembangunan sosial dan komuniti; perspektif islamik; serta kualiti hidup dan kepuasan. Dimensi-dimensi ini menegaskan bahawa kesejahteraan komuniti tidak hanya bergantung kepada aspek material, tetapi turut dipengaruhi oleh faktor psikososial, nilai agama, dan peluang pembangunan diri. Penemuan menunjukkan perkaitan signifikan antara ciri-ciri perumahan awam berkonsep integrasi dengan kesejahteraan psikologi komuniti, sekali gus menyokong pencapaian objektif pertama kajian. Bagi objektif kedua, analisis dokumen dasar mendapati bahawa walaupun Dasar Perumahan Negara dan Rancangan Fizikal Negara menyentuh keperluan kepelbagaian tipologi perumahan, aspek integrasi sosial masih belum diinstitusikan secara konkrit dalam pelaksanaan PPR. Garis panduan sedia ada lebih menumpukan isu kuantitatif seperti bilangan unit, saiz minimum, dan kemampuan kos, berbanding aspek kualitatif yang berkaitan kesejahteraan psikologi penduduk. Laporan *New Urban Agenda* serta penilaian Dasar Rumah Mampu Milik Negara menunjukkan bahawa pendekatan segregasi terus mendominasi pembangunan PPR, di mana kediaman berpendapatan rendah ditempatkan berasingan daripada perumahan kos sederhana dan bebas. Kajian antarabangsa, sebaliknya, membuktikan bahawa model perumahan bercampur atau integratif mampu meningkatkan jaringan sosial, mengurangkan diskriminasi, dan menyokong perkembangan psikologi komuniti rentan. Contohnya, model *HDB housing integration* di Singapura menggabungkan etnik dan kelas pendapatan secara terancang untuk memperkukuh perpaduan sosial, manakala dasar *mixed-income housing* di Eropah dan Amerika Syarikat dikaitkan dengan pengurangan segregasi bandar dan peningkatan kualiti hidup penghuni. Jurang ini menegaskan bahawa Malaysia berpotensi mengadaptasi amalan terbaik antarabangsa melalui penerapan konsep integrasi dalam pembangunan PPR. Walau bagaimanapun, transformasi ini memerlukan dasar yang lebih progresif serta pelaksanaan dinamik di peringkat negeri dan tempatan bagi memastikan keberkesanan dan kelestarian pelaksanaannya.

6. KESIMPULAN

Berdasarkan sorotan kepustakaan dan dapatan kajian, jelas menunjukkan terdapat keperluan untuk menilai semula pendekatan perancangan PPR di Malaysia dengan memberi penekanan kepada konsep integrasi sebagai asas bagi meningkatkan kesejahteraan psikologi komuniti. Pelaksanaan dasar dan perancangan yang lebih inklusif bukan sahaja berpotensi mengurangkan ketidaksamaan sosial, malah dapat memperkukuh struktur komuniti bandar yang harmoni dan sejahtera. Penemuan ini seterusnya menyumbang kepada pembangunan kerangka perumahan bersepadu yang lebih responsif terhadap keperluan psikologi golongan berpendapatan rendah. Secara keseluruhan, kajian ini dijangka dapat mengisi kelompongan dari sudut kontekstual, metodologi, dan teoritikal dalam wacana perancangan bandar, sekali gus membuka ruang kepada dasar yang lebih progresif dan amalan pembangunan yang lebih berdaya tahan.

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FROM FLOOD PREDICTION TO RESILIENT ROAD NETWORK GOVERNANCE UNDER EXTREME RAINFALL: A MACHINE LEARNING APPROACH WITH MULTI-SOURCE DATA IN CENTRAL GUANGZHOU

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1. INTRODUCTION

Urban pluvial flooding, driven by short-duration intense rainfall, insufficient drainage, impervious surface expansion, and climate change, has become a major hazard for contemporary cities (Chaudhary et al. 2022; Gao et al. 2024). Guangzhou, located in the Pearl River Delta, frequently experiences severe flooding during the May to September rainy season (Tang 2024). For instance, on May 10, 2016, a heavy rainstorm caused severe urban flooding in the central districts, inundating multiple roads and even disrupting traffic, with severe congestion occurring between 8:00 and 10:00 a.m. (Guangzhou Meteorological Bureau 2016), leading to significant economic losses and disruptions to daily life. As urban resilience is central to sustainable development (SDG 11), examining interactions among rainfall, drainage capacity, and transport networks is critical.

2. PROBLEM STATEMENT

Guangzhou is one of the cities suffering from the most severe flood disasters in China, where frequent rainstorms coupled with a highly complex traffic system often result in severe congestion during the flood season, disrupting daily life and economic activities (Ruan, Chen, & Yang 2021; Li, Zhao, & Fu 2015). Nevertheless, the relationship between urban flooding and systemic changes in the road network remains insufficiently understood, with resilience assessment largely underexplored. Evidence from neighboring regions indicates that increased rainfall intensity significantly reduces road connectivity, with the connectivity index dropping to 0.67 of its baselines under a 20-year return period rainfall (Zhang et al. 2020). Similarly, in the Chebei catchment of northern Guangzhou, studies show that flood depth strongly correlates with road closure rates, underscoring that drainage optimization, road redundancy enhancement, and flood avoidance strategies are vital to strengthening urban traffic resilience (Huang, Wang, & Liu, 2019). These insights highlight the urgent need for an integrated framework linking flood prediction and road network governance in Guangzhou.

3. OBJECTIVE

Therefore, this study aims to address the critical research gap by comprehensively evaluating the recovery capacity of Guangzhou's road network under increasingly extreme weather conditions, thereby providing stronger support for infrastructure planning and targeted flood prevention strategies in China's rapidly urbanizing megacities, particularly in terms of urban mobility and transportation sustainability. This research comprises four core objectives. For the Colloquium presentation, focus is on two of these objectives:

1. To evaluate the role of weather conditions over the past 30 years in contributing to urban waterlogging events and the resulting spatiotemporal evolution of traffic functional losses in Guangzhou.
2. To determine the impact of the historical development of urban roads, drainage systems in relation to recurrent waterlogging events in selected central districts.

4. METHOD

To achieve the first and second research objectives, this study adopts a multi-method approach integrating statistical, spatial, and machine learning analyses. First, daily accumulated precipitation data (1980–2024) from the Guangzhou Meteorological Station are analyzed in R Studio to reveal long-term rainfall trends, which are then correlated with the daily traffic congestion index of Guangzhou (2015–2023) obtained from Gaode Map to assess the relationship between extreme rainfall and traffic performance (Aditya, F., Gusmayanti, E., & Sudrajat, J. 2021). Second, urban development indicators, including road and drainage infrastructure, are extracted from the Guangzhou Statistical Yearbook (1984–2023) to conduct correlation analysis between infrastructure development and recurrent waterlogging. Third, six years of pluvial flood events are examined using GIS based spatial clustering of waterlogging points. In the absence of drainage network data, the SCS-CN method is applied to estimate drainage capacity, and a random forest model with SHAP interpretation is employed to quantify the relative contribution of eight influencing factors (Fan et al., 2013; Xu et al., 2016). Finally, buffer zones around waterlogging points for each event are overlaid with the road network to assess topological properties, and the results are validated against the distribution of congestion indices across all road segments on the event days (Liu, Yang & Ren 2023; Kozhabek & Chai 2025).

5. RESULTS AND DISCUSSION

Based on daily precipitation data from the Guangzhou National Meteorological Station for the period from 1980 to 2024, the number of days with precipitation exceeding 50 mm has increased significantly (Sen's slope = +0.125 days/year, $p = 0.003$). Meanwhile, the average rainfall intensity also exhibits a clear upward trend (Sen's slope = +0.073 mm/day/year, $p = 0.00953$), indicating a rise in moderate to extreme rainfall events. An analysis of Guangzhou's annual traffic congestion index from 2015 to 2023 reveals that when daily rainfall exceeds 50 mm, a strong and statistically significant positive correlation is observed between rainfall intensity and traffic congestion ($R = 0.54$, $p < 0.001$), indicating that heavy rain events substantially worsen urban traffic conditions. Due to the past four decades, Guangzhou has undergone rapid urbanization, accompanied by swift infrastructure development. In contrast, the expansion of drainage infrastructure has lagged behind. Between 2004 and 2013, the density of drainage pipelines showed a significant negative correlation with road length and area ($p = -0.8$), indicating a clear mismatch between road construction and drainage system development. In older districts such as Liwan, Yuexiu, and Haizhu, due to early construction, aging facilities, and difficulties in renovation, drainage infrastructure was designed for a 1-year return period. When rainfall exceeds 43 mm, low-lying roads in these areas are prone to surface water accumulation exceeding 30 cm, directly correlating with observed reductions in traffic speed or temporary road closures.

Urban flood points in Guangzhou exhibit a pronounced non-random spatial pattern (Nearest Neighbor Index = 0.772, $Z = -7.26$, $p < 0.001$). Using 2016, 2017, 2020, 2023, and 2024 flood

data, a Random Forest with SHAP analysis identified eight explanatory factors (daily rainfall, drainage capacity, built-up area, NDVI, DEM, slope, flow accumulation, population). Rainfall intensity (50%), topography (20%), and drainage (12%) are primary drivers, while NDVI, slope, flow, and built-up area contribute moderately; population density and human exposure are highly influential. High-density clusters are primarily located in central Yuexiu District, the Xiguan area of Liwan District, the intersection of Guangyuan Expressway and Keyun Road in Tianhe District, and localized areas in central and northwest Haizhu District. Notably, flood points are densely clustered in central Yuexiu, Xiguan in Liwan, and northwest Haizhu, where the mean drainage capacity and DEM are lower than the city-wide averages (drainage = 552, area mean = 590; DEM = 14 m, area mean = 21 m). The Xiguan area in Liwan exhibits the lowest drainage capacity (drainage = 437), indicating that low lying terrain, intense urbanization and insufficient drainage infrastructure are the primary causes. In central Haizhu, elevation is also lower than the average (DEM = 13.5 m) with moderately low drainage capacity (drainage = 520). In the area around the intersection of Guangyuan Expressway and Keyun Road in Tianhe, slope is the lowest (slope = 5.1%, area mean = 6.15%) and elevation is minimal (DEM = 12.7 m), suggesting that low elevation and gentle slopes are the main factors contributing to the frequent flooding in this region.

The topological analysis of road networks in the four central districts of Guangzhou shows an average degree of 2.1919, indicating limited overall connectivity and few links per node. Network density is 0.00021, reflecting extreme sparsity in edge–node coverage across the spatial extent. The normalized network diameter is 111, while the average shortest path length is 40.39, suggesting that traveling between nodes typically requires relatively long paths, reducing traffic efficiency. The clustering coefficient is 0.0559, implying extremely weak local clustering and limited redundancy, with minimal formation of small cohesive groups. Approximate global efficiency is 0.0338, further confirming the network's low efficiency in overall transmission and accessibility. Overall, the road network in central Guangzhou exhibits low density, weak clustering, and limited redundancy, which indicates high vulnerability and reduced resilience under potential disturbances such as flooding or traffic congestion. Under the impact of urban flooding, key road segments highly coincide with traffic congested streets identified from real-time traffic big data. Notably, Zhongshan Avenue, Tianhe Road, Meidong Road, Zhongshan First Road, Donghuanan Road, Jiangwan Road and Nantian Road exhibit the highest vulnerability. The spatial distribution of rainfall and waterlogging points has a significant impact on the performance of the road network.

6. CONCLUSION

Over the past four decades, Guangzhou has undergone rapid urbanization, while the development of drainage infrastructure has lagged, making low-lying roads and older districts highly susceptible to flooding during heavy rainfall. When daily precipitation exceeds 50 mm, traffic congestion increases significantly, and flood points exhibit a non-random spatial clustering, primarily in Yuexiu, Liwan, Tianhe, and Haizhu. Random Forest analysis combined with SHAP indicates that rainfall intensity, topography, and drainage capacity are the primary drivers, while population exposure are also highly influential. The road network topology shows low connectivity, sparsity, weak clustering, and limited redundancy, reflecting high vulnerability and low resilience. Key traffic corridors coincide closely with flood prone areas, highlighting the need to improve drainage, implement precise prediction, and optimize road network layout to enhance urban traffic resilience.

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ACHIEVING CLIMATE JUSTICE THROUGH ADAPTING THE TWIN TOWN RELATIONSHIP AS A MODALITY TO IMPROVE THE RESILIENCE OF PALESTINE'S WATER SECTOR

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1. INTRODUCTION

The Mediterranean basin is a climate change hotspot. Over the past few decades, the temperature in the Mediterranean area has increased by 0.4 °C more than the global average (1.1 °C)(Cramer et al. 2020). Moreover, all numerical simulation models indicate that the region will be increasingly affected by the consequences of climate change, such as extreme weather events, including heavy rainfalls provoking aggressive floods and longer and more frequent heatwaves, increased desert areas, or the rise of sea level.

Water resources management in the Palestinian Authority falls under the purview of the Palestinian Water Authority and the Palestinian Ministry of Agriculture. However, both entities encounter substantial challenges in adequately meeting the water demands of the Palestinian populace. According to the UN, more than 750,000 Palestinians in Gaza and the West Bank experience insufficient access to water. In 2023, several studies indicated a daily share of around 55 to 88 liters per person. These figures fall substantially short of the WHO-recommended average of 120 liters per capita per day (Palestinian Central Bureau of Statistics 2025; World Health Organization 2025; Zahra 2001). Compounding this issue are systemic inefficiencies, such as water loss exceeding 35% in the West Bank's water systems. This contributes to the current water deficit. Projections indicate that the water supply-demand gap will reach around 10 million cubic meters annually by 2032. However, as the war progressed, the aforementioned figures worsened with a severe demolition of water utilities, including waste and saline water treatment units and destroying the water distribution networks.

Accordingly, since 1992, climate change has been a top priority for international efforts, with developed and developing countries working together to mitigate and adapt to its consequences. However, global efforts are still behind commitments, leading to the failure of global mitigation and adaptation efforts, resulting in many vulnerable countries, such as Palestine, lacking the financial, technical, or institutional capacities to adapt. The international community is still developing international agreements and frameworks to improve the global response to climate change adaptation (Timilsina 2021).

While several national and international attempts have been made to improve Palestine's resilience and climate change adaptation, the present trend suggests that these efforts are insufficient to effectively plan for and respond to the increasing impacts. In this composite context situation, Palestine faces a multi-layered crisis regarding climate change, deteriorating infrastructure, geopolitical relations, and ongoing war, endangering public health, agricultural livelihoods, and the stability of society as a whole. Accordingly, the research explores a novel, innovative international cooperation framework, specifically adapting the twin-town relationship as a modality emphasizing the water sector most affected by climate change's impact.

2. PROBLEM STATEMENT

Global climate justice is a critical, yet often unaddressed, aspect of climate change. Despite contributing the least to global emissions, the most vulnerable countries are disproportionately impacted by its effects. This injustice is compounded by the persistent failure of global mitigation and adaptation efforts to meet their obligations, such as the unachieved 100 billion USD financial support target from the Paris Agreement. This global inaction directly translates into severe challenges for Palestine, facing rising temperatures, changing precipitation patterns, and increasing extreme weather events, which worsen water shortages, endangering public health, agricultural livelihoods, and societal stability. The current situation has been gravely exacerbated by the recent conflict, which has degraded infrastructure and cut off vital supplies, making the population even more exposed and vulnerable. Despite several national and international efforts to improve Palestine's resilience, the present trend suggests they are inadequate for the escalating crisis. The required measures must go beyond addressing climate risks and also reduce the vulnerability of the Palestinian people themselves. Creative, localized, and context-specific approaches are desperately needed to build community resilience and adaptive skills, especially for water resource management. Within the Palestinian context, the research will improve the current traditional twin-town relationships to provide the necessary support for creating a more resilient and sustainable future for climate risks and the specific vulnerabilities brought on by conflict.

3. OBJECTIVE

The research aims to propose an international cooperation framework for climate change adaptation in the water sector using the twin-town relationship approach. The research investigates the climate change challenges in the water sector, focusing on existing climate change adaptation measures, assessing existing international cooperation modalities and tools, and adapting twin-town relationships for climatic cooperation between Palestinian cities and other regions. Therefore, the following research objectives have been achieved and will be presented in the Colloquium.

1. To identify the climate change challenges and risks in the water sector in the Mediterranean area.
2. To examine the existing climate change adaptation measures in the water sector, the State of Palestine is adopting.

The general scope of the research includes 22 Mediterranean countries with coastlines on the Mediterranean Sea. The study investigates who among these countries is affected/will be affected, by what, and who is doing what to mitigate climate change risks in the water sector. Next, the research investigates the measures and actions carried out to adapt to the climate change challenges within the Palestinian context.

4. METHOD

The European Environment Agency identified 36 significant climate threats in the Mediterranean area. The study scope investigates significant climate hazards under significant water stress in the region. Consequently, the study redefines climate risk associated with the water sector, specifically the domestic water sector, emphasising fluctuations in precipitation, heat waves, and saline intrusion increases.

WP1 Objective 1: General Reviewing: Climate Change Risk: Concepts, Consequences, Likelihood, and Impact

This research project analyses climate risks to the water sector within the Mediterranean region, focusing on the qualitative assessment of likelihood, impact magnitude, and the resultant risk matrix value. The methodology involves a systematic literature review spanning a geographical region of the Mediterranean Sea. The study also provides an in-depth analysis of water-related climate hazards at an urban scale within these regions. Additionally, the study provides a granular examination of these water-related climate hazards at an urban scale. It offers a detailed overview across 319 Mediterranean cities, with each hazard systematically evaluated for its likelihood, impact magnitude, and assigned risk matrix value. The research examined various global entities, including the United Nations Framework Convention on Climate Change (UNFCCC), Intergovernmental Panel on Climate Change (IPCC), World Meteorological Organization (WMO), United Nations Office for Disaster Risk Reduction (UNDRR), UN-Water, and the Global Heat Health Information Network. It assessed climate change risks to the water sector in the Mediterranean area, focusing on droughts, floods, and saltwater intrusion. (Convention on Climate Change, 2025; IPCC | Data, World Meteorological Organisation).

WP2 Objective 2: Examine the existing climate change adaptation measures in the Palestinian water sector

The Work Package 2 aims to analyze the impacts of climate change on the water sector in Palestine and the policies, strategies, and plans developed for adaptation. Key documents include National Adaptation Plans (NAP), Nationally Determined Contributions (NDCs), national water policies, reports from the Palestinian Water Authority, the Environment Quality Authority, the Ministry of Agriculture, NGOs, academic studies, and international donor reports. Climate change impact assessments are reviewed to identify risks to the water sector, such as decreased precipitation, increased temperatures, droughts, floods, sea-level rise, and groundwater depletion. Existing adaptation policies and strategies are documented, including IWRM principles, water harvesting, wastewater treatment, water efficiency, infrastructure improvements, and institutional capacity building. The institutional framework is mapped, and gaps and challenges in the existing policy framework are identified, considering factors like political constraints, financial resources, institutional weaknesses, and data availability (Connor 2015; Palestinian Central Bureau of Statistics 2025; Palestinian Water Authority 2022; Zahra 2001).

5. RESULT AND DISCUSSION

According to a global analysis of climate change risks, increased temperatures are the most pervasive threat, with 128 cities at extreme risk and 111 cities at high risk, much higher than those in the medium 62 cities and low 18 cities categories. Conversely, fewer cities are at greater risk from sea level rise, with only four at extreme risk and seven at high risk, while the majority of 83 cities are at medium risk, and four at low risk. Comparably, elevated risk perceptions are widespread worldwide, with 193 countries classifying this as high risk, four at extreme and low risk, and 115 cities at medium risk. This suggests that many countries and cities are aware of and concerned about various climate-related issues. In the Palestinian adaptation plan context, the research reviews the current statutes accordingly and summarizes the main findings in the following table.

Adaptation plan	Adaptation Actions	Indicators 2030-2035	Current Progress & Geopolitical Context
Water: Water treatment and conservation	Enhance the use of additional and alternative water resources in the West Bank and Gaza Strip for non-domestic purposes.	*70% of the wastewater treated in large-scale wastewater treatment plants in the West Bank and Gaza will be reused by 2030 *7 MCM of rainwater is harvested by 2032.	Current: Less than 20% of wastewater is being reused; 4 MCM of rainwater harvested. Continuing under-funding has hindered progress (less than 5% of needs), and a recent conflict has destroyed much of the existing infrastructure.
Water: Improving water network infrastructure	Control of leakage from distribution systems Develop and improve stormwater systems and drainage infrastructure.	*Non-revenue water is reduced by 15% by 2032. *5% of rainwater in priority urban areas is drained and collected by 2032.	Current: Non-revenue water exceeds 30% by 2025. The conflict has exacerbated network damage and rendered maintenance efforts impossible.
Water: Improving water source infrastructure	Rehabilitate water sources: wells, canals, and springs.	*100% of identified wells and springs will be rehabilitated by 2030	Current: according to PWA, 85% of wells in Gaza have been wholly or partially damaged. The war has made current rehabilitation efforts impossible and has shifted the focus to post-war reconstruction.

6. CONCLUSION

While detailed plans have been made for improving climate change adaptation in Palestine, including targets for wastewater reuse, rainwater harvesting, and network rehabilitation, current progress remains significantly behind schedule. For instance, the goal of reusing 70% of treated wastewater by 2030 is severely hindered by the fact that less than 20% is currently being reused, a problem exacerbated by chronic under-funding and recent conflict that has destroyed much of the existing infrastructure. Similarly, efforts to reduce non-revenue water and rehabilitate wells and springs are failing. The conflict has rendered maintenance and rehabilitation impossible, with PWA reporting that 85% of wells in Gaza have been damaged, shifting the focus from proactive adaptation to desperate post-war reconstruction. This highlights the critical gap between ambitious adaptation plans and the harsh realities on the ground, where geopolitical factors and a lack of funding severely undermine progress.

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GOVERNANCE CHALLENGES AND INFLUENCING FACTORS IN JOINTLY OPERATED CROSS-BORDER OIL AND GAS FIELDS IN THE ARABIAN GULF

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1. INTRODUCTION

Cross-border oil and gas fields represent both an opportunity and a challenge for hydrocarbon-rich regions such as the Arabian Gulf. These jointly operated fields are managed by National Oil Companies (NOCs) from neighboring countries and are vital to the region's energy security and economic sustainability (Nassar 2025). However, managing such shared resources demands robust governance structures that transcend national interests and effectively mitigate risks (Khatib et al. 2025). The unique geopolitical, legal, and operational dynamics of the Arabian Gulf add complexity to the governance of these joint ventures (Brunet-Jailly 2022). Inconsistent policies, overlapping jurisdictions, and lack of integrated sustainability strategies often create governance challenges that directly threaten regional energy security, economic stability, and long-term sustainability. The sustainable and cooperative development of these cross-border resources is crucial to achieving long-term environmental, economic, and social objectives (Golovina et al. 2021; Nalule et al. 2022). This study explicitly investigates these core governance challenges by examining current management issues and exploring both administrative and non-administrative factors affecting these joint operations.

2. PROBLEM STATEMENT AND LITERATURE REVIEW

Despite the strategic and economic importance of jointly owned hydrocarbon fields in the Arabian Gulf, governance of these assets remains fragmented (Nassar 2025). Current arrangements often prioritize short-term national interests over long-term collective sustainability. Several unresolved issues, such as administrative overlap, regulatory inconsistency, lack of transparency, and trust deficit between stakeholders, hinder effective collaboration between NOCs (Weijermars & Al-Shehri 2022). In particular, NOCs tend to focus more on operational and technical collaboration while giving insufficient attention to the administrative and non-administrative dimensions of governance. This imbalance undermines efforts toward sustainability, especially in areas such as joint decision-making, regulatory alignment, and environmental accountability.

Furthermore, there is limited scholarly research focused specifically on the administrative and non-administrative challenges faced by NOCs in this geopolitical context (Brunet-Jailly 2022). Empirical evidence from recent Gulf joint ventures reveals recurring failures in institutional coordination, legal harmonization, and stakeholder engagement, factors critical for sustainable governance (e.g., delayed joint field development in the Khafji field). Without a comprehensive understanding of these issues, any framework aimed at risk mitigation and sustainable governance remains inadequate. Therefore, this study seeks to examine to what extent a sustainable governance framework, one that addresses both administrative and non-

administrative factors, which can facilitate the long-term, collective sustainability of jointly operated cross-border oil and gas fields in the Arabian Gulf.

3. OBJECTIVE

This study aims to explore how sustainable governance practices can be strengthened to support the long-term, collective sustainability of jointly operated cross-border oil and gas fields managed by NOCs in the Arabian Gulf.

This colloquium presentation focuses mainly on two objectives:

1. To identify key governance and management issues affecting the sustainable management of jointly owned cross-border natural resources (hydrocarbons) between NOCs in the Arabian Gulf, with a view toward promoting long-term collective sustainability.
2. To analyze the underlying administrative (e.g., regulatory harmonization, institutional coordination, joint budgeting) and non-administrative factors (e.g., trust and historical relationships, geopolitical alignment, environmental & SDG commitment) that influence sustainable governance practices in cross-border hydrocarbon fields in the Arabian Gulf.

4. METHOD

This study adopts a sequential explanatory mixed-methods approach, combining document analysis, case study review, semi-structured interviews, and survey questionnaires to achieve Objectives 1 and 2. The initial qualitative phase involved the review and analysis of bilateral agreements, legal frameworks, regulatory policies, and governance documents related to cross-border hydrocarbon management in the Arabian Gulf. A total of 35 official documents, including treaties, MOUs, national oil strategies, and joint field development agreements were reviewed. These documents served as the foundation for understanding current governance structures and identifying key management issues (Objective 1).

To further explore the administrative and non-administrative dimensions of governance (Objective 2), three case studies were purposively selected, focusing on existing jointly operated cross-border fields between: Saudi Arabia–Kuwait (Khafji Joint Operations), Bahrain–Saudi Arabia (Abu Sa’fah Field), and UAE–Oman (shared pipeline and coastal operations). These cases were chosen due to their strategic relevance, operational maturity, and availability of documented governance challenges. The total population includes key stakeholders from NOCs, regulatory bodies, and energy policy institutions across the six Gulf Cooperation Council countries. A purposive sampling technique was used to select 12 interviewees, including senior executives, project managers, and policymakers. In the quantitative phase, a structured survey was administered to 112 mid- and senior-level managers from NOCs operating in the selected joint fields. The survey instrument used a 5-point Likert scale to measure perceptions regarding governance, transparency, administrative efficiency, and sustainability practices. For data analysis, content analysis was applied to qualitative data, enabling the extraction of key themes and recurring governance challenges. The survey data were analyzed using descriptive statistics and inferential statistics to identify significant patterns and relationships.

5. RESULTS AND DISCUSSION

Objective 1 focused on identifying governance and management issues in jointly operated hydrocarbon fields. As shown in Table 1, stakeholders highlighted legal ambiguity (76%),

transparency deficit (71%), and political tensions (68%) as the most pressing challenges. These findings confirm that fragmented legal frameworks and limited cooperation hinder sustainable joint operations (Simões, 2024). Regulatory inconsistency (64%) and operational delays (59%) were also noted, indicating a need for aligned policies and faster decision-making mechanisms.

Table 1. Key management issues in jointly operated cross-border hydrocarbon fields.

Issue Category	Description	Stakeholder Agreement (%)
Legal Ambiguity	Lack of harmonized legal frameworks between states	76%
Transparency Deficit	Limited data sharing on production & environmental metrics	71%
Trust and Diplomacy	Political tensions affect operational cooperation	68%
Regulatory Inconsistency	Conflicting regulations across borders	64%
Operational Delays	Bureaucratic hurdles and delayed joint decision-making	59%

Objective 2 examined administrative and non-administrative factors shaping sustainable governance. As shown in Table 2, regulatory harmonization (Mean = 4.52) and institutional coordination (4.36) were rated most important, reflecting the need for aligned governance structures. Among non-administrative factors, trust and historical relationships (4.21) ranked highest, highlighting the influence of diplomatic relations on operational outcomes. Lower scores for geopolitical alignment and SDG commitment suggest areas for policy enhancement.

Table 2. Perceived Importance of Administrative and Non-Administrative Factors (Likert Scale: 1 = Not Important, 5 = Extremely Important).

Factor Type	Factor	Mean Score	Standard Deviation	Rank
Administrative	Regulatory harmonization	4.52	0.61	1
Administrative	Institutional coordination	4.36	0.70	2
Non-Administrative	Trust and historical relationships	4.21	0.75	3
Administrative	Joint budgeting & resource allocation	3.88	0.83	4
Non-Administrative	Geopolitical alignment	3.76	0.89	5
Non-Administrative	Environmental & SDG commitment	3.64	0.91	6

6. CONCLUSION

This study offers a preliminary investigation into the governance dynamics and sustainability challenges faced by NOCs involved in the management of jointly operated cross-border oil and gas fields in the Arabian Gulf. The analysis of qualitative interviews and Likert-scale survey responses highlights key management challenges such as legal ambiguity, transparency deficits,

and regulatory fragmentation that hinder long-term cooperation. Furthermore, both administrative (institutional coordination and regulatory harmonization) and non-administrative factors (trust and geopolitical alignment) significantly influence sustainable governance practices. The high perceived importance of these factors, especially regulatory harmonization and historical trust, underscores the need for an integrated and cooperative approach among NOCs. These insights lay the groundwork for the next stage of research, which will focus on the development of a comprehensive governance and risk mitigation framework. Addressing these challenges is essential not only for resource efficiency and environmental stewardship but also for promoting regional energy security and geopolitical stability.

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DESIGNING AN INTERACTIVE EDUCATION PLATFORM FOR THE DIGITAL PRESERVATION OF INTANGIBLE CULTURAL HERITAGE OF YANGJIABU NEW YEAR PAINTINGS, CHINA

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1. INTRODUCTION

Yangjiabu New Year paintings, from Weifang, Shandong, are distinctive traditional Chinese woodblock art with vivid folk colors and auspicious symbolism. The paintings hold profound historical and artistic values as it is a national Intangible Cultural Heritage (ICH) in China (Ministry of Culture and Tourism of the People's Republic of China 2006). Per UNESCO's ICH guidelines (UNESCO 2003), Chinese governments prioritize digital dissemination of ICH (China's State Council 2017 & 2021; Ministry of Culture and Tourism of China 2023).;

However, despite growing national efforts, digital preservation projects often lack educational depth. As noted by a researcher from the Yangjiabu Wood-block New Year Pictures Research Institute, existing initiatives rarely integrate systematic cultural education, leading to shallow public engagement. They also suffer from insufficient cultural interactivity and systematic evaluation. Yangjiabu paintings face dual challenges: modernization and digital media widen younger generations' gap with traditional culture (14th Five-Year Plan for the Protection of Intangible Cultural Heritage), existing digital projects are limited to static archiving without educational integration or user engagement, and systematic evaluation of digital tools is lacking (Xue et al. 2019; Chen et al. 2022). To address these, this research identifies traditional protection challenges, assesses digital technologies' impact, and integrates cultural education with digital application to contribute to SDG 11.4, ensuring the heritage's long-term preservation and digital sustainability.

2. PROBLEM STATEMENT

Yangjiabu New Year paintings, a significant intangible cultural heritage of China from Weifang, Shandong, known for vivid folk colors and unique woodblock techniques, face critical challenges. Traditional inheritance is hindered by declining artisan skills and shifting market demand (Li 2022), while existing digital efforts—per a representative from Weifang Yangjiabu Folk Art Co., Ltd.—focus on basic documentation (e.g., image archiving and text descriptions) rather than meaningful interaction, failing to engage modern audiences (Ioannides et al. 2021). This study addresses these gaps by identifying traditional challenges and evaluating digital technologies' impact.

3. RESEARCH OBJECTIVE

Therefore, this research aims to design and evaluate an interactive educational platform to bridge the gap between digital preservation and meaningful cultural transmission. It focuses on two distinct, interconnected objectives with clear scopes:

Objective 1: To systematically identify core challenges in the traditional protection and inheritance of Yangjiabu New Year paintings using SWOT analysis, categorizing four dimensions: internal weaknesses (e.g., declining artisan skills, lack of standardized educational systems), external threats (e.g., shrinking market demand, competition from modern media), missed opportunities (e.g., underutilization of local cultural policies), and existing strengths (e.g., national ICH recognition, unique woodblock techniques).

Objective 2: To construct a multi-dimensional framework for evaluating digital technologies' impact on Yangjiabu New Year paintings, focusing on three outcomes: (1) preservation efficiency (digitization speed, archive accessibility); (2) user engagement (interaction frequency, participation in online activities); (3) cultural authenticity (accuracy of symbolic meaning, retention of traditional techniques).

4. METHOD

A dual-method approach is adopted: Objective 1 employs qualitative methods, while Objective 2 applies quantitative techniques

Objective 1:

Semi-structured interviews target 15 stakeholders (5 master artisans, 5 cultural managers, 5 policy implementers) to cover the full chain of inheritance, management, and policy execution. Thematic analysis of 10-year official documents (policy files, project reports) used NVivo 12 (Allsop et al., 2022) for in-depth insight into traditional protection gaps.

Objective 2:

A structured questionnaire surveys 120 respondents (30 digital experts, 30 educators, 60 users) — this composition balances technical, educational, and public perspectives, ensuring the evaluation of digital technology impact is multi-dimensional and objective (consistent with the quantitative research design logic of Zhang & Liu, 2019).

5. RESULTS AND DISCUSSION

Traditional challenges (Objective 1): Content analysis of 10 policy documents and interviews with 15 stakeholders identified five core challenges: lack of systematic educational design, weak interactivity in existing digital platforms, symbolic rather than contextual cultural expression, insufficient financial support (annual funding <¥500,000), and fragmented policy implementation. Digital technology impact (Objective 2): Sample justification: 120 respondents (30 digital experts, 30 educators, 60 users) cover technical, educational, and public perspectives (consistent with Zhang & Liu, 2019). Key findings: The questionnaire showed good reliability (Cronbach's alpha = 0.78, meeting the ≥ 0.7 threshold for acceptable reliability). Ease of use (mean=4.10, SD=0.62) and cultural authenticity (mean=3.94, SD=0.71) were positively rated. Engagement (mean=3.10, SD=0.98) and educational value (mean=3.66, SD=1.02) scored lower,

with educators rating educational value higher (mean=4.2) than general users (mean=3.2). The low engagement score may stem from the fact that existing digital platforms for Yangjiabu New Year paintings mostly rely on static displays (e.g., image archives, text descriptions) rather than immersive interactive designs (e.g., simulated New Year painting creation, cultural story interactive Q&A) — a finding consistent with Zhang and Liu (2019)'s conclusion that 'insufficient interactivity restricts user participation'. Meanwhile, the gap in educational value ratings between educators and general users likely reflects the lack of systematic cultural education content in current platforms, which fails to align with public learning needs.

The challenges identified (e.g., lack of systematic educational design, weak interactivity in existing digital platforms) — a key finding from Objective 1's SWOT analysis — directly explain the low scores in engagement and educational value: the 'weakness of insufficient pedagogical integration' in traditional protection leads to digital platforms' failure to design targeted educational interactive content, ultimately resulting in low user engagement and unmet educational needs (consistent with Xue et al. 2019's argument that 'digital ICH preservation without educational integration lacks sustainability'). Positive ratings for usability and authenticity suggest digital technologies enhance accessibility but need better alignment with user learning needs (Zhang & Liu 2019). These results support the proposed platform's focus on interactive learning to address identified gaps.

6. CONCLUSION

Key challenges in the traditional protection and digital dissemination of Yangjiabu New Year paintings were identified, including the lack of systematic educational design, limited interactivity, and insufficient sustainability measures. The evaluation of digital platforms showed positive recognition of usability and cultural authenticity, but revealed gaps in user engagement and educational depth. These findings highlight that digital technologies alone cannot fully realize effective cultural transmission without integrating pedagogical strategies and active stakeholder participation. Therefore, the proposed interactive education platform aims to bridge these gaps by fostering an engaging, culturally authentic, and sustainable digital environment — its uniqueness lies in integrating 'SWOT-based traditional challenge identification' and 'multi-dimensional digital impact evaluation' into platform design, which differs from existing static archiving platforms and realizes the deep integration of digital preservation and cultural education. This approach contributes to the long-term preservation and digital sustainability of Yangjiabu New Year paintings: (1) For policy, it provides empirical support for the implementation of China's 14th Five-Year Plan for the Protection of Intangible Cultural Heritage (emphasizing 'digital + educational protection'); (2) For practice, it offers an actionable framework for digital platform designers and cultural heritage practitioners, guiding the development of user-centric ICH protection tools; (3) For future research, it lays a foundation for exploring the integration of education and digital technology in other ICH categories (e.g., traditional folk music, handicrafts). It also provides valuable insights for future intangible cultural heritage protection initiatives.

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MULTIMODAL VIRTUAL REALITY FOR IMMERSIVE LEARNING IN LEARNING MANAGEMENT SYSTEM IN MALAYSIA

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1. INTRODUCTION

Malaysian higher education is grappling with systemic challenges that threaten educational equity and quality. Department of Statistics Malaysia data reveals 17,613 public university students dropped out between 2020–2021, with 20,577 private students deferring studies (PTPM 2024). This crisis is compounded by low engagement in traditional online learning, where static content and limited interactivity fail to replicate hands-on experiences essential for engineering education. The rapid, unplanned shift to online learning during the recent pandemic highlighted significant infrastructural and pedagogical gaps, with many students facing challenges related to device access, internet connectivity, and a lack of engaging course design (Abdul Aziz et al., 2023); For disciplines like engineering, this "emergency remote teaching" often translated into a passive learning experience, failing to provide the practical, hands-on engagement that underpins conceptual understanding and sustains student motivation. This disconnect between theoretical instruction and practical application, exacerbated by inadequate technology, is a critical factor contributing to student disengagement and the subsequent decision to drop out. The 12th Malaysia Plan (2021–2025) advocates "leveraging advanced technologies" to ensure accessible education (Sani et al. 2020), yet non-immersive Learning Management Systems (LMS) remain ill-equipped to address these technology-induced drivers of attrition. Existing research highlights a critical gap: while Virtual Reality (VR) shows promise in enhancing engagement, its integration into LMS lacks systematic evaluation in the Malaysian context. This study responds to this need by investigating a multimodal VR-LMS framework, grounded in Gibson's ecological theory of perceptual affordances and constructivist pedagogy (Latta & Oberg 1994; Magoon 1977). By merging immersive technology with LMS analytics, the research aims to bridge the divide between theoretical knowledge and practical application, particularly for engineering students. The study's scope aligns with the Sustainable Development Goals (SDG 4), targeting equitable access to quality education through technology-driven innovation.

2. PROBLEM STATEMENT AND LITERATURE REVIEW

Reports (Abou-Khalil et al. 2021; Beck 2019; Dimitriadou & Lanitis 2022; Munoz-Carpio et al. 2018; Pena-Rios et al. 2012; Sani et al. 2020) indicate that Higher education face high dropout situation especially among engineering students due to lack of immersion, and insufficient practical, hands-on learning experiences provided by traditional and standard online learning methods, highlighting a critical need to explore innovative educational solutions. Specifically, the integration of immersive VR technologies into LMS, to enhance student immersion, improve learning outcomes. Thus, requiring urgent intervention through VR-LMS integration. By using technologies such as virtual reality (VR), teachers can create more engaging learning environments, capture behavioural data, and provide multidimensional assessment strategies (Dimitriadou & Lanitis 2022; Dewan et al. 2019). It helps students better understand difficult

points, interactively display connections between knowledge, and enhance personalized learning (Beck 2019). However, traditional online education faces challenges as low immersion and interactivity (Abou-Khalil et al. 2021; Pena-Rios et al. 2012); the immersive learning effect provided by VR courses also needs to be evaluated. (Beck 2019; Dimitriadou & Lanitis 2022); and LMS in Malaysia lack integration with immersive tools like VR (Munoz-Carpio et al., 2018; Sanı et al. 2020). Many challenges remain unresolved. This study is to understand how virtual reality (VR) can be integrated into the Malaysian education system to add meaningful content to the discussion on improving educational methods in Malaysia (Chandini Pendit et al. 2015; Pena-Rios et al. 2012).

Higher education, particularly in engineering, faces high dropout rates due to low immersion and insufficient hands-on learning in traditional and online methods, while existing LMS in Malaysia lack VR integration; therefore, exploring how immersive VR technologies can enhance engagement, learning outcomes, and personalized experiences remains a critical challenge.

3. RESEARCH OBJECTIVE

This study has two main objectives: (1) to identify shortcomings of online learning technique and technology of Engineering Subjects. (2) to determine the learning effects of virtual reality learning environments in rectifying shortcomings identified. These objectives are aligned with national education priorities such as quality assurance and the Education 4.0 policy, which aims to reform the way engineering education is delivered.

4. METHOD

To achieve research objectives 1 and 2 (phase 1&2), this study was reviewed by two social scientists and validated by the UKM Ethics Committee (approval code: JEP-2024-1032). Phase 1 (Data Collection) involves (Lee 2025) : Employ a triangulation approach 'combining literature review, structured interviews and analysis of educational statistics' to identify and validate core pain points. This includes mapping challenges faced by students (e.g., disengagement), lecturers (e.g., limited feedback tools), and institutions (e.g., infrastructure costs).

- **Literature Review:** Systematic analysis of 93 articles on VR, LMS, and online learning challenges, focusing on Gibson's affordances and constructivist frameworks.
- **Structured Interviews:** Semi-structured dialogues with Stakeholder representatives from E-access College, Langkawi Vocational College, and UKM (3 managers, 1 technician, and 6 engineering teachers), collect rich, contextual data that captures the nuanced experiences and perspectives of those on the front lines.
- **Policy Statistical Analysis:** National education statistics centres or international bodies like UNESCO. The focus is on data points that shed light on access, equity, engagement, outcomes, teacher preparedness, and institutional investment related to online learning, particularly in non-immersive forms. To contextualize macro-level trends.

Phase 2 (Evaluation) uses mixed-methods design (Creswell & Clark 2011): Metrics include 82 engineering students across three institutions performance in VR modules (e.g., engine mechanics tasks), engagement metrics (time-on-task, interaction patterns), and qualitative feedback on immersion, skill development, and satisfaction.

- **Quantitative Measures:** VR system logs tracking task completion times (mean=75.80 min), scores in lessons (mean=86.21–92.78), and exams (mean=84.95–89.87).
- **Qualitative Surveys:** Questionnaire used of 5-point Likert scales ($\alpha=0.79$ – 0.91 reliability) questions, analyses via descriptive analysis, regression analysis and SEM analysis administered to 82 students' post-VR module completion via a UTAUT framework.

5. RESULTS AND DISCUSSION

Phase 1 identified six current shortcomings of online learning through triangulation to achieve research goal 1: Behavioural Data is Missing, Weak Real-Time Intervention Capabilities, Evaluation Dimension is Single, Insufficient Personalized Diagnosis, High Resource Management Costs and Weak Interactive Experience. Objective performance metrics confirm significant learning gains (The mean training score of participants reached 92.55 (SD=8.12, range: 70.00–100.00), and the mean exam score was 89.78 (SD=9.54, range: 65.00–100.00)). Student performance in VR lessons/exams demonstrated steady improvement (Lesson 1 mean=88.49 vs. Lesson 3 mean=98.67, Exam 1=88.29 vs Exam 3=92.49), aligning with constructivist learning trajectories. Survey data showed 91.5% agreement with VR scoring, 75.6% confidence in skill application, and 89% preference for VR over traditional labs. Qualitative feedback highlighted demands for content expansion (e.g., diesel engine simulations) and collaborative features, with 56.1% preferring group-based VR learning. However, learning efficiency perceptions were mixed: while 71.9% reported improved problem-solving, only 34.2% felt VR reduced study time. Technical challenges, such as motion sickness in 5% of participants, underscored the need for ergonomic design adjustments. The Structural Equation Model (SEM) exhibited excellent fit (CMIN/DF = 1.95, CFI = 0.96, TLI = 0.95, RMSEA = 0.07) and explained 66.3% of the variance in Effective Outcomes. This high explanatory power ($R^2 = 0.663$) confirms that the VR course's impact on learning is not random but systematically linked to measurable factors, to fulfil the research goal 2.

6. CONCLUSION

This research validated a multimodal VR-LMS framework as an effective solution to Malaysian higher education's engagement and dropout crisis. The model addresses core pain points by integrating immersive experiences with data-driven analytics, improving both theoretical understanding and practical skill development. The study found that integrating VR into online learning effectively addresses six key shortcomings: missing behavioural data, weak real-time intervention, limited evaluation dimensions, poor personalized diagnosis, high resource costs, and low interactivity. While producing measurable learning gains (e.g., Lesson 1 mean = 88.49; Lesson 3 mean = 98.67). Strong positive attitudes (e.g., 91.5% agreement with VR scoring; 75.6% confidence in skill application) and an exhibited SEM excellent fit (CMIN/DF = 1.95, CFI = 0.96, TLI = 0.95, RMSEA = 0.07) with explained 66.3% of the variance in Effective Outcomes confirm VR's engagement benefits. Future work should explore mobile VR adaptations for low-resource settings and longitudinal studies on VR's impact on long-term retention. The study contributes to global conversations on immersive education, offering a scalable model for developing nations prioritizing educational equity.

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URBAN AGGLOMERATION-LED REGIONAL DEVELOPMENT: MECHANISMS FAND IMPLEMENTATION STRATEGIES IN THE JING-JIN-JI REGION

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1. INTRODUCTION

Urban agglomerations (UAs) have become a central pillar of China's regional development strategy, serving not only as economic powerhouses but also as experimental zones for advanced governance and sustainable urbanization (Liu et al. 2024). The Jing-Jin-Ji (JJJ) region (Beijing-Tianjin-Hebei) represents one of the most significant yet challenging of these initiatives, embodying a national strategic priority aimed at balancing growth and coordination across diverse administrative units. Since its formal elevation in 2014, substantial policy measures have been implemented to foster integration (Deng et al. 2022). Nonetheless, the region continues to exhibit pronounced imbalances, characterized by a sharp core-periphery divide, inefficient resource distribution, and institutional barriers that hinder synergistic development (Ma 2019).

This study seeks to unravel the underlying mechanisms of agglomeration-led development in the JJJ region and critically assess the effectiveness of current policy interventions. Grounded in complex systems theory and evolutionary economic geography, our framework offers a novel perspective by treating the UA as a multi-scalar, adaptive, and dynamically evolving entity—rather than a static or merely administrative construct. This approach allows for a more comprehensive understanding of how cross-jurisdictional synergies can be optimized through adaptive governance mechanisms that transcend traditional administrative boundaries.

By integrating quantitative spatial-econometric analyses with qualitative policy diagnostics, this study not deciphers the developmental trajectory of JJJ but also generates transferable insights for the governance of mega-regions worldwide.

2. PROBLEM STATEMENT

JJJ region, contributing approximately 8.1% to China's national GDP, exhibits profound regional disparities (Fang, 2019). A striking illustration is the per capita GDP gap, with Beijing's figure being 3.2 times that of Hebei. Core challenges include:

- (1) Core Overcrowding vs. Periphery Underdevelopment: Beijing suffers from “big city disease”—manifested as congestion and pollution - while Hebei experiences industrial stagnation.
- (2) Institutional Silos: Fragmented governance systems - fiscal autonomy, divergent environmental regulations, and uncoordinated transport planning - impede regional integration.
- (3) Innovation Asymmetry: Although Beijing generates 43% of the region's patents, technology diffusion to Hebei remains below 15%.

Theoretical frameworks such as Marshall-Arrow-Romer externalities (Glaeser, 2010) and New Economic Geography (Krugman, 1991) highlight knowledge spillovers and core-periphery dynamics. Complementary approaches stress the role of institutional thickness (Amin & Thrift,

1995) and multi-level governance (Hooghe & Marks, 2003). China-specific studies further identify administrative hierarchy (Xu & Yeh 2011) and hukou-related labor immobility (Chan 2019) as critical constraints.

However, significant research gaps remain, and a targeted research agenda must address the following specific problems:

- (1) Empirical analysis of cross-jurisdictional spillover mechanisms - examining how knowledge, capital, and policy effects diffuse (or fail to diffuse) across administrative boundaries within JJJ;
- (2) Systematic evaluation of implementation barriers - identifying and assessing the institutional, fiscal, and political obstacles that hinder the execution of urban agglomeration (UA) policies;
- (3) Dynamic modelling of industry-resource-ecology feedback loops - developing simulations to trace long-term interactions between economic development, resource allocation, and environmental outcomes in the region.

By addressing these specific issues, future research can generate actionable insights for achieving coordinated and sustainable development in JJJ.

3. OBJECTIVE

- (1) To determine the effects Economic-Environmental Spillovers across JJJ (2010–2023).
- (2) To identify institutional, fiscal, and infrastructural obstacles to UA integration.
- (3) To determine Policy Efficacy implemented for Urban agglomerations (UAs) of JJJ.
- (4) To propose Adaptive Governance Framework for Urban agglomerations (UAs) of JJJ.

4. METHOD

This study adopts a mixed-methods sequential explanatory design, combining quantitative and qualitative approaches to provide a holistic understanding of the complex, multi-dimensional issues facing the JJJ region.

Objective	Methods	Data Sources	Analysis Technique
1	Quantitative spatial panel data analysis	- Economic Data: City-level GDP, industrial output, FDI -Environmental Data: PM2.5, SO ₂ , and wastewater emissions from the China Environmental Statistical Yearbook -Nighttime Light (NTL) Data. Used as a proxy for economic activity and urbanization intensity. Specific variables: Annual mean light intensity and total lit area per prefecture. -Spatial Data: GIS data on administrative boundaries, road networks, and infrastructure	-Spatial Durbin Model (SDM): The dependent variable could be GDP growth or pollution concentration. Independent variables include local and neighbouring economic activity, NTL intensity, and environmental regulation stringency. -Gravity Model of Economic Cohesion: Applied to quantify economic interconnection, applying mass variables GDP (economic mass), population, and distance variables.
2	Qualitative document analysis	-Policy Documents: Regional plans, provincial and municipal fiscal reports, environmental regulations, and transport master plans.	Comparative Institutional Analysis: Systematically comparing policies, fiscal structures, and regulations

			across the three jurisdictions to identify silos and contradictions.
3	Quantitative policy evaluation using Difference-in-Differences (DID)	-Policy Interventions: Key JJJ policies -Outcome Variables: Data on economic output (from Yearbooks), pollution levels, patent co-applications (measuring innovation diffusion), and inter-city commuter flows (from mobile phone big data or transport surveys).	-DID: Treats the implementation of a major policy as an intervention. Cities in JJJ are the treatment group; a control group of comparable cities from other major urban agglomerations is selected.
4	Synthesis and iterative framework development	-Findings from Objectives 1-3. -Literature Review	Logical Analysis and Synthesis: Integrates quantitative evidence on spillovers and policy efficacy with qualitative insights on institutional barriers to identify leverage points for governance reform.

5. RESULTS AND DISCUSSION

The main findings of analysis for the two objectives are described as follow:

(1) Mechanisms of Agglomeration-Led Development:

Asymmetric Spillovers: Positive knowledge spillovers from Beijing to Tianjin, but negative to Hebei due to talent suction.

Pollution Transfer: 18% of Beijing's PM2.5 reduction (2015–2020) resulted from industrial relocation to Hebei, increasing Hebei's industrial emissions by 12%.

Infrastructure-Driven Integration: High-speed rail (HSR) boosted labor mobility within 1-hr commuter belts, yet amplified disparities beyond HSR nodes.

(2) Implementation Challenges:

Fiscal Disincentives: 73% of Hebei municipalities resisted industry reception due to revenue loss.

Regulatory Fragmentation: Environmental standards varied by 300%.

Innovation Decoupling: Only 7% of Beijing's tech startups collaborated with Hebei firms.

The JJJ development model exhibits truncated diffusion mechanisms:

Scale Mismatch: Macro-level policies ignored micro-level institutional realities.

Governance Trap: Top-down mandates without fiscal equalization exacerbated inter-regional competition.

Path Dependency: Heavy-industry legacies in Hebei hindered green transition despite innovation inflows (Zheng, 2018).

6. CONCLUSION

This study reveals that development in the Jing-Jin-Ji (JJJ) agglomeration is driven by three core mechanisms: selective diffusion of knowledge and pollution along hierarchical networks, self-reinforcing feedback loops from infrastructure integration, and adaptive governance capacity shaped by institutional and fiscal coordination.

To address imbalances, we propose three strategies: Differentiated Regulatory Zones with unified standards but phased timelines to harmonize environmental and innovation policies; Polycentric Innovation Hubs, using Xiongan as a sandbox to decentralize innovation and

encourage collaboration; and a Digital Governance Platform for transparent monitoring of cross-border flows.

The JJJ experience highlights that physical connectivity must be supported by flexible governance. Lessons for other mega-regions include the need to overcome administrative fragmentation through institutional innovation—such as adaptive policy tools and polycentric development—to achieve equitable and sustainable growth.

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GOVERNANS KELESTARIAN DALAM INDUSTRI MAKANAN DAN MINUMAN DI MALAYSIA: KAJIAN KES BAKER'S COTTAGE

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1. PENGENALAN

Industri Makanan dan Minuman (M&M) merupakan sektor strategik yang menyumbang secara signifikan kepada Keluaran Dalam Negara Kasar (KDNK) dan penciptaan pekerjaan di Malaysia. Namun begitu, industri ini turut berhadapan dengan cabaran kelestarian seperti penghasilan sisa makanan, penggunaan sumber semula jadi secara tidak mampan dan kesan sosial terhadap komuniti. Governans kelestarian menjadi aspek penting dalam menangani isu-isu ini melalui kerjasama pelbagai pihak berkepentingan termasuk kerajaan, syarikat dan masyarakat (FAO 2013; MOA 2021). Keperluan kepada pendekatan governans yang lestari ini juga selari dengan Matlamat Pembangunan Mampan (SDG) yang digariskan oleh Pertubuhan Bangsa-Bangsa Bersatu, khususnya (SDG 2) yang bertujuan menamatkan kelaparan dan memastikan sistem pengeluaran makanan yang mampan; (SDG 12) yang menekankan kepentingan pengeluaran dan penggunaan yang bertanggungjawab; serta (SDG 17) yang menggalakkan perkongsian merentas sektor bagi menjayakan agenda pembangunan mampan secara kolektif. Inisiatif governans yang berkesan memerlukan pengintegrasian tiga komponen utama governans secara strategik dan seimbang: governans hierarki untuk memastikan dasar dan peraturan yang konsisten (Kooiman 2003a; Lai et al. 2025; Pai et al. 2024), governans pasaran untuk merangsang inovasi dan respons terhadap permintaan pengguna yang menuntut kelestarian (Baldwin 2018; Sullivan et al. 2021a), serta governans rangkaian untuk membina kerjasama erat dan dialog berterusan antara semua pihak berkepentingan bagi memperkukuh amalan kelestarian yang holistik dan adaptif (Bahri & Ali 2022; Bigliardi & Galanakis 2020a; Kooiman 2003b). Keberkesanan governans kelestarian dalam industri ini bergantung kepada interaksi harmoni ketiga-tiga komponen tersebut untuk mencapai matlamat pembangunan mampan dan kelangsungan jangka panjang sektor.

2. PERMASALAHAN KAJIAN DAN SOROTAN KAJIAN

Pengurusan kelestarian dalam industri M&M menghadapi cabaran utama kekurangan integrasi dan kerjasama strategik antara governans hierarki, pasaran, dan rangkaian (Ansell & Gash 2008; Baba et al. 2019; Pierre & Peters 2000). Keberkesanan governans hierarki, yang mengawal dasar dan peraturan berkaitan keselamatan makanan dan sijil halal, bergantung kepada sistem pentadbiran yang berhierarki dan berdisiplin (Marinsah et al. 2025; Zakaria et al. 2022). Sementara itu, governans pasaran menumpukan kepada inovasi dan respons terhadap permintaan pengguna terhadap produk hijau dan lestari (Bigliardi & Galanakis 2020b; Sullivan et al. 2021b). Governans rangkaian pula penting dalam membina hubungan kerjasama strategik dan dialog berterusan dengan pembekal, NGO, dan pihak berkepentingan lain untuk menjamin kelestarian rantaian nilai (Peters et al. 2021). Tambahan lagi, kerajaan melalui inisiatif seperti pensijilan

halal dan standard keselamatan turut membantu memperkukuh governans hierarki dan rangkaian (Ramli 2020; Zakaria et al. 2022). Walaupun begitu, kejayaan inisiatif kelestarian sangat bergantung kepada keberkesanan integrasi ketiga-tiga governans ini, yang turut diperkukuh oleh kerjasama strategik dan (FAO 2013; SDG 12 2021) penggunaan teknologi digital inovatif (Agya 2025; Herrero et al. 2021). Kekangan utama termasuk kekurangan insentif jangka panjang, dasar tidak konsisten, serta kekurangan sumber dan teknologi digital yang sesuai (Isaac et al. 2025; Wachyuni et al. 2024). Oleh yang demikian, pembangunan model governans yang mampu menyatukan ketiga-tiga komponen secara strategik dan holistik adalah amat penting untuk memastikan pengurusan kelestarian yang berkesan dan mampu mengatasi cabaran global serta mencapai matlamat pembangunan mampan industri ini (FAO 2013; SDG 12 2021).

3. OBJEKTIF KAJIAN

Kajian ini bertujuan untuk memahami bagaimana governans kelestarian diaplikasikan dalam pengurusan industri M&M tempatan melalui kajian kes syarikat rangkaian makanan Baker's Cottage. Kajian ini menetapkan empat objektif utama. Objektif pertama adalah untuk mengenal pasti pihak-pihak berkepentingan utama yang terlibat dalam pelaksanaan amalan kelestarian syarikat. Objektif kedua pula adalah untuk mengenalpasti peranan dan bentuk kerjasama antara pihak-pihak berkepentingan berdasarkan tiga pendekatan governans utama, iaitu governans hierarki, governans pasaran dan governans rangkaian. Seterusnya, objektif ketiga adalah menentukan pengaruh setiap pendekatan governans terhadap keberkesanan pengurusan kelestarian di peringkat syarikat. Di samping itu, kajian ini juga bertujuan untuk membangunkan satu kerangka governans kelestarian yang sesuai untuk diaplikasikan dalam industri M&M di Malaysia. Namun begitu, bagi tujuan pembentangan kolokium ini, perbincangan hanya akan memfokuskan kepada tiga objektif pertama yang melibatkan pengenalan pihak berkepentingan, bentuk governans yang terlibat, dan penilaian terhadap pengaruhnya dalam pelaksanaan kelestarian di Baker's Cottage.

4. KAEDAH KAJIAN

Kajian ini menggunakan pendekatan kualitatif dengan reka bentuk kajian kes (De Sordi 2024; Yin 2018) terhadap Baker's Cottage (BC) sebagai subjek utama berdasarkan kedudukannya sebagai jenama terkenal dalam industri M&M Malaysia, beroperasi di bawah rangkaian Leong Hup International Bhd (LH), serta menunjukkan komitmen tinggi terhadap keberlanjutan seperti pelabelan hijau dan piawaian halal. Syarikat ini sesuai sebagai contoh kajian kerana hubungan strategik dengan pelbagai pihak berkepentingan dan pelaksanaan governans yang praktikal serta bersepadu. Sebanyak tujuh dokumen rasmi seperti dasar, laporan, piawaian, dan pelan tindakan berkaitan kelestarian dianalisis untuk memahami kerangka dasar dan prosedur yang diamalkan oleh syarikat. Di samping itu, sebanyak tiga belas temu bual separa berstruktur dijalankan terhadap pelbagai pihak berkepentingan termasuk pengurusan syarikat induk LH, pengurusan BC, kakitangan pelbagai peringkat, pembekal dan pelanggan. Data daripada temubual ini dianalisis menggunakan pendekatan analisis tematik (Braun & Clarke 2006; Wang & Ran 2023) dengan bantuan perisian NVivo versi 11, bagi mengenalpasti tema dan subtema berkaitan governans kelestarian. Pemerhatian terhadap operasi harian syarikat turut dilakukan bagi mendapatkan gambaran menyeluruh mengenai bentuk kerjasama yang terbentuk dalam konteks governans kelestarian. Kaedah triangulasi digunakan untuk meningkatkan kesahan dapatan. Pendekatan ini membolehkan analisis yang komprehensif dalam menjawab semua objektif kajian yang dinyatakan.

5. KEPUTUSAN DAN PERBINCANGAN

Dapatan kajian menunjukkan ketiga-tiga governans; hierarki, rangkaian, dan pasaran, berperanan penting dalam pelaksanaan kelestarian di Baker's Cottage. Peranan governans hierarki sebagai struktur utama dalam memastikan kawalan dan pematuhan dalam keberkesanan usaha kelestarian., dengan sebanyak 518 kod berkaitan kepada piawaian keselamatan dan kawalan mutu seperti ISO 22000, HACCP, dan Sijil Halal Malaysia. Sebanyak 70% responden percaya bahawa penguatkuasaan dasar melalui sistem hierarki menyumbang kepada kejayaan inisiatif tersebut. Governans rangkaian pula menunjukkan peranan penting dalam membina kerjasama strategik dengan pihak berkepentingan seperti pembekal dan NGO, dengan 273 kod yang menunjukkan keberadaan hubungan kerjasama aktif, termasuk kerjasama NGO dan perjanjian kerjasama dengan pembekal. Sebanyak 65% pihak berkepentingan menekankan perlunya komunikasi strategik dalam memperbaiki amalan hijau dan CSR syarikat. Manakala Governans pasaran dengan 250 kod pula berfokus kepada strategi promosi produk lestari dan pelabelan hijau. Sebanyak 55% pengurus pemasaran menumpukan perhatian kepada aktiviti promosi yang memenuhi keperluan pengguna sosial dan alam sekitar yang semakin peka. Inisiatif ini menunjukkan adanya sinergi kukuh antara governans hierarki, rangkaian dan pasaran, di mana keberhasilan sijil halal, kerjasama NGO, dan promosi produk berasaskan governans ketiga-tiga aspek tersebut sangat bergantung kepada kestabilan semua komponen governans. Sekiranya salah satu gagal, impaknya terhadap keberkesanan usaha kelestarian secara keseluruhan akan sangat ketara (Ahmad Hidayat & Zulzaidi 2012; Azizan et al. 2016; Hajar et al. 2023; Mohammad Hafeez et al. 2025; Rihawi 2024; Zahrul Akmal 2016; Zaiamri et al. 2021). Kekangan utama dalam mencapai matlamat kelestarian industri M&M di Malaysia ialah kekurangan insentif jangka panjang, dasar tidak konsisten, serta kekurangan sumber dan teknologi moden yang diperlukan (Fernandez & Ismail 2018; Mat et al. 2016; Mohd Nashir et al. 2020; Mohd Rifin et al. 2021). Hal ini menghalang inovasi, latihan, dan penerapan teknologi baru, sekaligus melemahkan integrasi governans dan keberhasilan jangka panjang (Ancín et al. 2022; Konfo et al. 2023; Sri Utami et al. 2024). Penyelesaian yang disarankan termasuk pemberian insentif fiskal berterusan, penyeragaman dasar, serta peningkatan sumber dan teknologi untuk memperkukuh governans, disokong komunikasi strategik yang lebih baik. Keberkesanan governans kelestarian sangat bergantung kepada sinergi dan kestabilan semua aspek governans; hierarki, rangkaian, dan pasaran, yang harus diintegrasikan secara padu untuk membina sistem yang holistik, efektif, dan mampu bersaing secara mampan.

6. KESIMPULAN

Kajian ini merumuskan bahawa keberkesanan governans kelestarian dalam industri M&M di Malaysia bergantung kepada interaksi strategik dan harmonis antara governans hierarki, rangkaian, dan pasaran, disokong oleh kerjasama kukuh, komunikasi efektif, serta penggunaan teknologi digital dan insentif fiskal. Pengintegrasian ketiga-tiga komponen ini penting untuk memperbaiki amalan hijau, serta menyokong pencapaian matlamat Pembangunan Mampan (SDG 2, 12, & 17). Namun, kekangan seperti kekurangan insentif jangka panjang, dasar tidak konsisten, serta kekurangan sumber dan teknologi halangan utama kepada pelaksanaan governans yang berkesan dan bersepadu. Oleh itu, pembangunan model governans yang holistik dan adaptif adalah kritikal untuk memastikan pengurusan kelestarian yang inovatif, berkesan, dan mampu menghadapi cabaran global serta memenuhi keperluan pembangunan mampan industri M&M di Malaysia.

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SUSTAINABLE CONSERVATION AND UTILIZATION OF RELIGIOUS PROPERTY: A CASE STUDY OF LONGMEN GROTTOES

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Co-supervisor: Dr. Chang Qing

1. INTRODUCTION

Buddhism was introduced to China along the ancient Silk Road, had generated various indigenous Buddhist schools and thousands of Buddhist temples and monasteries dotted the landscape (Silk 2014). The Longmen Grottoes were listed as a UNESCO World Heritage Site in 2000 and have since become one of the most valuable heritage resources for regional sustainable development. Currently, the Longmen Grottoes face growing tension between heritage conservation and tourism-driven utilization. Sustainable utilization or reutilization is to find new and creative ways to work in harmony with existing heritage or to make use of old or disused cultural heritage, which offer significant potential benefits for the future, as well as maintaining links with the past (European Urban Initiative 2024). This study explores, for the first time, a practical and sustainable solution for the sustainable conservation and utilization of religious property, particularly the Longmen Grottoes, to benefit the local tourism industry in terms of environmental and economic benefits.

2. PROBLEM STATEMENT

The sculptures of the Longmen grottoes are an outstanding manifestation of human artistic creativity (UNESCO 2000). Despite initiatives like real-time heritage monitoring, the digitization-driven 'Digital Longmen' project, and the development of tri-zone (park, scenic area, community) integration, current work often emphasizes tourism promotion over sustainable management. The Longmen Grottoes face dual challenges: natural weathering conditions in cave temples and anthropological causes both of which can lead to heritage resource deterioration and community tensions; and the absence of diverse cultural activities and insufficient heritage recognition in Longmen Grottoes weaken the long-term sustainability of heritage management. This research was therefore justified by its potential to contribute a new insight into heritage management model that can mitigate the contradiction between conservation efforts and heritage accessibility, ensuring both cultural continuity and sustainable tourism. This research aims to understand how conservation and dissemination can reinforce one another, using qualitative and quantitative analyses.

3. OBJECTIVE

Weathering effect on limestone sculptures (Lu & Jiao 2020) caused by climate change and temperature variation triggers the colour fading of sculpture, while damage by pests and plants and water seepage can enlarge the cracks of the stone heritage. On the other hand, the weak environment and limited resources both can be destroyed by human activities (Liu & Shi 2020), largely due to lack of conservation awareness. Thus, two research objectives were listed below:

- a) To identify the causes of degradation of limestone cave temples on a global level and to determine the root causes of the destruction of the Longmen Grottoes.

b) To align long-term management sustainability with regional development through diverse cultural activities and enhanced heritage recognition.

4. METHOD

For the first objective, a bibliometric literature review was conducted using VOS viewer. The search was performed within “All fields” in SCOPUS, the keywords selected are “Cave temple” AND “Limestone”. The inclusion criteria for the 91 documents with publication years ranging from 2001 to 2025 were that studies frame in the context of deterioration analyses of cave temples. For the second objective, this research employed Difference in Difference (DID) to predict outcomes of political documents implemented for the conservation of cave temples. Besides, this study adopts a participatory methodological approach that allows the residents to be involved in cultural activities designed to raise awareness of heritage conservation.

5. RESULT AND DISCUSSION

Co-occurrence and co-authorship analyses were conducted using VOSviewer. The keyword co-occurrence network visualization was set full counting, the minimum number of occurrences of a term was set as 2, and 103 items were selected; 7 clusters showed 7 main terms, which were “Cave”, “Cultural heritage”, “Bacteria”, “Rock mechanics”, “Karst”, “Biomineralization”, and “Weathering”. It should be mentioned that in the “Weathering” cluster, “Deterioration”, “Sandstone”, and “Water absorption” were closely linked (See Fig.1). Briefly, the visualization result reveals a thematic interdisciplinary network including geology, biology, engineering, and heritage conservation. The seven clusters were well linked, showing the effects of natural and cultural factors on cave-typed cultural heritage.

Additionally, 337 authors were selected for the co-authorship analysis; the minimum number of documents of an author was set 2. The author's collaboration network analysis, visualized in Figure 2, demonstrates that the field was characterized by a main cooperative community, a ‘giant component’, consisting of 51 scholars; alongside several independent, small collaborative groups (13 scholars) that lack cooperative links with the main community.

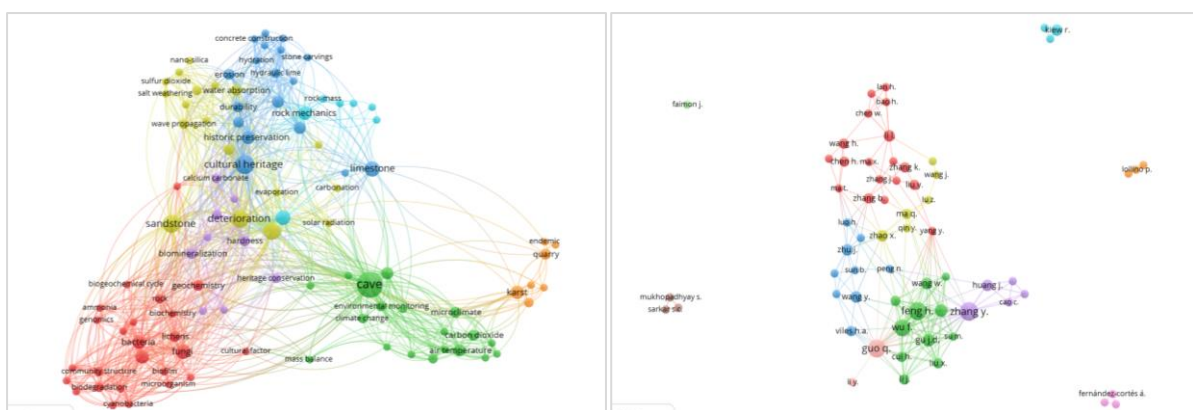


Figure 1. Keyword co-occurrence visualization (right); Figure 2. Co-authorship visualization (left)

Finally, the DID results showed a slight improvement after the implementation of the *Regulations on the Protection and Management of the Longmen Grottoes in Luoyang city*. The design of cultural activities includes thematic exhibitions on the Longmen Grottoes, theatrical

performances inspired by Buddhist classics, and artistic recreations of traditional music. This approach contributes to raising awareness of conservation while promoting sustainable dissemination of cultural heritage.

6. CONCLUDING REMARKS

Analysing the factors leading to heritage deterioration recognize two main issues from natural process and anthropogenic activities. The natural process is weathering, biomineralization, bacteria and water absorption. Most of these natural processes is relates to some extended time, while other such as landslide, rock fall or mudslide and to some lengths are earthquake was not in the main list. Meanwhile the anthropogenic impact by the tourism activities or human intervention affect the cave microclimate. The understanding of the main factor that impact the limestone cave at the global level and Longman Grottose will enabled better planning of conservation work at this World Heritage site, while analysing the political effects significantly mitigated conservation challenges. Due to space limitations, the complete research results were not shown here. The future discussion will be themed on the findings from the results. Briefly, this study emphasizes the importance of sustainable conservation and utilization for current and future management of Longmen Grottoes and for regional sustainable tourism.

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A COMPARATIVE STUDY OF CLASSICAL CHINESE GARDENS AND THAI GARDENS - GEOGRAPHICAL AND HUMANISTIC FACTORS

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1. INTRODUCTION

Gardens are cultural landscapes shaped by geography, climate, and human ideas. They combine natural features, plants, and constructions to express aesthetic, social, and philosophical values (Teuber 2021; Zakharova & Lopatchenko 2024). The geographical factors of garden include vegetation, water and topography while humanistic factors consider the element of culture, aesthetics and customs. Another side of garden is the “artistic conception” that refers to aesthetic and symbolic meanings created through imagery that evokes resonance (Cihai Editorial Committee 2009; Xu, Wang & Yu 2025; Zakharova & Lopatchenko 2024). The Chinese and Thai gardens that will be studied in this research has belonged to the Oriental Garden system. Comparing their geographical and cultural features helps us understand system diversity and guide future garden design. Globalization emphasizes the integration of regional culture and ecological conditions (Zhang, Huang, Zhang, Guo, Hu, & Wang 2025). This study highlights how geographical and humanistic factors interact to shape artistic conception, providing insights for sustainable and culturally grounded garden design.

2. PROBLEM STATEMENT

Vegetation and water are considered key factors that can represent geographical factors (Fernandes, Teixeira, & Veludo 2025; Hamer et al. 2024). Cultural values and aesthetic perception are the core humanistic components of landscape design (including gardens) and are an important foundation for achieving cultural sustainability (Liu et al. 2020). Although gardens, as an outstanding artistic carrier that integrates culture and nature, have been widely studied, most of the existing literature focuses on a single study, such as the impact of geographical environment or human culture on garden design. However, there is a lack of comparative research on how the interaction between geographical and human factors jointly shapes the artistic conception of gardens, especially between Chinese classical gardens and Thai gardens. This research gap limits our in-depth understanding of the diversity and complexity of the oriental garden system and also restricts the development of modern garden design towards a sustainable direction that integrates cultural characteristics and ecological environment.

3. OBJECTIVE

This study originally had four main objectives, mainly to study the comparison of artistic conception between Chinese gardens and Thai gardens, including geography, humanities and future development. However, in this stage of research and reporting, only two of the objectives were focused on: first, to identify the geographical factors that affect the artistic conception of Chinese classical gardens and Thai gardens; second, to identify the humanities factors that affect the artistic conception of Chinese classical gardens and Thai gardens.

4. METHOD

To achieve the research objectives, a multi-angle comprehensive analysis of Chinese and Thai gardens was conducted. First, a literature review was used to establish the historical and cultural context of garden development. Representative gardens were then selected for field investigation based on historical texts, contemporary research, and heritage status, including China's Summer Palace, Chengde Mountain Resort, Humble Administrator's Garden, Lingering Garden, Master of the Nets Garden, Mount Wutai, Mount Emei, Mount Qingcheng, and Thailand's Dusit Palace Garden, Bang Pa-In Royal Palace Garden, Suan Pakkad Palace Museum, Jim Thompson House, Wat Benchamabophit, Wat Phra That Doi Suthep, and Wat Arun. Geographical factors included climate (temperature, precipitation, seasonal variation), soil (pH, fertility, texture), vegetation (species, density, spatial arrangement, summarized in tables and figures), and water bodies (classified as central, auxiliary, or ritualistic to assess spatial and aesthetic roles). Humanistic factors included religion (temple distribution and influence of Buddhism, Taoism, Confucianism), royal authority and politics (spatial hierarchy and symbolic architecture), aesthetics (architectural features, decorative elements, landscape techniques), and society and culture (festivals, ceremonies, and public activities).

On-site observation, photography, spatial mapping, and symbol analysis were used to explore how geographical and humanistic factors jointly shape garden artistic conception. Interviews with management personnel provided insights into garden function and social adaptability, enhancing authenticity and understanding of how traditional garden conception integrates with modern social needs.

5. RESULTS AND DISCUSSION

The overall comparison is summarized in Table 1 below:

Factor	Chinese Gardens	Thai Gardens
Climate	Temperate to subtropical; dry in northern regions, humid in southern regions	Tropical monsoon climate; high temperature and humidity, abundant rainfall
Soil	Diverse; variations in pH and fertility affect plant selection and layout	Predominantly tropical red soil and loam, suitable for evergreen tropical vegetation
Vegetation	Pine, cypress, bamboo, plum, willow, etc.; drought-tolerant species in the north, moisture-loving species in the south	Native tropical plants such as banana, lotus, and bodhi; high coverage of broad-leaved evergreen species
Water Bodies	Auxiliary design; flowing or still water carries symbolic meaning but is generally not the central focus	Central and ritualistic; e.g., lotus ponds in front of temples serve both aesthetic and ceremonial functions
Aesthetics	Borrowed scenery, framed views, architectural elements, rockeries and ponds; emphasize "harmony between man and nature"	Rich architectural decorations, including eaves, gilded carvings, pagodas; reflect Buddhist grandeur
Religion	Influenced by Confucianism, Taoism, and Buddhism; focus on self-cultivation and moral education	Predominantly Buddhism; gardens integrated with temples, emphasizing religious rituals and symbolism
Society & Culture	Rituals, festivals, and literati activities influence garden use	Influenced by Buddhist and secular culture; gardens often serve communities and religious activities
Politics / Royal Authority	Royal gardens reflect social hierarchy and power symbolism	Royal or temple gardens reflect Buddhist authority and royal power

Geographical factors strongly influence garden design. Northern China's dry climate favors pine, cypress, and willow with symmetrical planting, as seen in the Summer Palace (Beijing) and Chengde Mountain Resort (Chengde). Southern China's humid climate supports pine, bamboo, and plum with more flexible layouts, exemplified by Suzhou's Humble Administrators Garden, Lingering Garden, and Master of the Nets Garden. Water bodies in Chinese gardens are usually auxiliary, reflecting symbolic meanings rather than serving as central features—for example, the Summer Palace's Lake mainly complements feng shui, while Mount Wutai and Mount Emei feature water integrated with religious and ceremonial spaces. Thailand's tropical monsoon climate supports broad-leaved evergreen species and native plants such as banana, lotus, and bodhi. Water elements, such as the lotus pond at Suthep Mountain Garden, are central and ritualistic, while palace gardens like Dusit Palace and Bang Pa-In Royal Palace also incorporate water for ceremonial and aesthetic purposes. These patterns demonstrate a close interaction between geographical and humanistic factors in shaping artistic conception.

Humanistic factors, including culture, religion, and aesthetics—directly affect garden design. Chinese gardens, influenced by Confucianism, Taoism, and Buddhism, emphasize harmony between man and nature. Techniques such as borrowed scenery and framed views guide visitors toward reflection and personal cultivation, with architectural elements carrying symbolic meanings, as seen in Suzhou Gardens. Religious gardens like Mount Wutai and Mount Qingcheng integrate Buddhist architecture and landscape to convey spiritual values. Thai gardens are strongly influenced by Buddhism and local secular culture, often integrated with temples such as Wat Benchamabophit, Wat Phra That Doi Suthep, and Wat Arun. Decorative elements such as gilded carvings, eaves, and pagodas enhance religious symbolism and ceremonial functions. Field observations confirm that the fusion of culture, religion, and aesthetics is a key determinant of garden artistic conception.

In the context of globalization, both Chinese and Thai gardens are adapting traditional concepts to meet modern urbanization and tourism needs. This evolution highlights the transformation of gardens from historical cultural landscapes to contemporary multifunctional spaces, guiding future garden design to integrate ecological, cultural, and social considerations.

6. CONCLUSION

Vegetation and water bodies, as the most representative geographical factors in gardens, reflect the adaptability of climate conditions in different regions, and have obvious differences in the layout and expression of artistic conception of gardens. Due to the diversity of regional climates, Chinese gardens show regional differences in vegetation selection and spatial forms, reflecting the orderly transformation of culture to nature; while Thai gardens make full use of the advantages of tropical climate, centering on native broad-leaved plants and water bodies, and make full use of vegetation factors to strengthen the spatial expression of religious rituals.

In the comparison of humanistic factors, different cultural differences show the different artistic conception of the gardens of the two countries. China is influenced by the three general religions of Confucianism, Taoism and Buddhism, interpreting the "harmony between heaven and man" of Chinese local culture; Thai gardens fully integrate Buddhist religious rituals with local secular culture, creating a sense of sacredness and ritual of Thai gardens.

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PENILAIAN RISIKO BANJIR DI MUKIM HULU LANGAT, SELANGOR

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1. PENGENALAN

Bencana alam dan bencana buatan manusia telah menunjukkan peningkatan beberapa dekad terkini. Data antarabangsa EM-DAT merekodkan peningkatan bencana sebanyak 74.4% antara tahun 2000 hingga 2019, yang disebabkan oleh perubahan iklim dan peralihan persekitaran (Mizutori & Sapir 2019). Pada tahun 2022 sahaja, 387 bencana dilaporkan, melebihi purata tahunan 20 tahun, menunjukkan kejadian bencana kekal tinggi selepas tahun 2019 (CRED 2023). Secara global, banjir mencatatkan kejadian tertinggi, mewakili lebih 44% daripada jumlah bencana dan paling banyak menjejaskan benua Asia. Di Malaysia, banjir turut menjadi bencana yang paling kerap berlaku serta memberi kesan terbesar berbanding risiko bencana lain (NADMA 2021). Banjir puing adalah bencana geologi yang terhasil dari proses geologi berangkai yang paling mengorbankan banyak nyawa dan kerugian ekonomi di Malaysia (Rosli et al. 2021; KeTSA 2022). Antara bencana banjir puing yang terburuk direkodkan adalah di Keningau, Sabah (1996) dengan 300 kematian, banjir lumpur di Kampung Orang Asli Pos Dipang, Kampar, Perak dengan 22 kematian dan banjir puing di tiga negeri iaitu Pahang, Negeri Sembilan dan Selangor (2021) dengan 23 kematian (Rosli et al. 2021). Majoriti peristiwa disebabkan oleh hujan lebat dan berpanjangan, dan sangat sedikit yang dicituskan oleh gempa bumi (Jaapar et al. 2023).

2. PERMASALAHAN KAJIAN DAN SOROTAN KAJIAN

Hulu Langat, Selangor merupakan antara daerah yang sering dilanda banjir kilat (Rosli et al. 2021; Mohamed et al. 2024). Banjir kilat yang berlaku secara berulang kali telah menimbulkan kebimbangan masyarakat, merosakkan rumah serta harta benda, dan menjejaskan kelangsungan hidup. Hulu Langat juga berisiko mengalami bencana banjir puing disebabkan oleh keadaan geografi yang berbukit serta kedudukannya berhampiran Sungai Langat menjadikannya mudah terdedah kepada aliran puing dan lumpur ketika hujan lebat berterusan (Jaapar et al. 2023; Jafar et al. 2020). Perubahan guna tanah yang pesat untuk pembangunan perumahan dan infrastruktur tanpa penilaian impak persekitaran menyeluruh telah mempercepatkan hakisan tanah, kehilangan litupan tumbuhan, dan gangguan terhadap sistem saliran semula jadi (Zahidi et al. 2023). Namun, kebanyakan kajian pemetaan bencana di Hulu Langat masih tertumpu kepada aspek bahaya fizikal, tanpa mengambil kira kemudahterancaman sosial dan daya tahan komuniti secara menyeluruh. Jurang pengetahuan ini penting kerana walaupun komuniti Hulu Langat kerap berhadapan dengan banjir, tahap daya tahannya masih rendah, menyebabkan mereka kekal terdedah terhadap risiko berulang. Ketiadaan integrasi antara dimensi fizikal dan sosial dalam penilaian risiko menjadikan usaha pengurangan risiko banjir kurang berkesan dan tidak sepenuhnya menyokong pendekatan berasaskan komuniti (*community-based disaster risk reduction*). Oleh itu, kajian ini bertujuan untuk menilai tahap risiko banjir puing dengan menggabungkan pemetaan risiko fizikal, kemudahterancaman sosial, dan daya tahan komuniti di peringkat mukim bagi mengisi jurang pengetahuan sedia ada serta menyokong perancangan strategik pengurangan risiko banjir yang lebih holistik dan setempat.

3. OBJEKTIF KAJIAN

Mengenal pasti risiko banjir puing di Mukim Hulu Langat melalui pendekatan pemetaan spatial, analisis hidrologi, dan pemodelan simulasi bagi membangunkan peta bahaya serta risiko banjir di Hulu Lembangan Sungai Langat.

4. KAEDAH KAJIAN

Kajian ini menggunakan pendekatan pemetaan spatial, analisis hidrologi dan pemodelan simulasi untuk membangunkan peta bahaya dan risiko banjir di Hulu Lembangan Sungai Langat. Dua komponen utama terlibat iaitu: (i) analisis hidrologi dan (ii) pemodelan simulasi banjir. Analisis hidrologi melibatkan data luahan sungai daripada JPS (2020–2024) bagi menilai purata, minimum dan maksimum aliran air di Kampung Batu 18, 20 dan 21. Nilai purata ini dibandingkan dengan rekod banjir terdahulu untuk mengenal pasti senario ekstrem. Pemodelan simulasi dijalankan untuk menggambarkan kedalaman dan keluasan banjir berdasarkan senario yang berbeza, disahkan dengan data empirik dan dikalibrasi menggunakan kaedah Gumbel. Bagi menyokong analisis morfologi lembangan, data Digital Elevation Model (DEM) dan Digital Terrain Model (DTM) daripada Shuttle Radar Topography Mission (SRTM) digunakan dalam ArcGIS. Data resolusi 30-meter ini penting untuk mengenal pasti cerun, arah aliran dan zon takungan. Maklumat ini membantu pembinaan model jaringan saliran dan pembangunan peta bahaya banjir. Peta bahaya dibangunkan berdasarkan integrasi data DEM, DTM dan analisis luahan sungai dan kemudian dikategorikan kepada tiga tahap: tinggi, sederhana dan rendah. Peta risiko banjir pula dibangunkan dengan menggabungkan data bahaya, simulasi kedalaman banjir dan ciri topografi, bagi menunjukkan potensi impak banjir yang lebih menyeluruh. Peta ini akan digunakan dalam objektif seterusnya untuk menilai daya tahan komuniti di Mukim Hulu Langat.

5. HASIL KAJIAN DAN PERBINCANGAN

Hasil kajian daripada objektif 1 telah menghasilkan peta bahaya dan risiko banjir bagi Kampung Batu 18, 20 dan 21 serta Hulu Lembangan Sungai Langat. Klasifikasi kawasan dibahagikan kepada tiga tahap iaitu **T (tinggi)**, **S (sederhana)** dan **R (rendah)** berdasarkan analisis spatial. **Peta bahaya banjir** menilai faktor semula jadi dan fizikal termasuk topografi, intensiti hujan, saliran sungai serta rekod sejarah banjir, manakala **peta risiko banjir** menggabungkan bahaya fizikal dengan faktor manusia seperti kepadatan penduduk, guna tanah, infrastruktur dan tahap kesiapsiagaan komuniti. Berdasarkan hasil analisis, Hulu Lembangan Sungai Langat mencatat kawasan bahaya tinggi seluas **2,108 km² (81%)**, sederhana **108 km² (4.1%)**, dan rendah **417 km² (15.8%)**. Di Kampung Batu 18, 20 dan 21 pula, lebih 60% keluasan berada dalam kategori bahaya tinggi dan sederhana. Kampung Batu 18 terdedah secara langsung kepada kawasan risiko tinggi, manakala Kampung Batu 20 dan 21 lebih dipengaruhi kedudukan berhampiran sungai dengan risiko limpahan dan aliran deras. Perbezaan utama antara **bahaya banjir** dan **risiko banjir** adalah ruang lingkungannya. Bahaya banjir hanya menggambarkan potensi ancaman fizikal berdasarkan keadaan semula jadi, manakala risiko banjir menilai tahap kerentanan dan keterdedahan manusia terhadap bahaya tersebut. Oleh itu, risiko banjir lebih penting untuk rujukan pihak berkuasa kerana ia menggabungkan dimensi sosial yang memberi kesan langsung kepada kehidupan penduduk. Penemuan spatial ini selari dengan banjir besar Disember 2021 yang menjejaskan lebih 2,250 penduduk di kawasan kajian. Laporan Khas NADMA (2022) menganggarkan kerugian harta benda sektor kediaman di Hulu Langat sebanyak RM 253.6 juta, di samping gangguan jalan utama akibat tanah runtuh dan limpahan sungai. Kesamaan antara

penilaian spatial dengan impak sebenar ini menegaskan keperluan pelaksanaan segera pelan pengurangan risiko banjir secara holistik dan berasaskan komuniti di Hulu Langat.

6. KESIMPULAN

Kesimpulannya, dapat dilihat bahawa hampir 60% daripada kawasan kampung-kampung ini terdedah kepada risiko banjir tinggi (8.42km²). Dapatan ini menunjukkan bahawa komuniti yang mendiami zon tersebut mempunyai tahap kemudahterancaman terhadap banjir. Situasi ini sekali gus menekankan keperluan untuk memberi perhatian khusus terhadap aspek kemudahterancaman sosial dan memahami tahap daya tahan mereka dalam perancangan dan pengurusan bencana secara holistik. Oleh itu, terdapat keperluan untuk menjalankan kajian dengan dengan analisis lanjutan yang memberi tumpuan kepada aspek sosial termasuk tahap kemudahterancaman sosial (seperti umur, tahap kesihatan, jenis pekerjaan, pendapatan dan pendidikan bencana) serta daya tahan komuniti (seperti keterhubungan komuniti, risiko dan keterdedahan, langkah-langkah tindakan dan kemampuan dan sumber daya). Pendekatan ini penting bagi memastikan aspek sosial masyarakat diambil kira selain faktor fizikal dan geografi. Hasil gabungan analisis spatial dan aspek sosial ini akan menjadi asas kepada perancangan pengurusan bencana yang lebih menyeluruh dan inklusif. Seajar dengan matlamat pembangunan lestari, dapatan kajian ini menyokong SDG 11 (Bandar dan Komuniti Lestari) dengan memperkukuh ketahanan komuniti terhadap bencana, serta SDG 13 (Tindakan terhadap Perubahan Iklim) melalui penekanan kepada adaptasi dan langkah proaktif dalam mengurangkan impak perubahan iklim terhadap kawasan berisiko banjir.

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MENEROKA JENIS-JENIS PELAKSANAAN LANGKAH BERJAGA-JAGA PERSENDIRIAN (LBP) SECARA LANGKAH STRUKTUR (LS) DALAM KESIAPSIAGAAN BANJIR DI MUKIM DENGKIL, DAERAH SEPANG, SELANGOR

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1. PENGENALAN

Banjir merupakan bencana alam yang paling kerap berlaku setiap tahun dan memberi kesan besar kepada populasi (EM-DAT 2024), serta kesan secara langsung kepada sosio-ekonomi khususnya individu atau persendirian (Kundzewicz et al. 2018; Chan et al. 2020; DID 2024) serta alam sekitar (Semnan et al. 2023; Usman Kaoje et al. 2021). Di Malaysia, banjir dianggarkan melibatkan keluasan sehingga 10.1% (33,298 Km²) serta memberi kesan kepada 16.8% Populasi (5.7 juta orang) DID, (2024) dengan nilai kerugian dianggarkan berjumlah RM2.85 billion setiap tahun (JPS 2022). DOSM (2022) pula melaporkan pecahan nilai kerugian akibat banjir Tahun 2021 sahaja antaranya melibatkan harta benda persendirian seperti kediaman dan kenderaan masing-masing bernilai RM1.6 billion dan RM1.0 billion. Justeru, tiba masanya pendekatan kesiapsiagaan banjir dibuat secara menyeluruh dan proaktif dengan melibatkan masyarakat khususnya individu (Ketua Isi Rumah) melalui pelaksanaan Langkah Berjaga-jaga Persendirian (LBP) secara Langkah Struktur (LS). Ini bermakna, LBP adalah tindakan individu membuat persediaan awal sebelum atau semasa kejadian banjir bagi menghalang atau mengurangkan kemasukan air banjir melalui LS seperti penggunaan “aras ketinggian” (Harish et al. 2023) antaranya dengan menambak tapak lebih tinggi dari paras banjir sebelum membina rumah, pembinaan rumah bertiang tinggi, pembinaan tembok konkrit tinggi keliling rumah, pemasangan Para atau Loteng dan sebagainya.

2. PERMASALAHAN KAJIAN DAN SOROTON KAJIAN

Pelbagai langkah pengurusan banjir telah dilaksanakan oleh pihak kerajaan namun terbukti masih belum mencukupi dalam membendung kesan banjir secara menyeluruh DID (2024). Kajian menunjukkan pendekatan pengurusan bencana di Malaysia masih bersifat berpusat (*top-down*) dengan penglibatan komuniti yang minimum serta kurang mengambil kira pengetahuan tempatan (Chan et al. 2020).

Pengurusan risiko banjir tidak seharusnya bergantung kepada kerajaan semata-mata tetapi harus secara holistik dan proaktif (Chan et al. 2020) dengan melibatkan pelbagai pihak berkepentingan khususnya pemilik rumah (Meyer & Hartmann 2023; Kundzewicz et al. 2018; Chan et al. 2020; Rauter et al. 2020) melalui Langkah Berjaga-Jaga Persendirian (LBP) (Fotian et al. 2023; Kundzewicz et al. 2018; Chan et al. 2020) yang terbukti mampu mengurangkan kerosakan harta benda persendirian (Semnan et al. 2023; Meyer & Hartmann 2023; Harish et al. 2023) antara 50% hingga 100% (Barendrecht et al. 2020; Harish et al. 2023).

Walau bagaimanapun, pelaksanaan LBP di peringkat komuniti masih kurang diamalkan (Nguyen et al. 2021; Semnan et al. 2023). Menyedari hakikat ini, kajian ini dibuat

memandangkan masih kurang kajian yang meneliti pendekatan secara “*bottom-up*” khususnya melalui LBP secara LS dengan melihat dari perspektif masyarakat atau ketua komuniti yang mewakili individu di dalam masyarakat dalam membuat persediaan awal sebelum kejadian banjir untuk menyelamatkan harta benda mereka seperti rumah, kenderaan dan isi kandungan di dalam rumah (Chan et al. 2020; Nguyen et al. 2021; Semnan et al. 2023).

3. OBJEKTIF KAJIAN

Terdapat Dua (2) objektif kajian seperti berikut :

- i. Untuk mengkaji jenis-jenis LBP secara LS sebagai kesiapsiagaan banjir di Mukim Dengkil, Selangor
- ii. Untuk mencadangkan rangka kerja kriteria-kriteria pemilihan LBP sebagai kesiapsiagaan banjir di Mukim Dengkil, Selangor

Namun begitu, dalam pembentangan kolokium kali ini hanya melibatkan objektif pertama sahaja.

4. KAEDAH KAJIAN

Bagi menjawab objektif kajian pertama iaitu untuk mengkaji jenis-jenis LBP secara LS dengan lebih mendalam dan dari perspektif komuniti khususnya individu, Kajian ini dilaksanakan menggunakan pendekatan kualitatif secara kajian kes di Mukim Dengkil, Daerah Sepang Selangor. Para informan ini terdiri daripada ketua-ketua komuniti kerana mereka telah diberi kuasa diperingkat kampung dan lebih memahami situasi di tempat masing-masing yang pernah terlibat banjir besar berdasarkan Tujuh Puluh (70) senarai lokasi banjir yang dikeluarkan oleh Pejabat Daerah dan Tanah Sepang pada tahun 2021. Data primer diperoleh melalui instrumen temubual mendalam dan telah mengalami tahap tepu (*saturated*) dimana tiada perkara baru yang ditemui setelah informan ke-6 dan ke-7. Borang soal selidik yang digunakan bagi kajian ini telah diadaptasi berdasarkan persoalan kajian dan disahkan oleh dua (2) orang pakar dalam bidang berkaitan. Temubual ini disusuli dengan sesi Perbincangan Kumpulan Berfokus (FGD) bagi tujuan pengesahan dan mendapatkan maklumbalas secara bersama. Analisis data terhadap Temubual dan FGD dilakukan secara analisis tematik menggunakan perisian NVIVO 15 seterusnya digunakan untuk membangunkan rangka kriteria pemilihan LBP secara LS.

5. KEPUTUSAN DAN PERBINCANGAN

Kajian mendapati komuniti secara jelas mengiktiraf keperluan untuk bertindak sendiri dalam menghadapi risiko banjir. Dari kajian literatur mendapati Dua Puluh Lapan (28) sub-jenis LBP dan telah diklasifikasikan semula kepada Lapan (8) Jenis utama iaitu Aras Ketinggian, Struktur Apungan, Bahan Binaan Mesra Banjir, Halangan Kekal, Halangan Sementara, Evakuasi, Mesin/Peralatan dan Saliran. Hasil analisis NVIVO mendapati Sembilan (9) Jenis dan Lima Belas (15) sub-jenis LBP telah digunapakai oleh Informan atau masyarakat di bawah seliaan informan seperti di bawah :

Bil.	Jenis LBP LS	Sub-Jenis LBP	Informan	Bilangan
1	Pindah	Pindah Lokasi	4	15
2	Aras Ketinggian	Angkat atas Perabot	4	5
		Para	2	9
		Loteng	2	7
		Pangkin	1	7
3	Struktur Kekal	Benteng	4	29
		Tambak Tanah	3	16
		Tangga	1	8
4	Perabot Mesra	Bahan	3	20
		Perabot Berkaki	2	4
5	Struktur Apungan	Bot	2	9
6	Kedap	Kedap	1	10
7	Saliran	Longkang/ Parit	1	8
8	Early Warning	Media Sosial	1	7
9	Minimum	Minimum Kuantiti	1	2

Dari Jadual di atas menunjukkan jenis dan sub-jenis LBP yang digunakan oleh informan dimana Empat (4) informan memilih untuk pindah lokasi, angkat atas perabot dan benteng. Tiga (3) informan pula menyentuh sub-jenis LBP iaitu bahan mesra banjir dan Tambakan Tanah. Seterusnya Dua (2) informan memaklumkan penggunaan sub-jenis seperti Loteng, Para, Perabot Berkaki dan Bot. Jenis dan bilangan penggunaan LBS yang agak terhad ini menunjukkan terdapat faktor-faktor tertentu yang menjadi cabaran dan halangan dalam pemilihan sesuatu LBP. Berdasarkan maklumbalas daripada semua informan juga menunjukkan mereka kurang pendedahan kepada pelbagai jenis LBP secara LS yang lain dan menjadi cabaran utama dalam pelaksanaan tindakan ini. Sebagai contoh elemen kos, magnitude banjir, demografi dan aspek teknikal adalah antara kriteria utama dan menjadi halangan kepada Masyarakat untuk memilih sesuatu jenis dan sub-jenis LBS secara LS. Model di atas boleh dijadikan rujukan bukan sahaja oleh komuniti, malah agensi berkaitan dalam merangka dasar dana insentif seperti peruntukan kewangan berupa geran one-off, diskaun, ribet cukai atau bantuan teknikal seperti latihan, demonstrasi penggunaan produk atau lain-lain secara berkala dan menyeluruh.

6. KESIMPULAN

Kajian terhadap Tujuh (7) orang informan yang terdiri daripada ketua-ketua komuniti menunjukkan penggunaan LBP adalah agak terhad dan tidak menyeluruh yang diamalkan oleh komuniti masing-masing. Kajian dari perspektif akar umbi ini, menyokong pendekatan *bottom-up* serta penyesuaian lokal. Ia turut membuktikan bahawa pendekatan kualitatif berasaskan komuniti mampu menghasilkan dapatan yang praktikal dan relevan. Hasil kajian menyumbang kepada pembangunan model kesiapsiagaan banjir berasaskan penglibatan komuniti secara proaktif, praktikal, berasaskan lokasi dan kapasiti individu berpotensi dijadikan asas kepada pembangunan panduan pemilihan langkah berjaga-jaga persendirian secara struktur untuk digunakan dalam dasar dan program komuniti oleh pelbagai pihak berkepentingan. Kajian juga mencadangkan pendekatan LBP perlu diarusperdanakan bersama langkah struktur awam (kerajaan) melalui penyelesaian yang bersifat sistematik dan inklusif khususnya polisi kehadiran sokongan institusi seperti subsidi bersasar untuk golongan B40, bantuan teknikal komuniti serta penglibatan NGO sebagai fasilitator. Dengan menyediakan kriteria asas boleh menjadi panduan untuk pemilihan LBP secara LS serta menyokong matlamat Pengurangan Risiko Bencana (DRR) seterusnya seruan pelaksanaan dasar *Sendai Framework* di peringkat tempatan. Dapatan ini

penting dalam usaha membina komuniti yang lebih berdaya tahan serta mampu ‘bangkit semula dengan lebih baik’ (*bounce back better*) selepas bencana banjir.

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FAKTOR-FAKTOR YANG MEMPENGARUHI PENERIMAAN TEKNOLOGI DRON DALAM KALANGAN PETANI BAGI PENANAMAN PADI DI LEMBAGA KEMAJUAN PERTANIAN KEMUBU (KADA), KELANTAN

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1. PENGENALAN

Aktiviti penanaman padi memainkan peranan penting dalam menjamin keselamatan makanan. Menurut Jabatan Pertanian (2024), pengeluaran beras di Malaysia pada tahun 2023 dianggarkan berjumlah 1,503,151 tan metrik, mencatatkan kadar penurunan sebanyak 4.56% berbanding tahun 2022 (1,574,956 tan metrik). Mengikut pengeluaran negeri, Kelantan menyumbang sebanyak 12.43% daripada jumlah keseluruhan dalam negara dan KADA mencatat sumbangan terbesar (78%) di peringkat negeri Kelantan. Penurunan pengeluaran ini berkemungkinan berpunca daripada beberapa cabaran, antaranya kekurangan tenaga kerja (Abdullah & Abu Samah 2013), perubahan iklim (Firdaus et al. 2020) kesuburan tanah yang merosot (FAO 2024), dan penggunaan air secara tidak cekap (Balafoutis et al. 2017), yang kesemuanya mengancam produktiviti dan kelestarian (Firdaus et al., 2020; Dorairaj & Govender et al., 2023). Bagi menangani cabaran ini, kerajaan Malaysia telah mempromosikan amalan pertanian mapan yang menekankan peningkatan produktiviti sambil mengurangkan kesan alam sekitar (NAP 2021). Salah satu strategi utama ialah penggunaan teknologi moden seperti dron, yang dilaksanakan secara rasmi pada tahun 2021 berikutan kejayaan projek perintis MADA pada 2019 (Baharin et al. 2025). Menjelang 2023, lebih 500 dron telah digunakan dengan penjimatan kos mencapai 40% (KPKM 2023). Namun begitu, kajian oleh Masitoh et al. (2023) menunjukkan bahawa penggunaan dron dalam kalangan petani masih terhad, walaupun 74% petani KADA menyatakan kesediaan untuk menggunakannya. Halangan utama termasuk kekangan kewangan, rasa tidak selesa, dan faktor demografi seperti majoriti petani berumur 60 tahun ke atas serta tahap pendidikan yang rendah. Justeru, pemahaman terhadap faktor yang pengaruhi niat petani dan penggunaan sebenar teknologi dron adalah penting bagi merangka strategi yang berkesan bagi menggalakkan penggunaan teknologi yang merupakan elemen pertanian tepat dalam penanaman padi.

2. PERMASALAHAN KAJIAN DAN SOROTON KAJIAN

Teknologi pertanian moden, seperti dron, telah diperkenalkan untuk mempromosikan pertanian tepat, menambah baik pengurusan sumber dan meningkatkan produktiviti tanaman. Dron menawarkan kelebihan yang ketara, termasuk keupayaan untuk memantau kesihatan tanaman, mengoptimumkan penggunaan baja dan racun perosak, dan meningkatkan kecekapan pengairan, sekali gus menyumbang kepada amalan pertanian yang lebih mapan (Shahibi et al. 2023). Namun begitu, menurut Kharim dan Rosdi (2024), yang melaporkan bahawa walaupun petani di KADA mengetahui kelebihan dron, kadar penggunaan kekal rendah disebabkan oleh kekangan kewangan, penyedia perkhidmatan terhad dan rintangan generasi. Hal ini juga sejajar dengan kajian Masitoh et al (2023), yang melaporkan bahawa lebih 70% petani di bawah pengurusan

MADA dan IADA bersedia untuk menerima pakai teknologi pertanian namun mengalami kekangan kewangan dan faktor umur petani yang lebih berusia. Selain itu, petani bersikap keberatan atau lambat menerima teknologi ini disebabkan oleh pelbagai faktor, termasuk kesedaran yang terhad, persepsi kos yang tinggi, kekurangan pengetahuan teknikal, dan akses yang tidak mencukupi kepada latihan dan sumber kewangan (Udimal et al. 2017; Azizul et al. 2023; Ahmad et al. 2024). Faktor sosioekonomi, seperti umur, saiz ladang, pengalaman kerja dan tahap pendidikan juga memainkan peranan penting dalam menentukan kesanggupan dan keupayaan petani untuk menerima pakai teknologi baharu (Nastis et al., 2019). Namun, kajian lepas kebanyakannya bersifat umum. Justeru, wujud jurang pengetahuan khusus mengenai faktor dominan yang menghalang penerimaan dron dalam kalangan petani padi di KADA, walaupun terdapat kesedaran dan kesediaan asas. Sehubungan itu, terdapat keperluan mendesak untuk menentukan faktor pengaruhi niat petani terhadap penggunaan dron di KADA, Kelantan, untuk memberikan pandangan yang boleh membimbing penggubalan dasar, program latihan, dan sistem sokongan yang bertujuan untuk mempercepatkan penggunaan teknologi pertanian lestari (Azizul et al. 2023).

3. OBJEKTIF KAJIAN

Kajian ini mempunyai tiga objektif utama, namun begitu, dalam pembentangan kolokium kali ini, hanya dua objektif akan difokuskan iaitu objektif pertama; mengenal pasti faktor-faktor yang mempengaruhi persepsi dan penerimaan petani terhadap teknologi dron dalam penanaman padi lestari di KADA, Kelantan, objektif kedua; menganalisis hubungan antara faktor-faktor yang mempengaruhi persepsi dan penggunaan teknologi dron dengan penerimaan petani dalam penanaman padi lestari di KADA, Kelantan.

4. KAEDAH KAJIAN

Bagi menjawab objektif pertama dan kedua, kajian ini menggunakan reka bentuk kajian kuantitatif untuk menganalisis hubungan antara faktor sosioekonomi dan niat tingkah laku petani untuk mengguna pakai teknologi dron dalam kalangan petani luar bandar di enam kawasan jajahan yang berada di bawah pengurusan KADA dengan populasi seramai 5099 petani. Saiz sampel bagi kajian ini ditentukan dengan merujuk kepada jadual Krejcie dan Morgan (1970), iaitu sebanyak 258 responden pada tahap kebolehpercayaan 95% dengan margin ralat 6%. Walau bagaimanapun, menurut Zuiderwijk et al. (2015), bilangan minimum 200 sampel dianggap sesuai untuk analisis. Sebelum kajian sebenar dijalankan, pra-ujian telah dilaksanakan melibatkan 20 orang petani yang berada di luar sampel kajian bertujuan bagi menguji kebolehpercayaan dan kesahihan instrumen soal selidik. Bagi kajian akhir, seramai 200 petani padi yang dipilih secara rawak telah menjawab borang soal selidik yang terdiri daripada lapan bahagian yang terdiri daripada profil sosioekonomi, pengalaman dalam pertanian, penerimaan dan penggunaan teknologi dron dan hasrat serta cadangan penambahbaikan dalam sektor pertanian. Proses pengumpulan data dilakukan secara bersemuka dengan bantuan pegawai pengembangan KADA bagi memastikan kadar respon yang tinggi dan pemahaman soalan yang baik. Data kajian ini dianalisis menggunakan kaedah deskriptif dan inferensi, di mana ujian Chi-Square diaplikasikan bagi menentukan hubungan yang signifikan antara pemboleh ubah. Menurut Cohen (1988), ujian Chi-Square sesuai digunakan untuk menganalisis data berbentuk kategori kerana ia menilai tahap kebergantungan antara dua pemboleh ubah yang tidak berterusan. Seterusnya, kebolehpercayaan instrumen dinilai menggunakan pekali Alpha Cronbach. Nilai ambang $\alpha \geq 0.70$, seperti yang disarankan oleh Hair et al. (2019), menunjukkan tahap ketekalan dalaman yang memuaskan. Hasil kajian rintis mendapati nilai Alpha Cronbach

bagi konstruk *Unified Theory of Acceptance and Use of Technology* (UTAUT) melebihi piawai tersebut, sekali gus mengesahkan bahawa instrumen kajian ini adalah boleh dipercayai. Keseluruhan proses analisis data dilaksanakan menggunakan perisian **IBM SPSS Statistics versi 29**.

5. KEPUTUSAN DAN PERBINCANGAN

Hasil analisis deskriptif menunjukkan 99% petani sedar akan kewujudan teknologi dron pertanian tetapi hanya 8% menggunakannya. Ujian khi kuasa dua ($\chi^2=0.21$, $p>0.05$) mengesahkan tiada hubungan yang signifikan antara kesedaran dan penerimaan, dengan saiz kesan yang boleh diabaikan ($\phi=0.03$). Halangan kewangan dikenal pasti sebagai faktor penghalang utama dalam kalangan 92% petani bukan pengguna, diikuti oleh kekurangan latihan (46%) dan halangan struktur seperti akses terhadap skim pembiayaan dan infrastruktur sokongan. Halangan ini turut disokong oleh kajian lepas yang mendapati keterbatasan pembiayaan dan kos pelaburan awal yang tinggi menjadi penghalang utama kepada pengadaptasian teknologi moden dalam kalangan petani kecil (Omar et al., 2024; Saili et al., 2023). Dalam konteks pertanian pintar di Malaysia, isu seperti kekurangan kemahiran teknikal, kos implementasi yang tinggi, dan infrastruktur yang tidak mencukupi turut dikenal pasti sebagai cabaran kritikal yang memperlambatkan transformasi sektor ini (Engku Elini et al., 2024; Ahmad et al., 2022). Oleh itu, mengenal pasti halangan struktur ini adalah penting bagi merangka strategi yang lebih bersasar. Analisis turut menunjukkan bahawa pemilik ladang berskala besar (≥ 20 ekar) mempunyai kadar penerimaan lebih tinggi (12.5%) berbanding petani kecil (< 5 ekar: 3.8%), menunjukkan pengaruh saiz ladang terhadap niat penerimaan. Selain itu, walaupun 82% petani generasi kedua memiliki telefon pintar, majoriti (58%) masih tidak menerima pakai dron, menunjukkan literasi digital sahaja tidak menjamin penerimaan teknologi. Hal ini sejajar dengan kajian Baharin et al. (2025) di Kedah yang turut mendedahkan bahawa literasi digital sahaja tidak menjamin penerimaan teknologi dalam pertanian. Semua konstruk UTAUT menunjukkan nilai Alpha Cronbach ($\alpha > 0.7$) yang memuaskan untuk kebolehpercayaan instrumen: Jangkaan Prestasi ($\alpha=0.937$), Jangkaan Usaha ($\alpha=0.821$), Keadaan Memudahkan ($\alpha=0.778$), dan Pengaruh Sosial ($\alpha=0.681$). Walaupun nilai alpha bagi Pengaruh Sosial adalah sederhana, menurut garis panduan Nunnally (1978) ianya masih boleh digunakan untuk penyelidikan sosial. Walau bagaimanapun, kajian menunjukkan bahawa pengaruh sosial adalah penting dengan 68% petani mengakui bahawa penggunaan dron dipengaruhi oleh cadangan rakan petani (45%) dan galakan daripada pegawai pertanian (32%). Dapatan ini disokong oleh Zaman et al. (2023) yang mendapati petani mudah terpengaruh untuk menggunakan dron setelah melihat kelebihan yang diperolehi petani lain, serta tidak mahu ketinggalan dalam trend teknologi pertanian.

6. KESIMPULAN

Kajian ini mengesahkan wujudnya jurang yang ketara antara kesedaran tinggi (99%) dengan penerimaan sebenar (8%) teknologi dron dalam kalangan petani KADA. Halangan utama termasuk kekangan kewangan (92%), halangan struktur, dan kekurangan peluang latihan (46%). Walaupun majoriti petani muda memiliki kemahiran digital asas, faktor sosioekonomi dan pengaruh sosial memainkan peranan penting dalam proses penerimaan teknologi. Untuk merapatkan jurang ini, program pengembangan perlu menawarkan sokongan kewangan yang disasarkan, latihan praktikal, dan penglibatan komuniti yang lebih menyeluruh. Penerimaan teknologi dron berpotensi menyumbang secara signifikan kepada pencapaian SDG 2 (Kelaparan Sifar) melalui peningkatan produktiviti pertanian dan ketahanan makanan, serta SDG 12 (Penggunaan dan Pengeluaran Bertanggungjawab) melalui aplikasi input pertanian yang lebih

efisien dan pengurangan kesan alam sekitar. Pelaksanaan skim pembiayaan, penyediaan pusat servis, program latihan berterusan, dan penambahbaikan infrastruktur logistik turut disyorkan. Pemantauan berterusan berdasarkan indikator prestasi yang jelas diperlukan untuk menilai keberkesanan dasar dan sumbangan sektor padi negara terhadap matlamat pembangunan mampan.

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AN INTEGRATED FRAMEWORK FOR ENHANCING ENERGY EFFICIENCY AND WASTE MANAGEMENT IN UNIVERSITI KEBANGSAAN MALAYSIA (UKM)

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1. INTRODUCTION

Universiti Kebangsaan Malaysia (UKM), Malaysia's second-largest public university, spans 1,096 hectares and employs approximately 28,500 students and staff. The university generated 5,600 tonnes of municipal solid waste and consumed 45 GWh of electricity in 2023; these numbers are expected to increase by approximately 4% annually (UKM Sustainability Report 2023). These challenges emphasize the importance of tackling energy efficiency and waste management at UKM. Globally, initiatives such as the UI GreenMetric World University Ranking and the QS Sustainability Rankings have encouraged colleges to implement more stringent standards for sustainability (UI GreenMetric 2024; QS World University Rankings 2024). Malaysian universities are responding to government priorities such as the government Energy Transition Roadmap and the Solid Waste and Public Cleansing Management Act. According to the UKM Sustainability Report (2023), these programs intend to significantly reduce energy consumption and garbage that ends up in landfills by 2030. Like many other higher education institutions worldwide, UKM is committed to promoting environmental sustainability on campus. Energy efficiency and waste management are two crucial aspects of sustainable campus construction, as they directly impact on resource preservation, operating costs, and long-term environmental sustainability outcomes (Muzanni et al. 2022; Tanavade 2023). Higher education institutions (HEIs) are significant drivers of energy and solid waste generation; therefore, their role in reducing carbon emissions and shaping a sustainable future is increasingly crucial (Abas et al. 2018; Sing & Beno 2025). Despite progress, many Malaysian HEIs continue to struggle with issues including inadequate facilities, uncoordinated administration, and lack of sustainable campus norms despite these progresses (Anthony Jr. 2021; Muhiddin et al. 2023). The wide range of building vintages (1970–2023), high demand for cooling in the tropical climate, and the fragmented administration of waste, energy, and procurement processes all contribute to these environmental strains. UKM has responded by enhancing sustainability through various initiatives. These initiatives include installing solar photovoltaic arrays, implementing a Centralised Energy Management System (CEMS), introducing a 3R waste separation program, and reducing disposable plastics and polystyrene in cafeterias (UKM 2022, 2023). These efforts are still dispersed, although they represent a substantial advancement. Currently, there is no integrated structure to unite policy, implementation, monitoring, and behavioural involvement across the campus. Previous studies emphasise that a well-defined sustainable framework, supported by institution-wide collaboration, is essential for the effective implementation of green campus initiatives (Azeiteiro et al. 2015; Nifa et al. 2016; Gomez & Yin Yin 2019). Therefore, the purpose of this study is to evaluate UKM current practices using a SWOT analysis, and to propose a comprehensive, empirically supported framework for improving waste management and energy efficiency on campus.

2. PROBLEM STATEMENT

Despite UKM's ongoing efforts to develop energy efficiency and waste management measures, current approaches often lack coordination, standardisation, and long-term effectiveness. Similar issues have been observed in many higher education institutions, as fragmented initiatives, poor stakeholder involvement, and inadequate evaluation remain significant challenges (Chan 2023; Elhalwagy 2024; Guerreiro et al. 2024; Zürn et al. 2025; Anyan et al. 2025). Recent studies have also shown that, when compared to Western universities, many Asian institutions, including those in Malaysia, still lag behind in terms of sustainability performance owing to governance gaps, limited infrastructure, and cultural hurdles (Leal Filho et al. 2019; Zeleniene & Pereira 2021; Zhang et al. 2021; Savelyeva 2022). Furthermore, the lack of a systematic approach to evaluating the SWOT of existing practices inhibits the university's capacity to manage waste and optimise energy use effectively. This underscores the critical need for a context-dependent, evidence-based framework that not only integrates best practices but also corresponds with UKM institutional sustainability objectives. Consequently, the purpose of this research is to close this gap by proposing an integrated framework for improving energy efficiency and waste management at UKM. Therefore, the question is: What types of energy efficiency and waste management measures are currently implemented at the UKM? What are the SWOT (strengths, weaknesses, opportunities and threats) to the existing energy efficiency and waste management practices at the UKM? How can the most effective strategies enhance energy efficiency and waste management practices on the UKM? For this colloquium, the SWOT is focused.

3. OBJECTIVE

Based on the research problem and questions, the following are three corresponding research objectives: (1) To examine the existing energy efficiency and waste management practices in the UKM campus; (2) To perform SWOT analysis for evaluating the current energy efficiency and waste management implementation in UKM campus; (3) To propose an integrated framework for improving energy efficiency and waste management at UKM campus. This phase of the study focuses on the **second objective**.

4. METHOD

The study adopted a mixed-methods approach to propose an integrated framework for enhancing energy efficiency and waste management at UKM. This approach was selected to capture both quantitative and qualitative perceptions because survey data alone would not provide enough context for current policies and programs, while institutional documents alone might not adequately reflect stakeholder opinions. A structured survey questionnaire was designed, consisting of both general awareness questions and SWOT-based items, and distributed online to UKM stakeholders, including students, staff, and academic personnel. The questionnaire was validated by experts and collected responses anonymously. The respondents were members of the UKM community, including students, faculty members, staff, and sustainability officers, as well as individuals involved in the planning, implementation, and monitoring of campus sustainability activities. A total of 190 valid responses were received from the intended respondents, which provided enough information for descriptive analysis. Ethical approval for the study was obtained from the UKM Research Ethics Committee (JEP-2025-396), and all participants provided informed consent, with confidentiality and anonymity ensured throughout the process. Descriptive analysis was carried out using SPSS software to calculate frequencies and percentages for each response.

5. RESULTS AND DISCUSSION

The survey utilised a SWOT analysis framework to evaluate perceptions of energy efficiency and waste management practices at UKM. Results were compiled based on the frequency (%) of responses for each provided option under each category.

1.1 Energy Efficiency

In the Strengths category, the most selected response was the use of LED lighting and energy-saving devices, with 43% of participants identifying it as a key strength of the campus's current energy strategy. This is consistent with findings from Unicamp, where large-scale LED replacement is expected to reduce power usage by 30% by 2030 (Dalbelo et al. 2024). This was followed by strategic campus lighting and daylight optimisation (30%) were also emphasised, lending credence to previous study highlighting the relevance of passive design in lowering energy consumption (Tanavade et al. 2023). while regular maintenance of electrical systems and passive design strategies in building infrastructure received (17%) and (10%), respectively were less commonly stated, but they are consistent with studies that emphasize the significance of system dependability and design efficiency in long-term energy management (Tanavade et al., 2023). These comments imply that infrastructure enhancements and environmental design are valued components of UKM energy management strategy. Under Weaknesses, the highest percentage (38%) identified lack of proper monitoring and energy tracking systems as a significant drawback which limits the capacity to optimise energy use and find areas for improvement. This is consistent with Tanavade et al. (2023), who highlighted the importance of good monitoring systems in minimizing energy waste and carbon footprints, while (32%) pointed to limited awareness and inconsistent user behaviour as a concern were also identified, indicating behavioural gaps that might undermine technology investments; comparable studies imply that infrastructure changes must be accompanied by awareness campaigns in order to produce real savings (Tanavade et al. 2023). Overreliance on air-conditioning (20%) emerged as another challenge, consistent with Rahman et al. (2018), who found that cooling loads account for the majority of energy usage in academic buildings but may be lowered by optimization approaches. Lastly, insufficient finance and a lack of trained labor (10%) were noted as obstacles, which is consistent with Dalbelo et al. (2024) results that emphasize the necessity of institutional support and personnel training to guarantee the long-term survival of projects. These findings indicate that, while physical systems are there, behavioural gaps and a lack of effective monitoring mechanisms impede complete efficiency realisation. For Opportunities, (41%) of respondents emphasised digital tools and smart systems integration as a major potential, emphasising the significance of automation and data-driven monitoring. This is consistent with previous studies indicating that IoT and smart grids improve energy monitoring and renewable integration (Attah et al. 2024; Yin 2024). Training programs and awareness campaigns followed with (34%), were also highlighted, in line with research showing that upgrading labor skills is essential for implementing digital solutions (Caldeira et al. 2024). While government funding support (15%) and cross-departmental sustainability initiatives (10%) were identified as extra facilitators, reinforcing earlier studies on the significance of monetary rewards and inter-organizational collaborations (Apata, 2024). These findings show a forward-thinking approach to investing in education and digitalisation. The main threat identified was budget constraints for large-scale energy upgrades, cited by (46%) of respondents, reflecting the high expenses of digital infrastructure, which are also recognized in other institutional contexts (Goel et al., 2024). This reflects institutional financial limitations as a perceived barrier to further development. Low stakeholder engagement was also noted by (28%), followed by resistance to technology adoption

(15%) and lack of maintenance culture (11%), identifying social and cultural obstacles to sustainable energy transformations (Barreto et al. 2024; Hakimzoda et al. 2024). The findings show that, despite gains in energy efficiency through infrastructure and digitalization, long-term success requires greater behavioral involvement, effective monitoring, and continued financial and institutional support.

1.2 Waste Management

A general awareness question was asked at the start of the survey to evaluate respondents' basic understanding of the campus's present waste management system. According to the findings, (68%) of respondents knew of the UKM waste management system, whereas (32%) had limited knowledge. The result indicates a comparatively high level of basic understanding, but it also emphasises the necessity of more transparency and communication about campus sustainability activities. In the Strengths category, (48%) of respondents selected existing recycling initiatives and segregation bins, indicating broad recognition of physical infrastructure supporting waste management. This was followed by environmental awareness campaigns (26%), green office and campus-wide programs (16%), and collaboration with local authorities (10%), suggesting that internal campaigns and partnerships are also considered valuable. These initiatives have been demonstrated to considerably increase university involvement and the rate of recycling (Sarkawi et al. 2024; Balewa et al. 2024), while integrated campus programs and collaborations with local authorities boost waste management systems (Dinglasan et al., 2021). For Weaknesses, the most cited issue was lack of real-time waste data and monitoring systems (42%), followed by inconsistent participation in waste separation practices (36%). Inadequate signage and bin placement (14%) and lack of policy enforcement (8%) were also highlighted, suggesting that both operational inefficiencies and behavioural inconsistencies are seen as key barriers. Respondents identified strong opportunities in technological innovation, with smart bins and digital waste tracking systems receiving (44%) support, followed by waste-to-energy research and innovation (31%). Similar technologies, such as IoT and RFID-enabled devices, have been proven to improve collection and minimize emissions (Somya et al. 2024; Osorio-Paredes et al. 2024), while pyrolysis and anaerobic digestion help to achieve circular economy goals (Rani & Yendluri 2024). Community-based engagement (15%) and incentive-based recycling programs (10%) were valued, consistent with research emphasizing the relevance of awareness campaigns and participation programs in encouraging sustainable habits (Giurea et al., 2024; Dada et al., 2024), indicating a willingness to expand participatory and research-based waste management strategies. The primary threat noted was low awareness among new campus entrants (e.g., freshmen, visitors), identified by (40%) of respondents. This was followed by insufficient funding for sustainable waste innovation (33%), operational complexity of waste audit systems (15%), and limited support from upper management (12%), identifying structural and institutional challenges that may impede growth. Previous study has identified comparable challenges, such as budgetary restrictions, aversion to technology, and inadequate leadership, which can impede sustainability projects unless backed by strong policies and collaborations (Dada et al. 2024; Giurea et al. 2024). Concluding the waste management section, participants were asked whether they support the implementation of a sustainable waste management strategy at UKM. A significant (79%) stated support, showing a high level of preparedness for future innovation and transformation, while (21%) indicated indifference or uncertainty. The institution's initiatives to improve the sustainability of waste management on campus are strongly enforced by this degree of support. In conclusion, UKM waste management is aided by its current infrastructure and stakeholder knowledge; yet, increasing sustainability calls for more

widespread use of technology, stricter adherence to regulations, and constant involvement from new students.

6. CONCLUSION

This study emphasises the necessity of an integrated framework to enhance waste management and energy efficiency at UKM. The SWOT analysis shows significant gaps in coordination, monitoring, and stakeholder involvement, despite the implementation of several sustainability initiatives, including waste separation programs and solar PV installations. The results highlight some institutional strengths and potential, especially in the areas of digital innovation and infrastructure, but they also highlight problems, including fragmented management, lack of awareness, and financial limitations. Remarkably, 79% of participants are in favour of implementing sustainable practices, demonstrating a high level of campus preparedness. This phase builds the basis to formulate a framework tailored to the particular situation, which is in line with UKM's sustainability objectives and national environmental priorities, by emphasising on opinions of stakeholders and institutional settings. Future research will focus on incorporating digital tools and smart technologies into the framework to improve real-time monitoring and decision-making.

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PENGHARGAAN

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