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Architecture as Urban Catalyst: Infographic Design Guideline on Kuala Lumpur Riverfront Revitalisation

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Abstract: In various areas, communities and localities worldwide, a traversing river plays a vital role as the lifeblood of many dwellings and urban areas. Kuala Lumpur's expanding urban spaces indicate a thriving economy. Despite this, the rapid development has led to the construction of many residential and commercial buildings along the river, resulting in pollution from domestic, physical, and chemical waste. This pollution poses a threat to urban waste management, impacting both health and the river's ecosystem. To address this issue, this study endeavours to recommend an updated set of design guidelines for the Dayabumi, Kuala Lumpur riverfront architecture. The recommended guideline will focus on alterations to the river form and build form interventions to achieve the desired results. Through case studies, literature reviews, and observations from developed countries, the study identified best practices for waste management and architectural design. The findings encompass waste management programs and design guidelines covering build form, river form, green coverings, economy injection, and the overall urban environment. By enforcing appropriate regulations and preparing for future waste production, we can protect and revitalize the riverfront at Dayabumi, Kuala Lumpur.

Keywords: Solid waste, river, urban, riverfront architecture, pollution, waste management, urban environment

1. Introduction

Cities around the world, including Kuala Lumpur in Malaysia, are experiencing rapid growth, which brings about numerous environmental and social challenges, particularly concerning waste generation (Gutberlet, 2017). The handling, storage, collection, and disposal of waste significantly impact both the environment and the well-being of urban residents. Kuala Lumpur, being a prominent city, is intersected by the Gombak River and the Klang River, acting as natural arteries within the urban landscape. The Gombak River originates in Selangor, flows through Kuala Lumpur, and converges with the Klang River at Masjid Jamek, ultimately reaching the Straits of Malacca, spanning a total length of 120km. The situation in densely populated urban centers like Kuala Lumpur presents a significant environmental challenge, with the Klang River suffering from severe pollution caused by waste accumulation. This issue has gained global attention, as The Ocean Clean-up (TOC), a Dutch non-profit organization, has highlighted Klang River's inclusion among the 50 most polluted rivers in the world (Yun, 2022). Furthermore, Malaysia's ranking among the top 20 countries for mismanagement of plastic waste is a cause for concern (Balasegaram, 2018), with individual behaviors, as investigated through the Theory

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of Planned Behaviour (TPB), being a contributing factor (Hasan et al., 2015). While plastic may not initially exhibit immediate chemical hazards, long-term implications are detrimental to both marine ecosystems and human health (Chen et al., 2021). This issue of plastic waste pollution becomes more profound in urban rivers like the Klang River due to the inadequate dissemination of knowledge and awareness on recycling, reusing, and waste reduction (Chen et al., 2022).

To address this pressing environmental concern, comprehensive strategies and public education initiatives are required to promote responsible waste management practices. Additionally, collaborative efforts among governmental bodies, non-governmental organizations, and the public are essential to curbing plastic waste pollution and restoring the ecological health of rivers like the Klang River. Emphasizing the significance of recycling, promoting the use of biodegradable alternatives, and implementing strict waste disposal regulations can lead to tangible progress in mitigating plastic pollution and safeguarding the delicate balance of aquatic ecosystems in urban settings. Addressing these issues holds promise but necessitates the implementation of appropriate infrastructure, effective management plans, and comprehensive education.

Riverfronts, defined as areas where land meets water bodies like lakefronts, riverbanks, canals, harbours, or bay fronts, serve various purposes, from public parks and recreational spaces to mixed-use areas and residential neighbourhoods (Üzümcüoğlu & Polay, 2022). Riverfront areas have long been recognized as strategic locations with diverse benefits, including trade, transport, recreation, and entertainment opportunities (Üzümcüoğlu & Polay, 2022). These regions offer immense potential for urban growth, paving the way for the construction of new housing developments, hotels, and sports complexes, thus creating employment opportunities for local communities. Notably, riverfront zones serve as vital green spaces, providing residents with breathing spaces and fostering various activities such as memorials, housing, recreation, and mixed-use development (Üzümcüoğlu & Polay, 2022). Moreover, the increasing trend of utilizing riverfront areas for ecotourism has been observed in Asian countries, enriching environmental conservation efforts and promoting sustainable tourism (Yodsurang et al., 2022; Zhu et al., 2023).

However, the escalating concern of river contamination is primarily attributed to mismanagement of solid waste in urban areas, as well as the discharge of harmful substances and contaminants into water bodies and the natural environment (Mauludi, 2020). The chemicals and toxins from these wastes pose risks to both wildlife and human populations. Furthermore, micro- and nano-sized waste particles can contaminate the environment, leading to chronic non-communicable diseases like cancer (Zaiki & Wong, 2021). Governance-related shortcomings and inadequacies in waste collection programs, both formal and informal, have negatively impacted numerous efforts, including recycling initiatives, affecting the community and the environment (Gutberlet, 2017). Additionally, riverfront developments have inadvertently contributed to environmental degradation and social issues, such as an increase in social problems, youth problems, crime and vandalism (Keyvanfar et al., 2018). In Kuala Lumpur, the rivers have been neglected and have become severely polluted, essentially functioning as open sewers for waste (Shukri, 2017). Historically, the Klang and Gombak Rivers were designed primarily for flood mitigation, resulting in a lack of public spaces and the exclusion of riverfront features from the urban landscape of Kuala Lumpur (Muhammad Husin et al., 2021; Shamsuddin et al., 2012). As a consequence, the urbanites of Kuala Lumpur are profoundly disconnected from their rivers (Kuan et al., 2022).

Recently, Yun (2022) emphasized the adverse impact of waste, especially plastic, on the livability and well-being of city dwellers and how it affects the design and implementation of the River of Life project aimed at enhancing environmental quality for the community. Consequently, the pressing issues involve the high pollution levels in the Kuala Lumpur River, rendering its riverfront unattractive and creating a real disconnection between the community, the river, and the city itself (Muhammad Husin et al., 2021; Kuan et al., 2022). Urgent improvements are therefore necessary to support the revitalization of the Klang River's riverfront in Kuala Lumpur.

2. Aim and Objectives

To address the aforementioned issues and contribute to the community solutions, this research endeavours to propose a novel and significant riverfront infographic framework designed to aid waste management and enhance the revitalization initiatives of the Klang River in Dayabumi Kuala Lumpur. Therefore, the specific objectives of this study are:

1. To identify and analyse the waste management programmes that are currently available in developed countries that are affecting their riverfront architecture.
2. To identify and understand how the current Kuala Lumpur waste management system affects its riverfront architecture.
3. To recommend suitable design elements and practices learned from developed countries in the new proposed riverfront revitalization design infographic guideline.

3. Case Studies

To accomplish the primary objective, several case studies were conducted in locations such as Clarke Quay, Tiber River in Rome, and Thames River in London. These studies focused on gathering data pertaining to the physical and functional elements of river form and the built environment along the riverfront. The preliminary investigation revealed a noteworthy gap in research concerning the integration of waste mismanagement into design guidelines, which holds significant implications for urban design. This study aims to bridge this gap and explore the impact of waste management on urban design. The selected case study locations were chosen due to their advanced waste management systems and relatively similar historical backgrounds. By conducting a comparative analysis of the existing practices in Italy and Singapore, both riverfront cities with distinct cultural contexts and varying degrees of river contamination, this research aims to understand the interaction between buildings, the river, and the community within the same vicinity.

Singapore and London, celebrated for their awe-inspiring riverfront architecture, serve as examples of successful riverfront architecture, demonstrating effective strategies that have gained acceptance at the policy and public levels (Chang et al., 2011; Thirumaran et al., 2023). Clarke Quay and Thames River showcase how waste management programs contribute to preserving the river and, consequently, impact riverfront architecture. Tiber River in Rome, selected for its historical significance, comparable levels of river contamination, and public disengagement from the river, serves as a relevant case study for comparison with Kuala Lumpur. Despite facing similar challenges, the Rome municipality has implemented an active program that involves the public and art in the revitalization of the Tiber River (Feldmann, 2022).

3.1 Clarke Quay, Singapore

Figure 1 depicts Clarke Quay, which was historically plagued by contamination from various sources, including chemical, solid, and domestic waste (Rahman et al., 2022). Similarly, the Singapore River holds immense significance in Singaporean architecture and planning (Micheli & Brugman, 2023). It served as the central nucleus for Singapore's formation, sharing a historical context akin to the Klang River, which was once utilized for transportation and settlement in the late 1800s. Notably, both Singapore River and Klang River faced severe contamination, posing challenges to the development of their respective riverfront architectures. However, Singapore's proactive approach, bolstered by policy implementations and extensive river cleanup efforts, spearheaded by its first Prime Minister, transformed the city into a renowned global hub known for preserving its natural assets through exemplary architecture and urban planning (Furlong et al., 2022). Throughout the study, observations were conducted in both outdoor and indoor settings. The historical settlement along rivers, similar to Kuala Lumpur, inevitably led to undesirable waste disposal practices directly into the river (Sreenivasan et al., 2012). Clarke Quay faced additional challenges, as numerous factories and animal farms were situated along its riverbanks. In response, a significant river cleanup initiative was undertaken for Clarke Quay and Kallang Basin between 1977 and 1987. This endeavour included the physical removal of highly polluted materials from the river, marking a crucial step in revitalizing the riverfront (Centre for Liveable Cities, 2022).

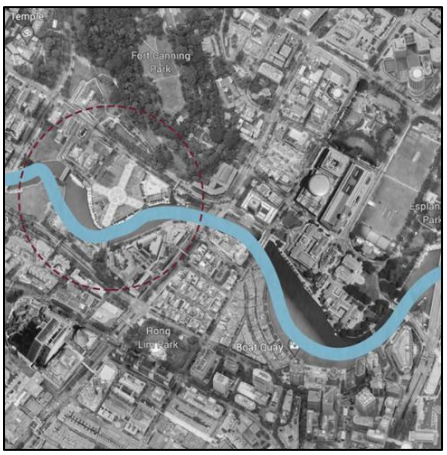


Fig. 1 - Ground mapping on Clarke Quay (Google Earth, 2022)

3.2 Thames River, London, United Kingdom

The Thames River stands as one of London's most prized natural assets, serving as a vital component of the city's transportation network and supporting the livelihoods of its inhabitants (Devereux et al., 2023). However, it is crucial to acknowledge that the current clean and pristine state of the Thames River was not always the case. Similar to Kuala Lumpur's past experiences, the Thames River endured significant contamination, stemming from sewage and waste disposal channels, as illustrated in Figure 2. In the year 1858, the river faced a dire health crisis known as "The Great Stink," during which the deplorable state of the river emitted a foul odour that plagued London, leading to the tragic

demise of thousands (Friedman, 2020). The prevalence of cholera, a waterborne disease resulting from sewage pollution, further tainted the river's watercourse, and an alarming 40,000 lives were lost due to the consumption of contaminated water (The Historic England, 2022). Nonetheless, relentless efforts have been made over time to enhance the conditions of the Thames River, culminating in its present status as a World-class River teeming with thousands of lives and boasting the necessary infrastructure to cater to the needs of the city's residents along the riverfront (Moore & Mell, 2023).

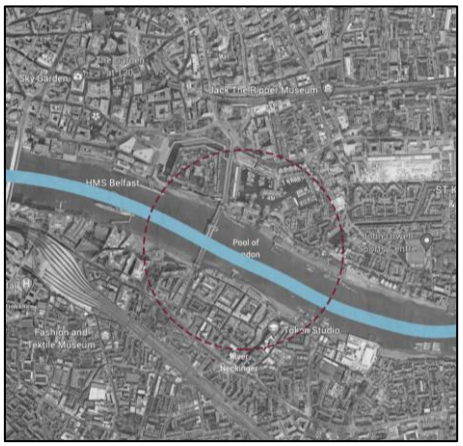


Fig. 2 - Ground mapping on Thames River (Google Earth, 2022)

3.3 Tiber River, Rome, Italy

The Tiber River, depicted in Figure 3, held immense significance as an integral element in ancient Rome. However, in the present day, it has become rather isolated from the community, and even from the city itself, despite flowing through the heart of the city. The construction of a high embankment wall has further exacerbated this sense of isolation, leading to significant social problems (Feldmann, 2022). It is evident that the community's appreciation of nature, exemplified by rivers, significantly impacts their daily lives. Living alongside the river fosters a harmonious environment, with alfresco dining and public activities becoming intertwined. However, this also draws attention to the issue of river contamination, as littering waste, such as drinking bottles and domestic refuse, finds its way into the river. Much like Kuala Lumpur's historical context, the Tiber River served as a crucial trade route, connecting Rome to the ancient port of Ostia. It played a pivotal role in transporting goods across multiple empires, ultimately leading to the open sea. Unfortunately, the contamination of sewage in the river posed a grave challenge, making it difficult for people to access clean drinking water. While efforts were made to treat the sewage, it was only able to reduce toxins in the river by 50%. Harmful bacteria, including E-coli, persisted in the water. Consequently, river pollution has taken a toll on Italy's aquatic life and fishing economy (Rankin, 2015).

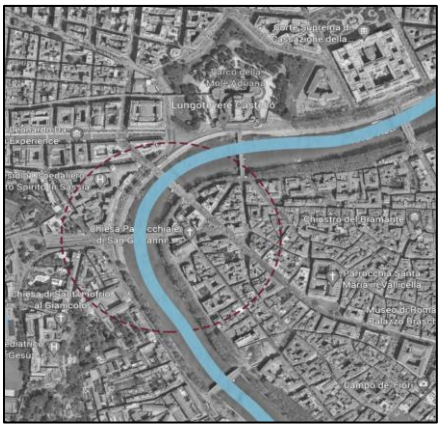


Fig. 3 - Ground mapping on Tiber River (Google Earth, 2022)

4. Literature Review

The literature review section will focus on three main keywords: 'Riverfront Architecture,' 'Urban Waste Management,' and 'Urban Environment.' These keywords serve as the foundation for this study and will provide valuable information. Firstly, the section will explore 'Riverfront Architecture' to gather relevant data. Following that, it will investigate 'Urban Waste Management' to understand its significant impact on a city's architecture, along with the

contributing factors to mismanagement. The third keyword, 'Urban Environment,' will be used to examine verified data endorsed by local authorities. This will involve delving deeper into the water quality index and recent environment reports. The government and authorities have various ways to help the public reduce waste production, such as community education. Additionally, they can implement a more effective waste management system by optimizing waste collection schedules and increasing waste collection points. In conclusion, this chapter will cover different systems used, national-level initiatives, and the roles of various parties responsible for river contamination due to urban waste mismanagement. Figure 4 provides a simplified representation of the impact on riverfront architecture in Kuala Lumpur.

Fig. 4 - Scope of literature review

Metropolitan riverfront redevelopment is an increasingly popular and multidisciplinary topic of discussion in the fields of urban development, architecture, and topography (Thirumaran et al., 2023; Üzümcüoğlu & Polay, 2022). Kuala Lumpur's foundation can be traced back to the Klang River and Gombak River, as depicted in figure 5. The city's rapid urban expansion, fueled by a robust Malaysian economy (Yassin et al., 2018), has led to a dilemma wherein the development of more buildings and businesses comes at the cost of sacrificing the rivers and environment (Tang et al., 2021). Initially, Kuala Lumpur originated and flourished alongside these two rivers, which served as the lifeblood of the community. However, the increase in population and urban growth has led to challenges. In early 2022, the city faced severe flash floods that affected the River of Life area itself. Many buildings' lobbies and reception floors were flooded due to clogged drainage and irrigation systems caused by accumulated trash, as reported by Dewan Bandaraya Kuala Lumpur (DBKL) (MalaysiaKini, 2022).

Fig. 5 - Ground mapping on Klang River

In 2013, several efforts were reported to address the pollution in our rivers, including the installation of trash traps and the construction of river water treatment plants. However, despite these initiatives, they have proven to be insufficient in effectively mitigating the pollution in the rivers. As part of the River of Life project, the Federal Government allocated RM 4 billion to improve the river quality from its current classification of Class III and IV to Class IIB by 2020 (Keng, 2013). The Interim National Water Quality Standards (INWQS) presented in Table 1 serve as vital measurement tools for evaluating the health of our river system (Afroz et al., 2014). These initiatives hold promise for revitalizing the waterway, promoting environmental well-being, fostering sustainable water resource management, and enhancing ecosystem resilience.

Table 1 - INWQS class definitions (Afroz et al., 2014)

Class	Definition
I	Conservation of natural environment
	Water Supply I - Practically to treatment necessary (except by disinfection or boiling only)
	Fishery I - Very sensitive aquatic species
IIA	Water Supply II - Conventional treatment required
	Fishery II - Sensitive aquatic species
IIB	Recreational use with body contact
III	Water Supply III - Extensive treatment required
	Fishery III - Common of economic value and tolerant species; Livestock drinking
IV	Irrigation
V	None of the above

The generation of solid waste in Malaysia has seen a significant increase of over 91% in recent years, necessitating prompt adjustments to cater to the changing lifestyle of city dwellers, considering the amount, quality, and quantity of waste being generated. In Port Klang, the waste coming from the Klang River constitutes the highest for Peninsular Malaysia (Sany et al., 2019). The mismanagement of waste dumped into the Klang and Gombak rivers has hindered any design exploration that could benefit the riverfront, resulting in the rivers becoming dumping grounds for waste.

Waterfront redevelopment has been underway since the 1970s, with numerous projects transforming abandoned waterfront spaces into commercial, residential, and recreational areas, symbolizing the city's progress into a 21st-century metropolis (Yassin et al., 2018). Consequently, designing along the rivers plays a crucial role in preserving historical value, providing space for activities, and enhancing aesthetics for the community's pleasure. Building confidence in individuals' ability to take environmental actions and fostering collaboration among various stakeholders is essential (Pratap, 2021). Multiple associations must contribute and support efforts to improve riverfront architecture in Kuala Lumpur, initiating discussions at institutional, national, and international levels. Experts possessing relevant information should participate in public discussions and act as advisors on current issues (Rafia Afroz, 2014). Collaborative relationships among decision-makers, advisory boards, and the public are vital for enhancing the riverfront architecture. Design ideas should prioritize creating comfortable and enjoyable experiences for urban dwellers, achieved through living vegetation, ambient sound, and smart lighting that visually integrates the environment, such as the river, with human activities (Thirumaran et al., 2023). When people feel connected and responsible for the river, a reduction in waste contamination is likely. Utilizing vegetation can create visual and sensory connections to the urban environment, with the sound of the river acting as a healing element (Smardon, 1998; Jeon, 2012).

Continued optimization of physical environment designs holds promise for enhancing various aspects of human life, including social activities, health, safety, quality of life, education, and learning (Othman et al., 2023; Shaari et al., 2020a; 2020b; Xue et al., 2022). These efforts align with the United Nations Sustainable Development Goals (SDGs), emphasizing 'Good Health and Well-Being' and 'Clean Water and Sanitation' for global development (Bozdağ, 2022; Lederman & Anders Whitney, 2022). Given the current global health challenges such as rising poverty, crime rates, mental health issues, and overloaded healthcare systems due to non-communicable diseases (Kam et al., 2023; Ramos et al., 2023; Zaiki et al., 2023), the need to focus on improving access to spaces fostering community activities and well-being is paramount (Bozdağ, 2022; Lederman & Anders Whitney, 2022). In this context, the sustainable and effective design of the riverfront along the Klang River presents a significant opportunity to create activity spaces that bring joy to the community while also aligning with the UN SDGs' objectives in safeguarding Kuala Lumpur's urban community (Connolly, 2020). Moreover, enhancing urban waste management programs is of utmost importance to prevent waste contamination from entering the river system (Naruka, 2022; Xue et al., 2022). By addressing these challenges, cities can take significant strides toward a healthier, more sustainable future.

5. Methodology

The research methodology employs a comprehensive mixed approach, integrating literature review, case studies, and guided observation using synthesized data from previous sources. This multifaceted approach involves conducting a thorough literature review, insightful case studies, and guided observations, where synthesized data from previous

research serves as a valuable resource. To attain a comprehensive understanding of the issue at hand and to explore potential solutions more effectively, the study pursued a comparative analysis in two distinct riverfront cities, Italy and Singapore. These selected cities boast unique cultural backgrounds and varying levels of river contamination, offering a diverse range of insights and experiences to investigate. By closely examining the interactions between buildings, rivers, and the surrounding communities in these contrasting contexts, the research aims to glean invaluable knowledge on how different factors shape the dynamics and development of riverfront areas.

In pursuit of this ambitious objective, site visits were meticulously conducted, with the neighbouring city of Singapore being thoroughly explored in September 2022, followed by an equally immersive study in the enchanting city of Rome, Italy, in mid-September of the same year. These on-site observations provided unparalleled opportunities to witness and comprehend the practical implementations, challenges, and successes of various riverfront development approaches in real-life settings. Through this meticulous and diverse research approach, the expected outcome is to harness a rich pool of information, forming the bedrock and foundation upon which the study will construct the appropriate benchmarks and principles. This comprehensive data synthesis will be pivotal in driving the research towards insightful and innovative conclusions, ultimately contributing to the development of meaningful recommendations for riverfront architecture and urban planning that address the complexities of different cultural contexts and river contamination conditions. This approach is consistent with many recent high impact studies.

6. Findings and Data Analysis

The study findings are organized in accordance with the delineated research objectives, culminating in the eventual aim of this paper. The potential for governmental or authoritative intervention to mitigate public waste generation is underscored through community education initiatives and the implementation of a robust waste management system. This system should encompass judicious waste collection scheduling and an extensive network of waste collection points strategically positioned to meet demand. Emphasizing the concept of future-proofing the city, a holistic approach to waste management necessitates a profound examination of the role of architecture in redefining the foundational principles of ecological infrastructure. Such an integrated approach duly addresses pressing urban river challenges while placing the community at the heart of urban development. The primary findings from the first research objective encompass comprehensive case studies from Singapore, the United Kingdom, and Italy, elucidating their exemplary urban waste management programs, meticulously outlined in table 2 below. Through the meticulous organization of research outcomes, this study offers valuable insights into the effectiveness of waste management strategies and the pivotal role of architecture in shaping a sustainable urban environment that aligns with ecological imperatives:

Table 2 - Summary of urban waste management programme for each case study

Research Objective	**Research Objective 1 (RO1)**		
Case Study	Clarke Quay, Singapore	Thames River, London, United Kingdom	Tiber River, Rome, Italy
Methodology	Literature Review	Literature Review	Literature Review
Responsible Agency	Ministry of Environment and Water Resources	Environment Energy, Port and Land Authority	Lazlo Regional Environment Protection Agency
River clean-up initiative	1. Improve environmental health and support socio-economic development. 2. Inspect and remove any debris and sedimentation. 3. Improve refuse collection services.	1. Monitor river water quality. 2. Inspect sewage disposal into the river. 3. Replace concrete embankment into rubble. 4. Infuse oxygen into the river using bubble boat technology.	1. Monitor river water quality. 2. Alter the direction and shape of the river. 3. Properly treat the wastewater before being released into the river.
Waste collection programme	Public Waste Collectors (PWC) was appointed through open tender by the National Environment Agency to: 1. Ensure considerably clean and translucent water to support the growth and life of	1. Regular street cleaning including road sweepers to pick up trash and rubbish. 2. Constant Thames River cleaning for tourism purposes.	Collect waste, removing obstacles and debris

	both aquatic animals and plants. 2. Plant more trees at both sides of the riverbanks.		
Landfill alternative	Utilising waste to energy facilities more than Pulau Semakau landfill.	Improve waste treatment facilities.	Impose European stringent rule – to convert waste to energy.
Public awareness program	Sustainable Bright Spot Programme.	Thames 21 Initiative - to remove litter or foreign species.	Actively engage with public to raise awareness.
Campaign	Minimising waste production through the 3R programme.	River Cleaning Campaign in 2015 by Paul Roger.	Regular river clean-up to remove litter and waste from river.
Additional act and reinforcement	Reinforce Environmental Public Health Act.	Reinforce Water Resources. Marine, and Environmental Protection Acts as regulated by the National Rivers Authority in 1989.	Reinforce European Union (EU)'s Water Framework and Urban Wastewater Treatment Directives.

6.1 Urban Waste Management in Kuala Lumpur

Urban waste management issues present a significant challenge for countries globally, especially in developing nations like Malaysia (Adipah & Kwame, 2019; Choon et al., 2017). In the context of research objective number two (2), this section delves into the urban waste management system in Kuala Lumpur.

As the capital city covering an area of 243.65 km^2, Kuala Lumpur faces the pressing concern of river pollution. Unlike well-established cities, Kuala Lumpur's relatively youthful status (Shaari et al., 2020c) necessitates adaptability to policies that may not always suit its unique context, resulting in adverse repercussions for its urban rivers. Adding to the complexity is the rapid population growth experienced by Kuala Lumpur (Mahat et al., 2019), leading to an unprecedented surge in waste generation. Figure 6 provides an illustrative depiction of the waste management program in Kuala Lumpur, revealing the escalating volume of waste produced. Notably, low to middle-income countries typically exhibit a higher waste generation compared to high-income nations. This can be attributed to the more sophisticated urban waste management programs prevalent in high-income countries, leading to significant waste reduction (The World Bank, 2022). In addressing the urban waste management challenges faced by Kuala Lumpur, scientific insights and innovative solutions are indispensable.

A comprehensive understanding of waste generation patterns, waste composition, and waste disposal practices can pave the way for more efficient and sustainable waste management strategies. Integrated waste management approaches, incorporating waste reduction, recycling, and proper disposal, must be employed to mitigate the environmental impacts of waste and protect the urban river systems. Additionally, sustainable waste management initiatives should be tailored to the specific needs and characteristics of the city. Assessing the social, economic, and environmental dimensions of waste management will enable policymakers and stakeholders to develop targeted interventions that promote responsible waste behaviour among citizens and businesses. Collaborative efforts between government bodies, local communities, and private enterprises are essential to establish effective waste management systems that address the challenges faced by rapidly growing cities like Kuala Lumpur. Furthermore, technology and innovation play a pivotal role in optimizing waste management processes. Advanced waste treatment technologies, such as anaerobic digestion and waste-to-energy systems, can offer viable solutions to manage the increasing waste burden while also generating renewable energy. Implementing smart waste management solutions, such as sensor-based waste collection and monitoring systems, can optimize waste collection routes, reduce operational costs, and enhance overall efficiency.

A holistic approach encompassing education, policy reforms, public awareness campaigns, and infrastructure development is paramount to create a sustainable urban waste management system in Kuala Lumpur. Research and data-driven insights are vital in guiding evidence-based decision-making, fostering continuous improvement, and achieving the ultimate goal of a cleaner and healthier urban environment for the city's residents and visitors alike (Shaari et al., 2020b; 2020c). By integrating scientific principles with pragmatic solutions, Kuala Lumpur can overcome its urban waste management challenges and pave the way for a greener and more sustainable future.

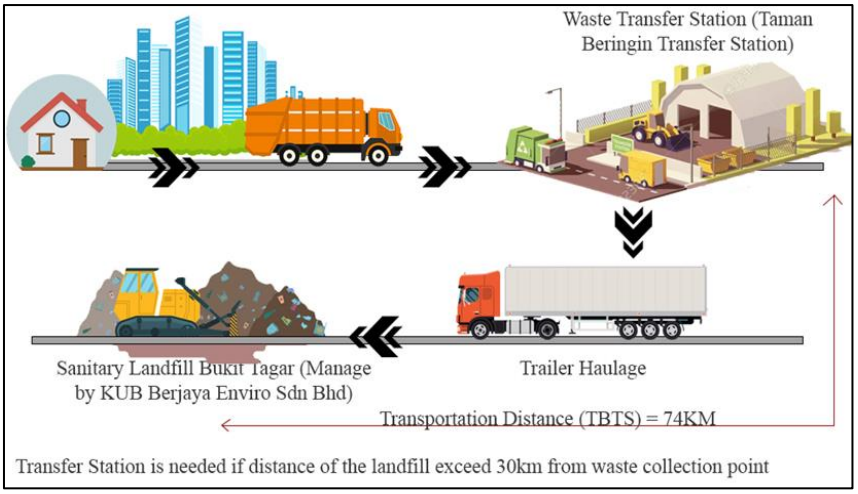


Fig. 6 - Process of waste collection in Kuala Lumpur (Said, 2019)

To address the challenge of urban river contamination in Kuala Lumpur, a community-centred approach within the riverfront architecture is necessary. This involves employing an innovative design strategy that repurposes waste materials to create a program, catering to the community's needs, including the provision of suitable spaces like shelters and incorporating new placemaking concepts. Integrating waste materials as an integral part of the architectural exploration is essential (Kozlowski & Yusof, 2022). According to Yassin et al. (2018), the riverfront zone possesses unique characteristics that can play a significant role in revitalizing urban rivers. These distinctive attributes can be considered as contributing factors when analysing the requirements for successful urban river revitalization endeavours. The following section elaborates on these characteristics:

- **Ecological**
  The riverfront zone is a dynamic area that has evolving biological and chemical attributes. Ecologically, it should be productive and biologically diverse that cater to an ecosystem for aquatic life to seek habitats and shelter.
- **Economic**
  Riverfront zone can help contribute significantly to community welfare with a business injection directly or indirectly.
- **Social**
  The riverfront zone is important as a social medium as it provides access and a common unifying element of cultures of the community nearby.

6.2 Clarke Quay, Singapore

Practical riverfront developments demonstrate responsiveness to the needs of businesses, livelihoods, and the health of the river in conjunction with the local community (Table 3). Several key initiatives have been implemented to enhance this integration, such as expanding car-free zones, advancing water taxi systems as sustainable transportation options, and establishing dedicated riverfront playgrounds for children. Moreover, the involvement of the public in decision-making processes is actively encouraged by the authorities, exemplifying a commitment to respecting and safeguarding the river environment through community engagement.

Table 3 - Clarke Quay revitalization approach

Element	Clarke Quay
Revitalisation action	Detect and relocate sources of pollution like factories, and commercial. One of the initiatives is to locate a hotspot or place that is a litter-prone drain to be covered with slab, and steel grating (as the first step for rubbish to enter the drainage system that will end up in the main river stream.
Key role in riverfront revitalisation	To make sure adequate cleaning is done before ensuring good quality of river water to allow people to touch and interact physically with the water.
Collaborations with other agencies	Urban river regeneration must include various agencies and professionals/experts to tackle the river issue holistically and effectively. Planners, architects, biologists, and government agencies to maintain the project implementation.

Continuous work	The riverbed was inspected and removed any debris and sedimentation for better flow of the river stream.

6.3 Thames River, London, United Kingdom

London, as the capital of the United Kingdom, bears the responsibility of maintaining its pristine state. The local authorities exhibit efficiency and dependability in ensuring the cleanliness and vitality of the Thames River. A comprehensive analysis of the authorities' actions and political interventions concerning the Thames River is presented in table 4 below:

Table 4 - Thames River revitalization approach

Element	Thames River
Revitalisation action	Revitalisation action is barely needed as the Thames River has been kept clean since the Industrial revolution
Key role in riverfront revitalisation	The active role of the Port and Land Authority (PLA) to constantly monitor and innovate the Thames Riverfront
Collaborations with other agencies	Develop long-term partnerships among agencies and experts to make sure the riverfront and river are always maintained and protected.
Continuous work	Thames River is celebrated as an asset and the United Kingdom is planning to expand its water transportation as many roads' congestion is happening frequently in central London

Londoners deeply appreciation the Thames River and take proactive measures to ensure its vibrancy, cleanliness, and overall health. The river's significance to the community, businesses, and tourism is evident through world-leading approaches. Some of these valuable insights can be incorporated into the new infographic guideline for Kuala Lumpur.

6.4 Tiber River, Rome, Italy

The management of the Tiber River falls under the responsibility of the Lazio Regional Environmental Protection Agency (LREPA), which was entrusted by the Italian Government to safeguard the river. The details of the authority's actions regarding the Tiber River can be found in Table 5 below:

Table 5 - Tiber River revitalization approach

Element	Tiber River
Revitalisation action	Simple technique of selective cleaning of the Tiber embankment walls
Key role in riverfront revitalisation	The Romans are detached from the Tiber River Themselves
Collaborations with other agencies	Artists are looking for new ways to use the Tiber River as new art canvas/background for their art
Continuous work	No continuous work was recorded for the Tiber River during the observation

The Tiber River shares similarities with Kuala Lumpur, as both cities face challenges in their riverfront development. The majority of building frontages do not directly face the riverfront in both locations, but there are a few prominent plazas designed along the riverfront in Rome. To compensate for the lack of seating areas, Rome offers numerous restaurants and cafes along the riverfront, allowing locals to enjoy the visual connection with the river while relaxing at these establishments. However, there is a dearth of water sports or dedicated recreational activities for the community along the Tiber River. Based on on-site observations, it is evident that Romans prefer to experience the river by sitting at cafes, emphasizing the importance of visual connections with the riverfront. Additionally, major bus stations are strategically positioned along the river, ensuring a seamless connection between the river and public transportation.

To enhance the public's access to the Tiber River, several new entrances should be designed. Transforming the existing river wall into a vibrant space with green coverings would invigorate the riverfront. Moreover, addressing issues of signage and vandalism along the riverfront embankment is crucial. Introducing urban river parks would further enhance the recreational opportunities available to the community. Revitalizing the Tiber River's riverfront requires thoughtful planning and design interventions. Creating inviting entrances, adding green elements, and promoting a vibrant and safe environment will contribute to the enhancement of the riverfront experience for both residents and visitors.

6.5 Klang River, Dayabumi, Kuala Lumpur, Malaysia

The responsibility for the care and maintenance of the Klang River lies with the Federal Government, with support from KLCH and Alam Flora Sdn Bhd. The actions carried out on the Klang River are documented in Table 6.

Table 6 - Klang River, Dayabumi, Kuala Lumpur revitalization approach

Research Objective	Research Objective 2 (RO2)
Element	Observation in Kuala Lumpur
Revitalisation action	River of Life completion in 2016 marks a new beginning for the Kuala Lumpur Riverfront
Key role in riverfront revitalisation	ThinkCity and DBKL are looking for more ways to express the river better with more community engagement
Collaborations with other agencies	Dewan Bandaraya Kuala Lumpur collaborate actively with Alam Flora (Waste management) and Think City as think tankers to help revitalise Kuala Lumpur Riverfront
Continuous work	Alam Flora is continuously working to clean Kuala Lumpur

The Dayabumi riverfront along the Klang River, situated in the heart of Kuala Lumpur, has exhibited indications of urban degradation and neglect (Iqbal et al., 2020). According to Iqbal et al., (2020), the waterfront lacks integration with the surrounding urban landscape, resulting in a fragmented environment. Contributing to this disconnection are deteriorating waterfront features, primarily caused by compromised water quality and restricted access to the water body from its sides and along its length. Moreover, the block nature of urban design hampers permeability to the water's edge. Additionally, the building massing and articulation challenge the desired enclosure ratio of 1:2 (width of the water body: height of the building) due to the narrow water body and the uneven texture of modern high-rise structures.

However, the presence of heritage structures with finely detailed facades lends a distinctive identity to the area. Drawing on past studies and current recommendations, two potential urban spaces, one at Menara Dayabumi and the other at the Central Market open car park, emerge as promising opportunities to serve as new focal points for the historic waterfront (Iqbal et al., 2020). These spaces have the potential to forge connections between the historic city center and the contemporary city extension. Although strategies can be implemented to revitalize the riverfront into a community-friendly refuge, it is essential to adapt approaches learned from three other international cities, considering the impact of varying climates. Nevertheless, the overarching principles align with the Kuala Lumpur Strategic Plan for the Klang River, providing a cohesive foundation for enhancing the riverfront area.

7. Discussion and Recommendation

Riverfront development in Malaysia faces significant challenges, particularly in Kuala Lumpur, where the Dayabumi Riverfront has been showing signs of urban degradation and negligence. As highlighted by Iqbal et al. (2020), this once central and vibrant area has suffered from a lack of integration with the urban form and spaces, leading to a disconnected environment. The deteriorating waterfront features, coupled with poor water quality and limited access to the water body, further exacerbate the issues. Presently, riverfront development in Malaysia is governed by ten laws and regulations, as documented by Yassin et al. (2018).

The existing laws and regulations related to riverfront development in Malaysia have evolved over the years. The Sanitary Board Enactment, dating back to 1907, primarily focused on health and public sanitation, laying the groundwork for subsequent laws such as the Water Act 1920. Even today, the Department of Drainage and Irrigation of Malaysia continues to rely on the Water Act 1920 to govern water-related matters. The introduction of the Kuala Lumpur Structure Plan in 1984 marked a pivotal moment as it emphasized the importance of the waterfront as public space and discussed the development of natural features. Various other laws and plans, including the Malaysia Plan and the Town and Country Planning Act 1976, have been instrumental in shaping riverfront development in Malaysia.

Despite these regulations, the riverfront development still faces serious challenges. Insufficient controls, poor enforcement, and conflicting policies have hampered progress. The lack of proper gazetting for some policies has resulted in confusion and conflicts between different authorities responsible for different aspects of riverfront development. The current state of the Dayabumi Riverfront, marred by trash and pollution, demands urgent action. Recommendations put forth by Winston et al. (2023) advocate the installation of trash catchment systems in drainages to reduce contamination. Additionally, conducting more frequent trash pickings in residential areas and establishing additional trash collection points within 5km of the Dayabumi riverfront are essential steps to mitigate the pollution. To revitalize the Dayabumi Riverfront, a holistic approach is necessary, integrating both hardscape and landscape elements. The alteration of the river's form, the incorporation of modern technologies, and active involvement of the public are crucial for success. Integration of heritage structures with the modern landscape adds a unique identity to the area and create a sense of place.

Promoting connectivity and permeability to the waterfront, along with adequate green coverings and well-designed public spaces, can attract more people to the riverfront. By fostering a sense of ownership and pride in the riverfront, the community can play a vital role in its preservation and maintenance. Engaging local communities in riverfront initiatives can lead to better stewardship and long-term sustainability. Given the complexities and challenges associated with riverfront development, collaboration between various government agencies, stakeholders, and the public is paramount. Coordinated efforts and a shared vision for the future can transform the Dayabumi Riverfront into a vibrant, clean, and thriving urban space, ensuring its sustainability and enhancing the overall quality of life for the residents of Kuala

Lumpur. Through a combination of scientific research, effective policies, and community involvement, Malaysia can set an example for other cities facing similar riverfront challenges worldwide.

7.1 Summary of Recommendation

Drawing from the findings and discussion, the following is a summary of how the Dayabumi riverfront can undergo revitalization to improve its liveability and ambiance. The images in Table 7 further function to visually represents the elements discussed for better understanding.

Fig. 7 - Proposed design guideline at Dayabumi Riverfront

As depicted in Figure 7, the importance of thoughtful building orientation along the riverfront is seen. By strategically positioning building frontages to face the river, the visual connection between the built environment, the public, and the water body is significantly enhanced. This design approach not only creates an aesthetically pleasing and inviting urban landscape but also fosters a sense of harmony and integration with the natural surroundings. Moreover, the wider boardwalk showcased in Figure 7 plays a pivotal role in promoting active engagement with the riverfront space. With ample space for stalls to operate and pedestrians to traverse, the boardwalk becomes a bustling and vibrant area, offering opportunities for social interactions and leisure activities. By accommodating various modes of travel, such as walking and cycling, the boardwalk encourages a diverse range of users to partake in the riverfront experience, further reinforcing its role as a popular and accessible public space.

Figure 8 highlights the significance of direct access points to the river. The presence of steps leading directly to the water's edge is a key design feature that facilitates an intimate connection between people and the river. Such accessibility is crucial in promoting a deeper appreciation and understanding of the water body, fostering a sense of ownership and responsibility towards its conservation. In addition to building orientation and accessibility, the integration of green coverings along the riverfront emerges as a crucial aspect of sustainable riverfront development. The use of creepers and native plants on concrete wall embankments not only softens the urban landscape but also contributes to ecological enhancement. Greenery along the riverbanks provides habitats for wildlife, improves air quality, mitigates urban heat island effects, and enhances the overall ecological resilience of the area.

Furthermore, the presence of native plants helps preserve local biodiversity and supports the establishment of an ecologically balanced ecosystem along the riverfront. The interplay of urban structures with green spaces fosters a harmonious coexistence between the built environment and nature, promoting a healthier and more sustainable urban ecosystem. Overall, the amalgamation of thoughtful building orientation, wider boardwalks, direct river access, and green coverings exemplifies a holistic and people-centric approach to riverfront development. By designing spaces that cater to the needs and aspirations of the community, while preserving and enhancing the natural environment, cities can create vibrant, inclusive, and ecologically resilient riverfronts. The lessons drawn from the presented figures provide valuable insights for urban planners, policymakers, and stakeholders to shape sustainable riverfront developments that enrich the urban experience, foster community well-being, and preserve the precious natural resources for generations to come.

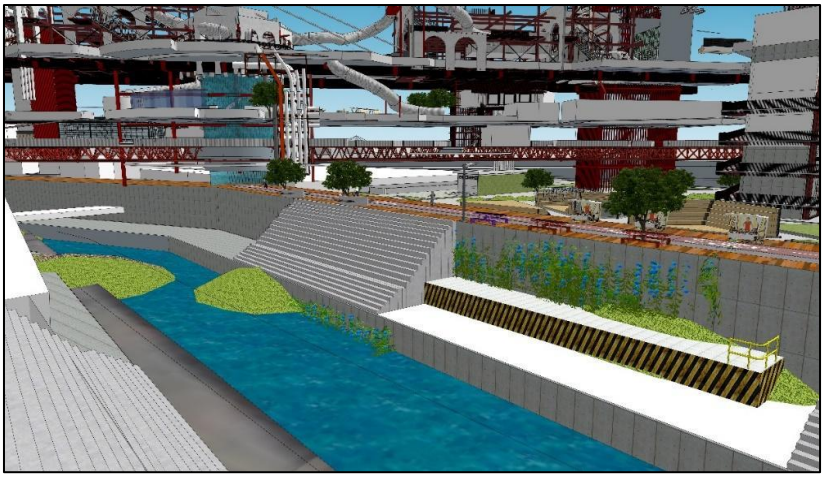


Fig. 8 - Proposed design guideline at Dayabumi Riverfront

Fig. 9 - Proposed design guideline at Dayabumi Riverfront

Figure 9 depicts the Dayabumi Riverfront revitalization project which incorporates various seating arrangements and mixed-use spaces along the riverfront to encourage a vibrant and bustling atmosphere. The seating options range from benches and amphitheatre-style seating to dining areas, providing ample opportunities for people to enjoy and utilize the riverfront.

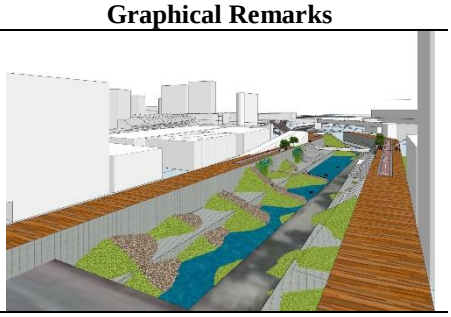
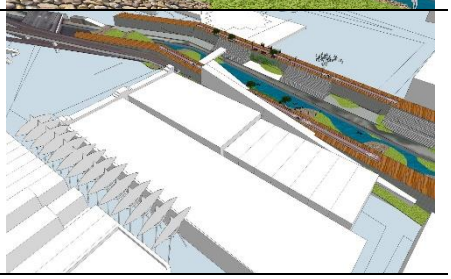
Fig. 10 - Proposed design guideline at Dayabumi Riverfront

The river form depicted in Figure 10 showcases a transformation of Klang River, once characterized by an uninteresting and monotonous concrete embankment. Through thoughtful design and innovative concepts, it has now evolved into a dynamic and inviting riverfront adorned with lush greenery, mountains, and pebbles, beautifully blending urban infrastructure with natural elements. This transformation is not merely an aesthetic improvement; it holds immense ecological significance. The introduction of green coverings along the riverbank has created a thriving habitat for aquatic life, restoring biodiversity and contributing to the rehabilitation of Klang River's ecosystem. The significance of this revitalization effort goes beyond just the visual appeal and recreational benefits. With the riverfront now enriched with natural features, it has become a focal point for the community, attracting both locals and tourists alike. The positive impact on the quality of life for residents cannot be understated, as they now have access to a rejuvenated space for leisure, relaxation, and interaction with nature. This transformation also serves as a prime example of sustainable urban planning, highlighting the potential for other cities to re-imagine and revitalize their waterways.

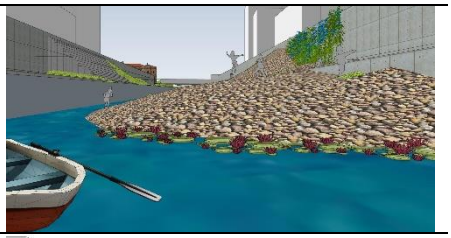
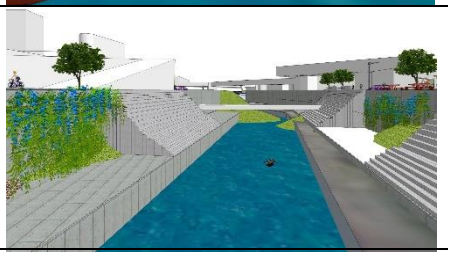
As mentioned in the description, the positioning of buildings facing directly towards the river has a profound effect on the river's overall aesthetic and atmosphere. By avoiding a "back-lane effect," where buildings turn away from the river, the design encourages a more vibrant and engaging waterfront experience, promoting connectivity and fostering a sense of community engagement. Table 7 provides considerations that further augment our understanding of the transformation process. It outlines the various elements integrated into the riverfront design, such as the specific types of green coverings used, the careful placement of mountains and pebbles, and the strategies employed to restore and protect aquatic life in the river. The table also elucidates the rationale behind the architectural decisions, explaining how they contribute to the overall revitalization goals and align with the broader vision for the city's sustainable development.

This transformation of Klang River represents a turning point in the city's history, signalling a paradigm shift in urban planning towards more environmentally conscious and community-oriented designs. It stands as a living testament to the power of creativity, collaboration, and a shared commitment to reclaiming and preserving our natural heritage amid the challenges of urbanization. Through responsible stewardship and a focus on ecological restoration, cities can rediscover the intrinsic value of their water bodies and create resilient, thriving, and beautiful riverfronts for generations to come:

Table 7 - Summary of recommendations to revitalise Dayabumi Kuala Lumpur Riverfront

Injection to instil in Klang River in Kuala Lumpur		
Research Objective	**Research Objective 3 (RO3)**	
Element	**Consideration**	**Graphical Remarks**
Building frontage and orientation	Allow the building in Kuala Lumpur to have **double frontage to eliminate the back lane effect on Klang River.** Having a frontage facing the river suggests that the buildings have trust that the river is part of the site and thus have a **better design connection between these two entities**. Natural setting frontage proof to be pedestrian friendly and evoke a different sense of welcoming to the site.	
River contamination quality	Better river quality can also be translated into **better planning and permeability between human and river life.**	-
Public amenities	Creating a **sustainable river community like river rangers** that actively engage with river enhancement programme.	
Identity	Translated into patterns, motives that are contextual to the site to evoke the historical identity of Kuala Lumpur and its river.	

Pavement / Boardwalk	Continuous, OKU-friendly and **universal design.** Provide street trees to link the river corridor with city green space.	
Shadings	Coverings along and off riverfront walkways through roofing and **trees covering for thermal comfort** and weatherproof design. Sufficient canopy for shading and shelter to carry out activities along the riverfront.	
Sittings	Adequately **sitting with multiple arrangements and configurations** to give liberty for user's comfort and better engagement through hardscape, street furniture can incorporate timber and other natural material than just pure concrete.	
Natural-induced elements (Trees, creeks)	Adopted from findings in the literature review, vegetation is and could be the most important element to restore the riverfront of Kuala Lumpur as well as helps to improve the quality of river water. Rule of thumb: cleaning river water, better ecological, more successful integration between the city, humans and the river itself. The urban river is the reflection of the community around it.	
Public space (Performing space, plaza, programme)	Besides connecting elements to a different part of the city, public spaces can be introduced like pocket parks and many other outdoor well-designed public spaces that provide refuge and shelter to the community to express themselves creatively or as a therapeutic refuge.	
Space utilization / Space activation	Abandoned space along the river needs to be activated to stop it becoming a disposal landfill for the community.	
Economy injection / Work opportunity	Allowing economic intervention along the riverfront can be healthy for the community itself allowing monetary changes between humans and the river itself. Dining al-fresco, pushcart, food trucks.	

Low maintenance, High performance	Introduced resilient planting that is suitable to Malaysian weather and material used in built form to be weatherproof for several years with a religious maintenance regime.	
Infiltration plant garden bed	Using the garden as a form of filtration and debris retention to protect any pollutant from entering river streams. Part as an aesthetic element as well as functioning as an active member in river cleaning. The filter bed can incorporate shrubs and flowers to further help in river beautification.	

8. Conclusion

The outcomes of this study provide a comprehensive set of strategies for effectively revitalizing the riverfront through the implementation of an improved waste management system, ultimately safeguarding the riverway. As previously mentioned, Malaysia currently has ten laws and regulations related to waterfront development. However, the inadequacy of these regulations and poor enforcement practices raise concern. To address the contamination issue, it is imperative to install trash catchment systems at every drainage point before it enters the main river stream, thus reducing pollution. Additionally, conducting more frequent trash pickings in residential areas is essential. Authorities must also increase the number of trash collection points within commercial and residential areas within a 5km radius from the Dayabumi riverfront. These measures are crucial in combatting the unattractiveness of the Kuala Lumpur riverfront, plagued by an excessive amount of waste. The revitalization of the Dayabumi Riverfront requires a multifaceted approach, combining both hardscape and landscape elements, altering the river's form, introducing innovative technologies, and actively engaging the public in the initiative. Establishing a more robust waste management system that effectively addresses the increasing waste production is of paramount importance. Furthermore, the role of architecture must be all-encompassing, contributing to the transformation of the urban environment by creatively addressing river-related issues through innovative riverfront designs. By adopting these strategies, cities can effectively revitalize their riverfront areas, transforming them into attractive and sustainable urban spaces that resonate with the needs and desires of the community. The integration of architectural elements, landscape design, and advanced waste management practices contributes to the creation of vibrant and ecologically responsible riverfronts, fostering a deeper connection between people and their natural surroundings. Ultimately, the successful implementation of these strategies leads to enhanced riverfront experiences, increased community engagement, and a more resilient urban environment. As cities worldwide face the challenges of urbanization and environmental degradation, such research-backed strategies play a pivotal role in creating sustainable and thriving riverfronts that will benefit both present and future generations.

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