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URBAN FLOOD PROJECT MANAGEMENT: UNCOVERING SOLUTIONS FOR KUALA LUMPUR

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Abstract

Kuala Lumpur is the most developed city in Malaysia, facing heightened risks of flash floods due to rapid urbanisation and intense rainfall. This study evaluates the effectiveness of structural interventions in mitigating flash floods through qualitative methods, using semi-structured interviews with experts from the Department of Irrigation and Drainage (DID) and consultant engineers. Content analysis revealed that existing measures, including the JPS manual and guidelines (MASMA), retention and detention ponds, on-site detention systems, and rainwater harvesting tanks, contribute significantly to flood risk reduction but cannot fully resolve the problem. Experts highlighted the importance of consistent maintenance of current infrastructure while recommending innovative approaches to strengthen resilience. Proposed strategies include adopting sponge city concepts, developing coastal reservoirs, integrating green spaces in urban planning, and applying advanced practices from Singapore, such as underground tunnel systems. The findings underscore the need to complement MASMA with innovative structural measures to address persistent flood challenges more effectively. The study contributes to strengthening existing flood management frameworks in Malaysia and urges the DID and local authorities to consider their adoption in future urban flood resilience planning.

Keywords: Disaster risk reduction, Flash floods, Flood disaster, Mitigation plan, Structural measures, Developing countries.

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INTRODUCTION

The world is currently facing severe impact from climate change, such as rising sea levels, droughts, typhoons, and floods (Said, Gapor, & Hamat, 2024). Floods have already caused widespread disruption, including damage to critical infrastructure such as railway tracks, bridges, roads, vehicles, and properties, often resulting in loss of life (Saad et al., 2024). The consequences extend beyond physical damage: communities are often cut off, delaying emergency response and restricting daily movement, which affects people, goods, and services alike.

Floods have become more frequent and severe, with devastating impacts on the environment, society, and economy (Aldardasawi & Eren, 2021). The urgency of enhancing flood resilience is growing, as buildings and infrastructure remain highly vulnerable to flood damage. However, current approaches are inadequate due to outdated materials, poor design standards, and a general lack of awareness and education within the construction industry. Despite efforts to communicate risk and promote preparedness, adoption of mitigation measures remains low (Abunyewah et al., 2018). While many cities are now investing in urban parks and open spaces to increase water retention and reduce flood risks (Ibrahim et al., 2020), such efforts must be part of a broader strategy.

Kuala Lumpur is one of the busiest cities in Malaysia, frequently affected by flash floods. This is due to the rapid development in the city, poor drainage maintenance, and unsuitable design, as reported by Samsuri et al. (2018). The government has implemented various initiatives to mitigate flood impacts, such as building the Stormwater Management and Road Tunnel (SMART Tunnel), stormwater drains, retention ponds, dams, and more, but these measures seem insufficient as floods persist. Therefore, the goal of this research is to assess the effectiveness of the structural measures and non-structural measures implemented in Kuala Lumpur in mitigating flash floods. Three research objectives are the following: (1) To examine the existing flood prevention strategies implemented in Kuala Lumpur, (2) To evaluate the effectiveness of these flood prevention strategies in mitigating flood risks, and (3) To explore potential improvements for enhancing flood prevention measures in Kuala Lumpur.

LITERATURE REVIEW

Flood Implications in Kuala Lumpur City Centre

One of the most common infrastructure-related consequences of flooding is the shutdown of roadways, particularly in low-lying areas. Vehicles attempting to pass through these inundated zones may become stranded or submerged, resulting in severe traffic congestion and extended travel delays (Al-Qadami et al., 2024). Apart from that, floodwater frequently damages or washes away business

premises and the merchandise within them. Such events disrupt business operations, and recovery depends heavily on the extent of losses and the time taken to restore capital (Maleki et al., 2022). Frequent flooding events can lead to significant economic losses, thus affecting business sustainability. Moreover, floods can inflict significant structural damage on buildings. The force of floodwaters can compromise building integrity; roofs may be torn off, walls may collapse or crack, and foundations may weaken. Wooden structures, in particular, may swell, warp, or decay after prolonged submersion. Flash floods are triggered by various factors and tend to be especially destructive near rivers or streams, often resulting in property loss and fatalities. In mountainous regions, intense rainfall can cause soil erosion and mudslides, further damaging infrastructure, homes, and roads, and heightening the risk to human life (Othman et al., 2023). In the commercial sector, the impact is equally devastating.

Beyond physical and economic damage, the social consequences of flooding are far-reaching. These impacts are generally classified into four key aspects: socio-economic, socio-political, socio-demographic, and psychological. Psychosocial effects refer to the mental health challenges faced by flood victims, including emotional distress, anxiety, depression, and grief. Victims often experience behavioral changes as a result of trauma (Zhong et al., 2018). Sociodemographic impacts include the loss of residential property and the forced relocation of affected individuals. Housing recovery typically unfolds in stages, and for many, the psychological toll can be long-lasting, especially for those who remain near flood-prone areas. Each monsoon season, these individuals relive the trauma through recurring anxiety and fear. Flooding also disrupts the broader social fabric of affected communities. Displacement and homelessness are common outcomes, with some victims facing temporary relocation while others are permanently uprooted (Odula, 2020). In such situations, individuals may be forced to stay with relatives or in emergency shelters, which can erode their sense of community and belonging. Tragically, floods can also result in the loss of life, triggering collective grief and disrupting social networks. Furthermore, community life often grinds to a halt. Children may miss school, adults may be unable to work or operate their businesses, and recreational or cultural events are often cancelled. This disruption can weaken community cohesion and lead to increased social stress. In extreme cases, unmet basic needs may give rise to interpersonal and communal conflict (Ullah et al., 2025). Lastly, floods can lead to financial strain and resource shortages, not only for affected individuals but also for surrounding regions. The temporary closure of public facilities like parks, community centers, and recreational venues limits opportunities for social engagement and affects the overall quality of life in the community.

The Structural Measures in Kuala Lumpur

The severe flood that struck Kuala Lumpur's Business District in 1971 prompted the Malaysian government to begin seeking long-term solutions to the city's recurring flood problems. By the mid-1970s, a comprehensive flood mitigation master plan was developed. This plan included strategies such as stormwater ponding, pumped drainage, upstream water storage, and the enhancement of the Klang River's drainage capacity along with its key tributaries (Shahrulnizam et al., 2020). Several structural interventions were implemented to further reduce flood risks, including the construction of dams, floodwalls, levees, revetments, pump stations, and river deepening works (Martinez et al., 2020). A major milestone in Kuala Lumpur's flood management was the launch of the Stormwater Management and Road Tunnel (SMART Tunnel) in 2004. Jointly developed by the Malaysian Highway Authority and the Department of Irrigation and Drainage, the RM1.9 billion project served a dual purpose: mitigating flood risk and easing traffic congestion in the city (Ibrahim et al., 2020). The tunnel, which passes through the challenging Kuala Lumpur Limestone Formation, spans 9.7 km in length. It includes a 3 km double-deck motorway and stretches from the Kampung Pandan roundabout to the Kuala Lumpur-Seremban Highway near the TUDM airfield in Sungai Besi. The SMART Tunnel primarily serves central Kuala Lumpur, which is the most congested area during working days (Monday to Friday). The areas include like Masjid Jamek, Jalan Tun Perak, Dataran Merdeka, Kampung Baru, Jalan Munshi Abdullah, and Jalan Tunku Abdul Rahman. There have been no flash floods caused by Klang River overflow in these areas since its opening (Samsuri et al., 2018).

Other than the SMART tunnel, retention ponds are commonly used to help manage stormwater. These ponds collect runoff from surrounding areas and release it slowly through a low-flow outlet to minimize environmental harm. Unlike detention ponds, which eventually dry out, retention ponds are designed to always contain some water, as their outlets are positioned higher. This distinction is critical when designing water management infrastructure (Curtis, 2024). Stormwater problems can be solved in part by installing retention ponds. Stormwater collected in these ponds drains off from the surrounding watershed and is released into the surrounding environment at a preset, slower pace through a low-flow aperture to prevent environmental damage. Similar to detention ponds, which are intended to allow water to flow out until they are entirely dry, retention ponds are made to always contain water. When it comes to building, this distinction means that retention ponds have higher outflow points that permit some water to stay in the pond always, while detention ponds have their orifices near the bottom of the pond. To date, multiple retention ponds have been constructed as initiatives towards flood measures, as presented in Table 1. These

are among the initiatives taken by the Department of Drainage and Irrigation (DID) in Kuala Lumpur.

Table 1: List of Retention Ponds Developed by DID

Name	Size (hectares)	Agency in charge	Status
Kampung Benteng	6.6	DID Director	-
Taman Sri Segambut	4.2	DID Director	-
Batu	71.6	FT Department Director-General	Alienated for development
Nanyang	20.1	DID Director	Flood mitigation project
Delima	8.1	DID Director	Approved for development
Taman Wahyu	25.4	DID Director	Approved for development
Kampung Puah	2.3	DID Director	-
Batu 4 1/2	0.9	DID Director	Alienated for development
Midah	17.5	DID Director	-
Flat Sri Johor	24.8	FT Department Director-General	-
Taman Desa	17.6	Federal Territory Land Exco	Project cancelled
Taman Berembang	13.4	DID Director	-
Setapak Jaya	4.5	Federal Territory Land Exco	-
Boyan	8.9	Federal Territory Land Exco	-
Bohol	37.8	FT Department Director-General	Proposed for alienation

Source: Department of Drainage and Irrigation (2023)

Dams are another essential component of flood control. Beyond their regular storage capacity, dams designed for flood mitigation have dedicated compartments for holding excess water (Xia & Chen, 2021). During heavy rain, dam operators can retain more water and release it gradually, lowering the downstream flood risk. Dams also help recharge groundwater and trap sediment behind their barriers. Outlets installed in the dam's structure control water discharge efficiently. As defined in the Malaysia Dam Safety Management Guideline (MyDAMS), a structure is classified as a dam if it stands at least 10 meters high with a storage volume of over 20,000 m³ or over 5 meters in height with storage exceeding 50,000 m³. In Malaysia, most dams are earth-fill types and are over 40 years old. These dams serve multiple roles, including water supply, irrigation, hydroelectric power generation, flood control, and sediment retention

(Mohd, 2019). Batu Dam is a flood mitigation structure constructed in Kuala Lumpur at 44 meters high, which is the tallest dam in Malaysia.

An increasingly recognized solution for water management is the use of rainwater harvesting systems (RWHS). These systems are gaining popularity as a sustainable alternative to piped water and an effective method to manage stormwater. Studies have shown that RWHS provide significant environmental, economic, and technological benefits (Qi et al., 2019). Although Malaysia hasn't experienced a major water crisis recently, rainfall is unevenly distributed across regions and seasons. As such, integrating rainwater harvesting can help balance water availability and reduce the risk of flash floods. When widely adopted, these systems not only reduce reliance on treated water but also help manage urban runoff, reduce soil erosion, prevent pollutants from entering waterways, and mitigate flash floods. Promoting RWHS at a larger scale is therefore crucial for sustainable urban development.

RESEARCH METHODOLOGY

A series of expert semi-structured interviews was conducted with engineers, specifically targeting consultant engineers and professionals from the Department of Irrigation and Drainage (DID) and engineering who are experts in flood management. These individuals were selected due to their direct involvement in the planning and implementation of structural flood mitigation measures from the early stages of the respective projects in Kuala Lumpur City. These sample selections fall under a non-probability sampling method and are categorized as a purposive sampling method. It is anticipated that the small sample size would be adequate since the majority of participants have extensive experience in flood mitigation strategies, with some having up to 43 years of expertise. A similar study related to experience respondents was found by Rahimin et al. (2026).

The interview recordings will be transcribed verbatim and manually translated into English before being analyzed using content analysis. Content analysis will be employed as the primary qualitative data analysis technique to identify themes and interpret the findings.

ANALYSIS AND DISCUSSION

Respondents' Profile

The results of the respondents' background are presented in Table 2. All selected respondents are civil engineers with relevant work experience or knowledge related to structural measures for flood mitigation in Kuala Lumpur. Two of the respondents are civil engineers from the Department of Irrigation and Drainage (DID) of Wilayah Persekutuan Kuala Lumpur, while the other two represent Engineering Consultancy Services. All respondents have over 20 years of

professional experience, with the most experienced being Respondent 3 (R3), who has 43 years in the field. This extensive experience makes them highly qualified to provide relevant insights into flood mitigation.

Table 2: Details of the respondents

Participant	Designation	Working Experience (years)
R1	Director	32
R2	Assistant Director	21
R3	Executive Director	43
R4	Project Engineer	33

Source: Authors (2025)

Identification of the Flood Prevention Plan in Kuala Lumpur

Table 3 presents the current flood prevention strategies implemented in Kuala Lumpur. The findings highlight that the Department of Irrigation and Drainage (DID) Manual and Guidelines, commonly known as MASMA, and the use of rainwater harvesting tanks are frequently cited as key flood mitigation measures within the Kuala Lumpur City Centre. The overarching goal of MASMA is to reduce the risk and severity of urban flooding during heavy rainfall events. Accordingly, developers must obtain approval from JPS prior to construction to ensure compliance with MASMA requirements. Before the implementation of MASMA, water from developments was typically discharged directly into rivers without adequate control measures. While previous literature, such as Abunyewah et al. (2018), categorizes MASMA primarily as a non-structural measure focused on policy and planning, These findings contradict previous literature that MASMA also incorporates structural elements by enforcing design standards that directly influence flood mitigation infrastructure. MASMA can also be regarded as part of emergency preparedness planning or overall flood management strategies within the Kuala Lumpur flood mitigation plan. Although it is not discussed in the existing literature, this represents a significant finding of the study, highlighting its contribution to the understanding of flood mitigation strategies.

Rainwater harvesting was also mentioned as a flood mitigation measure among the respondents. Specifically, respondents R3 and R4 emphasized the importance of promoting rainwater harvesting tanks in all households. These systems are designed to capture, store, and manage rainwater runoff for later use. Typically, rainwater is collected from rooftops and directed into storage tanks, where it can be reused for various non-potable purposes. Beyond effective water resource management, rainwater harvesting presents a sustainable and cost-efficient approach to reducing dependency on treated water supplies. It serves as

a practical solution for enhancing household-level water conservation and contributes to broader environmental sustainability efforts.

In addition to MASMA and rainwater harvesting, detention ponds play a crucial role in managing peak stormwater runoff. During heavy rainfall, these ponds temporarily store excess water and release it gradually, thereby reducing the volume and velocity of water entering downstream drainage systems. This helps to mitigate the risks of flooding and erosion. In contrast, retention ponds are designed to permanently hold stormwater runoff on-site. Unlike detention ponds, retention ponds maintain a constant water level, allowing the water to either infiltrate into the ground or evaporate over time. This process not only supports groundwater recharge but also enhances water quality through the natural removal of pollutants. Respondent R1 emphasized the importance of a multi-faceted structural approach to flood mitigation in Kuala Lumpur. R1 added that “In Kuala Lumpur as a whole, the SMART system is only part of the structural measures that divert a portion of water from certain rivers. A more viable flood mitigation strategy requires a combination of multiple methods to provide comprehensive protection. For example, in developed areas, the river basin functions as a catchment where rainwater is impounded. Effective flood mitigation must cover all areas such as upstream, midstream, and downstream. At the upstream level, structures regulate and control water flow; at the midstream, measures such as detention, retention, and diversion are employed; while downstream, coastal bunding is used to manage water outflow.” To conclude, R1 highlighted that all structural components like retention, detention, diversion, dams, and coastal bunds play a vital and interconnected role in managing flood risks across the entire river basin in Kuala Lumpur. These integrated measures are essential for controlling water flow and minimizing flood impacts throughout the catchment area.

On-Site Detention (OSD) systems were also another mitigation strategy mentioned by the experts, further strengthening localized stormwater management strategies. The primary objective of OSD is to control stormwater runoff by temporarily storing excess rainwater during heavy rainfall events. This stored water is then gradually released at a controlled rate into the stormwater drainage network or adjacent natural water bodies. By regulating the flow, OSD helps to reduce downstream flooding, prevent erosion, and improve water quality by allowing sediments and pollutants to settle before the water is discharged. Building on this, respondent R1 highlighted that flood mitigation in Kuala Lumpur requires an integrated approach involving multiple structural measures. R1 explained,

“In Kuala Lumpur as a whole, the SMART system is only part of the structural measures that divert a portion of water from certain rivers. A

viable flood mitigation system must comprise multiple components to provide comprehensive protection. For instance, in a developed area that includes a river basin or catchment area, flood mitigation should cover upstream, midstream, and downstream levels." [R1]

R1 elaborated further, noting that

"Upstream interventions help regulate and control water flow, while the midstream zone involves detention, retention, and diversion structures. Finally, the downstream area utilises coastal bunding to manage water discharge." [R1]

This holistic approach ensures that all areas of the river basin are adequately protected against flood risks. R1 emphasised that no single structural measure can effectively manage flood risks on its own. Instead, a combination of dams, detention and retention ponds, and diversion channels, particularly in the midstream sections of river basins, is essential for controlling and redirecting water flow during heavy rainfall.

Table 3: List of flood prevention plans in Kuala Lumpur

Flood prevention plans/ respondents	R1	R2	R3	R4
JPS manual and guideline (MASMA)	✓	✓		
Retention and Detention Pond	✓			✓
On-Site Detention (OSD)	✓			✓
Rainwater harvest tank			✓	✓
Total word frequency	✓	✓		

Source: Authors (2025)

Effectiveness of the Flood Prevention Plan in Kuala Lumpur

The findings indicate that there is no single flood mitigation strategy in Kuala Lumpur that can guarantee the complete prevention of flood disasters. However, structural measures have proven effective in significantly reducing the impact and severity of flooding. R1 & R2 have a similar opinion that the mitigation strategies must involve a combination of structural approaches, for example, dams and water retention, smart tunnels, and retention ponds, as each measure serves a distinct function and is suited to specific contexts. For instance, the SMART Tunnel is primarily designed to divert stormwater, ponds are constructed to store excess water, and dams function to control river flow. These structural solutions are not universally applicable; their effectiveness depends on factors such as geographical location, population density, and urban development

intensity. In addition, R1 explained that the SMART Tunnel, while effective, is geographically limited to the city center, specifically benefiting impacted areas. As such, it has minimal impact outside its operational zone. This illustrates that no single measure can address flood risks citywide, and instead, a comprehensive, location-sensitive strategy is essential. Further insights were gathered from Table 4, where respondents R3 and R4 evaluated the efficiency of various structural measures used for stormwater management and flood mitigation in Kuala Lumpur.

(i) SMART Tunnel

R3 assigned a low efficiency rating, suggesting that the SMART Tunnel contributes minimally to overall stormwater management. This could reflect concerns about operational limitations, capacity constraints, or the belief that other interventions offer greater impact.

(ii) Dams

Dams received the highest effectiveness score. R3 highlighted their ability to store excess rainfall, regulate flow, and prevent downstream flooding. The rating reflects a broader global consensus on the importance of dams in water resource infrastructure.

(iii) Retention Ponds

R3 considered retention ponds moderately effective. These structures temporarily hold stormwater runoff, allowing pollutants to settle before discharge. Their effectiveness, however, may depend on design quality, maintenance, and site-specific factors such as catchment size and urban density.

Overall, R3's assessment indicates that dams are perceived as the most reliable structural solution, followed by retention ponds, with the SMART Tunnel viewed as having limited effectiveness in broader flood mitigation. Unlike R3, respondent R4 did not rate the SMART Tunnel, dams, or retention ponds, citing limited personal experience with these measures. However, R4 assigned a high effectiveness rating to general water retention strategies, underscoring her strong support for sustainable, decentralized approaches to flood control. Water retention techniques aim to retain stormwater on-site and enhance groundwater infiltration. These include practices such as green roofs, rain gardens, permeable pavements, and other forms of green infrastructure. R4's perspective reflects an understanding of the multi-functional benefits of these systems, including urban greening, water quality improvement, groundwater recharge, and flood reduction.

Table 4: Most Effective Flood Measures in Kuala Lumpur

Theme/Respondent	R1	R2	R3	R4
It must have a combination of a few approaches.	✓	✓		
Different structural measures and locations serve different purposes.		✓		
Dam			✓	
Water Retention			✓	
Smart Tunnel			✓	
Retention pond				✓

Source: Authors (2025)

Strategies in Enhancing the Flood Prevention Plan in Kuala Lumpur

According to respondents R1 and R2, one of the key strategies to enhance Kuala Lumpur's flood prevention efforts is to continue implementing flood mitigation projects in areas still affected by recurring floods. For example, a project at Sungai Bunus has recently been completed, and the Department of Irrigation and Drainage (DID) is currently working on new initiatives at Sungai Kuyoh and other critical locations. R1 emphasised that a long-term, basin-wide flood mitigation strategy is necessary to ensure sustainable protection against future flooding. Similarly, respondent R2 highlighted that, over the next five years, a master plan is being developed for diversion projects along Sungai Klang and Sungai Kuyoh, which will further strengthen the city's stormwater management system.

Beyond local initiatives, R1 also recommended adopting international best practices, specifically the Sponge City concept, which originated in China. This urban planning approach aims to reduce flood risks by enabling cities to function like natural sponges, absorbing, storing, and purifying rainwater rather than allowing it to overwhelm drainage systems. Unlike traditional urban areas with impervious surfaces, sponge cities incorporate green infrastructure such as rain gardens, green roofs, permeable pavements, and bioswales. These features allow water to infiltrate into the ground, reduce surface runoff, and improve water quality. By slowing down water flow and enhancing infiltration, sponge city elements like wetlands, retention ponds, and vegetated swales can help prevent downstream flooding while also providing ecological and aesthetic benefits. Integrated drainage systems, which combine traditional infrastructure with nature-based solutions, are key to the sponge city model and offer a comprehensive strategy for increasing urban flood resilience.

In addition to this, respondent R2 identified coastal reservoirs as another promising structural measure. Coastal reservoirs, located near shorelines, use natural coastal formations such as bays or estuaries to store water without the need for extensive damming. These structures offer benefits including a reliable water

supply, drought resilience, and potential for desalination, making them a strategic asset in managing both flood risks and water scarcity.

Respondent R4 added that increasing the allocation of green spaces in development plans is crucial for flood mitigation. She emphasised the importance of green lung projects and preserving trees and forests. Vegetated areas such as parks, gardens, and urban forests act as natural sponges, absorbing rainfall and reducing surface runoff. These spaces help to delay water discharge into drainage systems, thus preventing overload during heavy rains. Additionally, tree-lined streets and green zones contribute to soil stabilization, erosion control, and improved infiltration, further enhancing flood prevention capabilities.

From a maintenance perspective, respondents R3 and R4 stressed the need for strict enforcement of routine upkeep for existing infrastructure, particularly retention ponds. Regular maintenance including sediment removal, debris clearance, and pollution control is vital for preserving the pond's storage capacity and water quality. These actions help ensure that the infrastructure performs effectively during rain events and meets environmental regulations.

Lastly, R3 proposed constructing underground tunnels beneath roads and buildings, similar to systems used in Singapore. These drainage tunnels increase the capacity to channel stormwater away from urban surfaces, easing the burden on surface infrastructure and lowering the risk of urban flooding. Singapore's approach serves as a model for densely built cities like Kuala Lumpur, where space constraints require innovative, subterranean solutions. In conclusion, the insights from all four respondents underline that an effective flood mitigation plan for Kuala Lumpur must integrate ongoing structural projects, innovative international models like sponge cities, green infrastructure, regular maintenance, and adaptive planning. This holistic approach is essential to enhancing the city's resilience to future climate challenges and ensuring sustainable urban development. The result of this section was presented in Table 5.

Table 5: Strategies for reducing the flood impact in Kuala Lumpur

Theme/Respondent	R1	R2	R3	R4
Maintain flood mitigation efforts.	✓	✓		
Sponge City	✓			
Coastal Reservoir		✓		
Planning Provision for Green Areas			✓	
Carry out regular maintenance.			✓	✓
Structural measures in Singapore			✓	

Source: Authors (2025)

CONCLUSION

Flood mitigation strategies need to be improved since the flood's disaster has become a major problem in many countries. This research was guided by three key objectives: (1) to identify the current flood prevention plans in Kuala Lumpur, (2) to assess the effectiveness of these measures, and (3) to explore potential enhancements to further strengthen flood mitigation strategies. A semi-structured interview with the experts' engineers from the DID department discovers the current structural measures in Kuala Lumpur are dams, retention ponds, and the SMART Tunnel. Other measures such as green infrastructure and rainwater harvesting were also considered as prevention strategies. These findings align with prior studies (Ibrahim et al., 2020; Martinez et al., 2020) that the current implementation is integrated flood management. On the other hand, respondents highlighted that each structural measure plays a different role; their effectiveness varies depending on geographic location and implementation scale. Overall, it was found a combination of structural and non-structural solutions is necessary for comprehensive flood mitigation. Notably, some respondents considered dams to be the most effective, though this perception was recognized as subjective and context-dependent (Xia & Chen, 2021). Sustainable management practices such as rainwater harvesting further enhance the body of knowledge on urban flood resilience (Qi et al., 2019). These insights provided valuable directions for future improvements in Kuala Lumpur's flood management strategy.

The study contributes to both theory and practice by confirming the importance of integrated structural and non-structural measures and highlighting the relevance of emerging concepts such as the sponge city model, which offers a nature-based solution to the urban flooding challenge. It also clarifies misconceptions of MASMA's role, positioning it as a hybrid strategy encompassing both structural and emergency preparedness elements, thus extending the conceptual framework of flood mitigation planning in Kuala Lumpur.

Future research could incorporate quantitative data analysis and broader stakeholder engagement for a more comprehensive evaluation. Practically, this study implies that enhancing routine maintenance of existing infrastructure, expanding green urban spaces, and adopting international best practices such as coastal reservoirs and underground drainage tunnels are critical for improving flood resilience. Strategic planning should also emphasize basin-wide interventions across upstream, midstream, and downstream areas to ensure holistic management (Shahrulnizam et al., 2020).

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