Integrated Approach to Flood Risk Management: A Comprehensive Thematic Review in the Malaysia Context

Mohammad Syamsyul Hairi Saad[*a,1], **Mohamad Idris Ali**[a,2], **Putri Zulaiha Razi**[a,3], **Noram Irwan Ramli**[a,4], **Adi Setiabudi Bawono**[b,5]
[a]Faculty of Civil Engineering Technology, Universiti Malaysia Pahang, Malaysia
[b]Faculty of Science and Technology, Universitas Teknologi Yogyakarta, Indonesia

*Corresponding author: msyamsyulhairi@umpsa.edu.my

Abstract

This research addresses a need in the literature on flood risk management in Malaysia, particularly as it relates to development projects. Understanding and improving risk management strategies is crucial as Malaysian floods increase. A thematic literature review was used to search relevant 2018–2023 literature. It exhaustively searched scholarly databases, and government, and international organization reports. Multi-thematic analysis was used to understand the flood risk management narrative. The study shows that Malaysian flood risk management strategies need a more holistic and integrated approach. The development of an integrated framework is a significant step forward because it allows for the better coordination of developmental project initiatives with strategies meant to mitigate and manage flood risks. Effective collaboration between the federal government, Malaysian local authorities, urban planners, developers, and construction firms is crucial. Effective flood management requires accurate risk assessment by consultants, developers, and local authorities to integrate current and future development projects in flood-prone areas. Project development requires strategy, overview, and flood risk assessment in planning permission can produce creative and secure results.

Keywords: Flood Risk Management, Flood Management, Flood Risk Reduction, Integrated Flood Management, Disaster Management.

I. INTRODUCTION

According to the World Bank Group [1], floods are one of the most devastating natural disasters that Malaysia has ever experienced. They affect millions of people, the economy, and the fragile ecosystem of the country. Development projects have dramatically improved employment, GDP, infrastructure, and society's well-being; they are central to Malaysia's socioeconomic advancement [2]. Not only do these projects drive growth, but they are also crucial for managing and reducing disaster risks. One effective way to lessen the impact of climate-related disasters like tropical storms, landslides, and floods is to incorporate resilient design methods and materials into these projects [3]. Climate change is becoming an increasingly serious threat to Malaysia, making this preventative measure all the more important [4].

Flood Risk Management (FRM), is defined as the process of "identifying, assessing, and reducing the risk of flood damage to human life, health, property, and the environment"[5], is paramount for Malaysia's enduring growth and stability in the face of global climatic shifts [6][7]. FRM encompasses four pivotal steps: mitigation, preparedness, response, and recovery [8]. These measures draw upon both structural solutions, such as dams and levees, and non-structural strategies like land-use planning and insurance schemes. However, FRM in Malaysia is confronted with formidable challenges. These range from coordination gaps among agencies and stakeholders, ambiguous governance roles, and data insufficiencies concerning flood hazards, to dwindling public engagement and the heightened effects of climate change on flood patterns [9][10][11]. Recognizing these challenges necessitates a shift toward an Integrated Flood Risk Management (IFRM) approach. IFRM fosters an integrative methodology, aligning economic, social, and environmental facets of FRM while also emphasizing stakeholder involvement [12]. A cornerstone of IFRM is the Flood Risk Assessment (FRA), which aids in discerning and ranking FRM interventions.

While historically, Malaysia has leaned towards a primarily structural, top-down approach in FRM, the rising flood risks attributed to factors like climate change, urban sprawl, and deforestation underscore the need for a more encompassing strategy. Such a strategy should amalgamate non-structural measures and champion synergy among stakeholders across sectors and governance tiers. Thus, this study provides a comprehensive review of the prevailing FRM practices and knowledge in Malaysia, spotlighting salient gaps and potential avenues for enhancement. The overarching intent is to augment the scholarly discourse in this vital domain and galvanize awareness among researchers, policymakers, and the broader stakeholder community about the imperative for a holistic approach to FRM in Malaysia.

II. METHOD

This study employed a multi-stage approach to comprehensively review the literature on flood risk management in Malaysia. An exhaustive exploration of scholarly databases, including SCOPUS, and Google Scholar, along with reports from governmental and international organizations, formed the foundational stage of this research. The initial phase involved the careful selection of keywords, guided by predetermined research objectives. Keywords and phrases such as "flood risk management," "Malaysia," "flood risk strategies," "urban flooding," "flood resilience," and "flood risk mitigation" were chosen. Boolean operators (AND, OR, NOT) were applied to refine the search by combining or excluding specific keywords. Table 1 delineates the search methodology adopted for this investigation.

Table 1 Keywords for Literature Search

Keywords	Number of Articles
Flood Risk Management AND Malaysia	106
Flood Risk Management AND flood Risk Strategies AND Malaysia	101
Flood Risk Management AND urban Flooding AND Malaysia	*51*
Flood Risk Management AND flood Resilience AND Malaysia	55
flood risk management AND flood risk mitigation AND Malaysia	91

Articles from various sources are displayed in Figure 1. At first, the search was quite extensive, yielding 404 articles. A stringent screening process was implemented to assess these articles for relevance to the study's objectives. The initial review focused on the articles' titles and abstracts, after which full-text articles were scrutinized based on predefined inclusion and exclusion criteria. A quality assessment was conducted to evaluate the scientific rigor and validity of the studies that met these criteria. Data extraction was then undertaken for each of the qualifying studies, including their objectives, methodologies, findings, and implications.

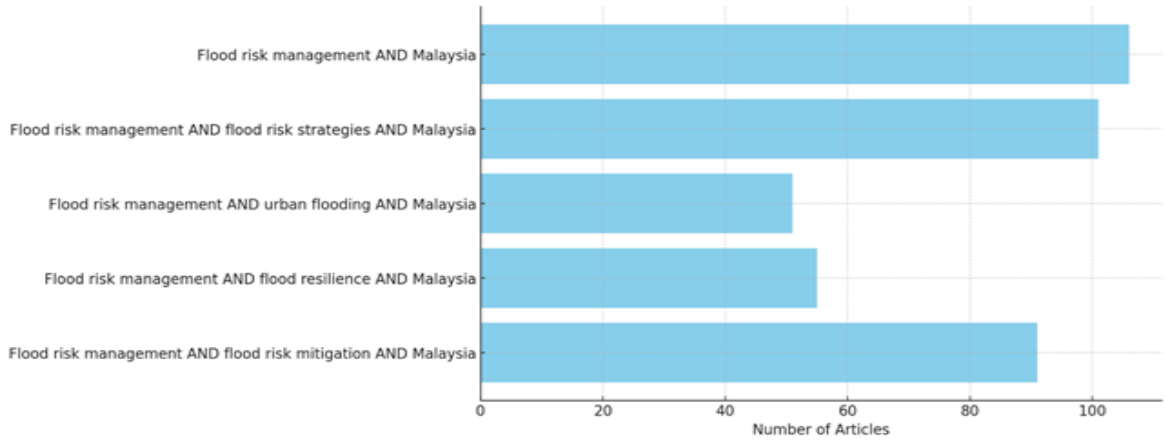

Figure 1 Number of Articles Related to Flood Risk Management in Malaysia

As a result of this selection procedure, 375 publications were disqualified for a variety of reasons, including preliminary results, a lack of relevance to the management of flood risk in Malaysia, inadequate data, or inaccessibility. According to the information presented in the following sections, the final corpus consisted of a total of 29 articles. The research approach that was utilized for this study is illustrated in Figure 2.

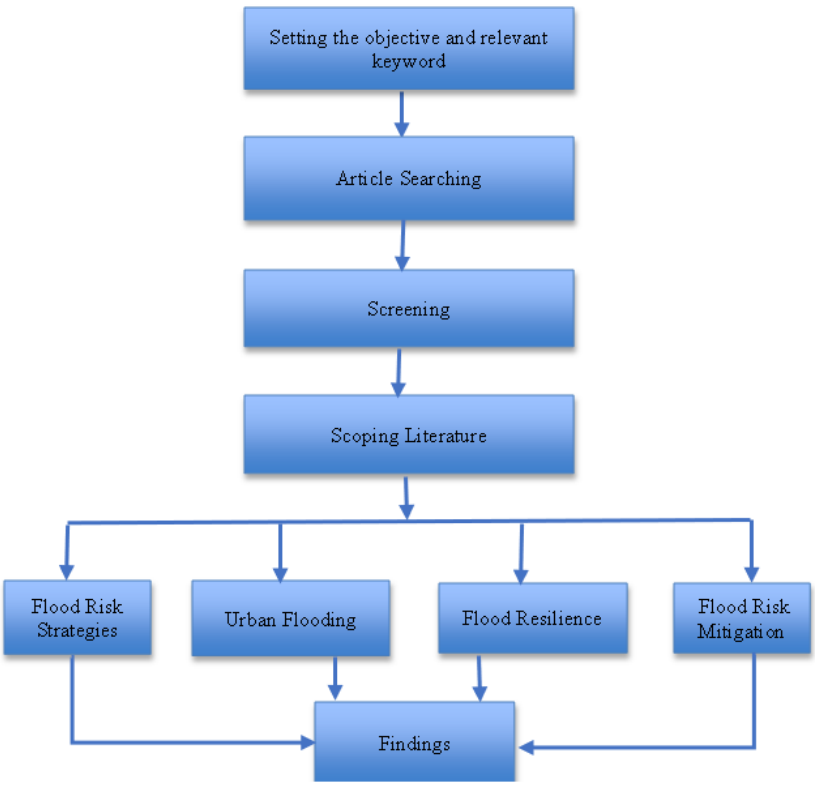

Figure 2 Research Methodology

III. RESULTS AND ANALYSIS

This section presents the principal findings of our analysis, followed by an in-depth discussion. The study underscores the complexity of flood risk management in Malaysia. Additionally, the resilience and adaptive capacities of various stakeholders are examined, highlighting their essential roles in effective flood risk management. Figure 3 summarizes the key conclusions drawn from the thematic review conducted for this study.

Figure 3 Type of Theme Discussed in the Literature

A. Theme 1: Challenges in Flood Risk Management

Flood risk management in Malaysia constitutes a multi-dimensional challenge that incorporates a range of interrelated issues. This section disentangles these complexities by presenting solutions advocated by experts in the field. Effective management of flood risk necessitates well-coordinated actions aimed at reducing the probability of flooding and its associated repercussions. Achieving this goal demands an amalgamation of short-term and long-term planning, infrastructural developments, awareness campaigns, and policy articulations.

Hashim et. al [13] argue that Malaysia must undertake definitive steps to alleviate the gravity of flood incidents within the country. Their perspective embodies a holistic approach, which considers not just the immediate ramifications of flooding, but also the potential long-term impacts. This reiterates the essentiality of proactive, long-term flood risk management strategies to mitigate the influences of both current and anticipated floods. The absence of a unified legal framework in Malaysia, that effectively encompasses flood management policies, is evident [14]. The existing legal and policy structures are identified as inadequate since municipal plans insufficiently integrate flood preparedness criteria. To bridge this gap, more robust legislative actions and the assimilation of preparedness protocols into local planning are imperative.

Various exacerbating factors, including inadequate drainage systems, unregulated urbanization, intense rainfall, public indifference, and a lack of interagency synergy, contribute to flood disasters in Sarawak [15]. This standpoint indicates an urgent need for enhanced flood risk management strategies, achievable via infrastructural improvements, greater public consciousness, and superior inter-agency cooperation. The research shows that rural regions of Malaysia are more prone to flooding compared to urban areas [16]. Utilizing vulnerability and risk indices, the uneven distribution of flood risk on a global scale is demonstrated, signaling the need for concentrated regional efforts to tackle these challenges in rural locales.

In summary, optimizing flood risk management in Malaysia requires a proactive, multi-dimensional strategy that includes comprehensive planning, a streamlined legislative framework, infrastructural advancements, and heightened public awareness and interagency collaboration. Furthermore, prioritizing areas most susceptible to flooding should be central to risk management initiatives. Together, these insights enrich our comprehension of the intricacies involved in flood risk management and emphasize the necessity for tailored nuanced approaches.

B. Theme 2: Measures in Flood Risk Management

Effective flood risk management necessitates the implementation of various strategies designed to both minimize the probability of floods and alleviate their consequences when they do occur. This section examines the perspectives of three researchers on the deployment and effectiveness of specific flood risk reduction techniques in Malaysia. These measures, whether aimed at decreasing the likelihood or the severity of floods, may be implemented as structural solutions such as flood barrier constructions and drainage system enhancements, or as non-structural approaches encompassing land-use planning and vulnerability analyses.

While flood reduction measures have found their way into Malaysian local plans [17], the authors emphasize the critical need to bolster disaster resilience initiatives, especially those oriented toward preparedness and adaptation. This perspective accentuates the importance of not just integrating measures but also fortifying their resilience and performance. It alludes to the imperative of ongoing scrutiny and enhancement of strategies, focusing primarily on the elevation of community capability to anticipate and adjust to flood incidents.

The efficacy of diverse flood risk mitigation techniques in the Segamat River Basin is explored [18]. The study identifies detention ponds as significantly more influential in flood reduction compared to other techniques, such as rainwater harvesting systems and permeable pavements. Liew's research elucidates that the efficiency of varied flood risk mitigation measures fluctuates considerably, underscoring the need for contextually tailored strategies.

Drawing upon a prior study by Ashikin et. al. [4], Ashikin's assessment of the vulnerability index reveals that Temerloh faces a heightened risk of flood-induced damages compared to its neighboring towns of Pekan and Kuantan. Additionally, her findings indicate specific food components are notably susceptible to water-related damage. For precisely targeted and effective flood risk management interventions, Ashikin accentuates the relevance of vulnerability evaluations in pinpointing susceptible populations and sectors.

Consolidating insights from Norizan, Liew, and Ashikin, the successful management of flood risk demands the application of a spectrum of techniques, meticulously tailored to specific regional nuances. Merely incorporating these measures into planning documents is insufficient; they must be robust, effective, and undergo periodic evaluations. Emphasizing the role of recurrent vulnerability assessments, their research points towards the necessity of both infrastructural and non-structural solutions in flood risk management, highlighting the significance of recognizing and addressing the distinct vulnerabilities of various sectors and communities.

C. Theme 3: Organisational and Institutional Challenges

The institutional and organizational facets are paramount in the management of environmental adversities, including floods. These facets not only influence the efficiency of response mechanisms but also govern the resilience of communities confronting flood hazards. Organizational and institutional challenges encompass obstacles inherent in bureaucratic architectures and systems, which impede the efficacy of policies and initiatives intended to address and alleviate flood-related risks.

A recent study underscores environmental exposure and socioeconomic determinants as principal factors rendering individuals in Malaysia more susceptible to flood impacts [18]. The researcher emphasizes the imperative to integrate these determinants into flood risk management strategies and advocates for comprehensive planning cognizant of the multifaceted nature of vulnerability. Constraints in authoritative capacity, shortcomings in enforcement powers, inadequate financial resources, and communication hindrances represent a few of the impediments encountered by flood management agencies in Malaysia [19]. Such challenges underscore the necessity for structural reforms aimed at amplifying the operational capabilities and efficacy of these agencies. Further, the research in Mabahwi et. al.[19] highlights a palpable dearth of inter-agency collaboration in the nation's flood management landscape. The researcher posits that successful flood risk management hinges not only on sufficient human and logistical resources but also on robust collaboration and coordination amongst diverse stakeholders. To mitigate these constraints, Romali and Yusop [20] propose a methodological framework tailored for flood damage and risk assessment in the town of Segamat, located in the state of Johor. The emphasis is placed on the identification of regions of vulnerability and the initiation of pre-emptive strategies to attenuate the repercussions of prospective flood events.

In synthesis, the discourse accentuates that organizational and institutional barriers are formidable detractors to proficient flood risk management in Malaysia. Consequently, it is of utmost importance to confront these barriers head-on, by augmenting the competence of pertinent entities, nurturing inter-agency collaboration, and endorsing a holistic approach to risk assessment frameworks. Adopting these modifications can potentially set the stage for Malaysia better fortified against escalating flood challenges.

D. Theme 4: Innovative Approaches for Flood Risk Management

In addressing the burgeoning challenges posed by flooding, innovative strategies in flood risk management have emerged as indispensable. These avant-garde methods harness technology, computational models, and bespoke strategies to enhance flood prediction, prevention, and management. Specifically, innovative approaches encapsulate the adoption of pioneering or unconventional methodologies, models, and technologies to comprehensively understand, evaluate, and mitigate flood-associated risks and ramifications.

Ziarh et. al. [21] employed a groundbreaking multi-criteria decision analysis to map flood risk across Peninsular Malaysia. Their research accentuated the pronounced vulnerability of coastal zones, emphasizing the exigency for specific interventions in such high-risk locales. Advocacy for flood insurance and the deployment of flood hazard maps has been suggested as a potent strategy to diminish monsoon flood-induced damages in Kota Bahru, Malaysia [22]. This initiative can bolster the financial preparedness of local communities, consequently diminishing the economic repercussions on the broader populace. Dano *et al* [23] introduced avant-garde tools such as Geographic Information Systems (GIS), the analytic network process, and remote sensing to assess flood vulnerability in Perlis, Malaysia. Their methodology astutely identifies highly susceptible zones, furnishing pivotal data for refining flood management protocols. Another examination of flood risk in the Kg. Kolopis region of Sabah, Malaysia, leveraged an AHP model merged with GIS software [24], underscoring the merits of amalgamating varied models to refine the precision of flood risk evaluations. Norhisham and Roslee [25] utilized a multi-criteria evaluation model to discern flood susceptibility in the Kota Kinabalu vicinity. Their inquiry pinpointed determinants such as slope gradient, elevation, and drainage distance as salient contributors to flooding, underscoring the essence of an all-encompassing grasp of these physical variables in flood risk management. Complementing this, Roslee and Norhisham [26] executed a flood hazard investigation in the Penampang region, shedding light on rainfall, land utilization, and soil texture as pivotal flood triggers. Lastly, Norhisham and Roslee [25] conducted a geohazard scrutiny in the Kota Kinabalu region utilizing a multi-criteria evaluation model. By encompassing both flood and landslide risks, their study extolled the merits of a multifaceted hazard analysis.

Flood risk management requires innovative methods, according to the findings. Innovative technologies, multi-faceted evaluation models, insurance paradigms, and inclusive geohazard appraisals can boost flood risk management plans. These innovative methods require strong institutional support, community participation, and sustainable financing to create a resilient flood management paradigm in Malaysia.

E. Theme 5: Multi-Stakeholder Involvement and Local Context Considerations

The pivotal role of multi-stakeholder participation, coupled with astute local context considerations, is paramount in flood risk management. A profound grasp of local community dynamics, stakeholder decision-making intricacies, and the distinct geographical and socioeconomic determinants that sway flood risk is indispensable for refining management frameworks. Multi-stakeholder involvement encompasses the concerted engagement of diverse entities, spanning local inhabitants, municipal bodies, and governmental institutions, in flood risk mitigation endeavors. Local context considerations pertain to the assiduous inclusion of region-specific geographical, socioeconomic, and cultural nuances during the formulation and execution of flood risk management measures.

Salleh & S Ahamad's flood risk assessment for Kelantan [27] exemplifies the profound utility of spatial analysis in the flood risk management realm. Their scholarly contribution accentuates the imperativeness of harnessing state-of-the-art technological methodologies for meticulous delineation of flood-susceptible zones. Advocating for robust community engagement in flood preparedness schematics, Shariff and Hamidi [28] underscore that the local populace, being intrinsic stakeholders, is instrumental in efficaciously managing and alleviating flood perils. In alignment with this perspective, Azimi *et. al.* [29] probed the decision-making paradigms of stakeholders embroiled in flood risk governance. The individual discovered that flood risk management is intricate and that stakeholder viewpoints are essential for decision-making frameworks. Building on this discourse, [30] embarked on an empirical inquiry into flood-vulnerable townships in the Johor precinct, shedding light on the resilience quotient of denizens and municipal entities during flood cataclysms. The findings accentuate the imperative for an inclusive stratagem, galvanizing all stakeholder cohorts, to bolster resilience and proficiently steward flood risk dynamics.

Summarizing the insights, multi-stakeholder operations, and local contextual understanding are essential for prudent flood risk management. Understanding stakeholders' roles and local geographical and socioeconomic factors can help design and implement effective flood management plans. Still, more research is needed to determine how to integrate these dimensions into a sustainable flood risk governance architecture for Malaysia.

F. Theme 6: Importance of Damage Assessment and Community Preparedness

In the realm of flood risk management, a rigorous comprehension of the prospective damage, allied with the emphasis on community preparedness, is indispensable for attenuating detrimental outcomes. Achieving flood resilience necessitates a nuanced strategy, interweaving damage appraisal, preventive interventions, readiness blueprints, and pioneering operational tactics. Damage assessment encapsulates the methodical evaluation of the tangible, societal, and fiscal repercussions stemming from floods. Concurrently, community preparedness pertains to the orchestrated deployment of tactics and blueprints at the communal tier to adeptly navigate and rebound from flood-induced calamities.

Romalia *et. al.* [31] foreground the primacy of flood damage quantification, advocating for the synthesis of a plethora of determinants to sculpt efficacious management paradigms. This proposition underscores the mandate for an encompassing perspective on prospective flood repercussions to proficiently curtail associated perils. A seminal inquiry [32] illuminates the centrality of proactive interventions and disaster readiness as quintessential facets of flood cataclysm governance in Malaysia. This academic endeavor accentuates the inextricable role of communal engagement in flood risk stewardship, epitomizing the essence of grassroots-driven disaster management strategies. In a complementary vein, Ishak and Hashim [33] elucidate the innovative precept of dam pre-release as a tactical modus operandi to mitigate flood ramifications. This scholarly contribution emphasizes the pertinence of astute dam governance predicated on precipitation dynamics and catchment area attributes, heralding a malleable stance towards flood risk management attuned to evolving meteorological scenarios.

Analysis of the literature shows that damage prognostication and community readiness are crucial to flood risk management paradigms. Most effective strategies combine technical expertise with social concerns. Communities are uniquely important in mitigation and readiness efforts. Experimental methods like dam pre-release require agile and evolutionary tactics. These stratagems must be seamlessly integrated into existing flood management constructs, requiring increased research and policy debate.

G. Theme 7: Flood Risk Assessment and Management Strategies

Effective flood risk assessment and management requires a thorough understanding of vulnerability factors, flooding causes, predictive methods, and flood category effects. This theme discusses early warning systems, rapid urban expansion, drainage infrastructure, hazard cartography, and flood classifications' complex effects. Flood risk assessment carefully evaluates flood-induced damages, including flood probability and population susceptibility. Meanwhile, management strategies are systematic interventions to reduce flood risks and impacts.

The salience of early warning mechanisms in flood risk management is elaborated upon in [4]. This study shows Malaysia's alarming lack of early warning systems, highlighting communities' vulnerability. Such an oversight underscores an exigent need to augment forecasting and disseminating capacities. Rapid urban sprawl, coupled with obsolete drainage designs, escalates the frequency of flash floods in Kuala Lumpur, as delineated in [34]. Advocacy for a synergistic application of structural and non-structural interventions to attenuate flood impact accentuates the imperative for an equilibrium confluence of infrastructural augmentation and policy recalibration. [35] delves into a rigorous critique of flood hazard cartographic techniques, asserting the supremacy of the statistical index method for demarcating zones with heightened flood vulnerability. Such an assertion amplifies the urgency for relentless innovation in flood projection and risk delineation methodologies. [36] embarks on a taxonomic examination of flood varieties and their distinct repercussions, accentuating the debilitating aftermath of the 2014 floods on both human lives and infrastructural assets. This analysis reiterates the pertinence of a nuanced comprehension of varied flood genres, fostering a customized flood management paradigm.

In conclusion, the literature provides a comprehensive view of flood risk and risk management in Malaysia. These insights reveal the cardinality of pre-emptive warning systems, effective drainage schematics, methodological precision in predictive frameworks, and a detailed understanding of flood typologies and implications. This highlights the need for a more integrated approach to flood risk management that integrates technology, infrastructure, policy frameworks, and social resilience. This domain may warrant increased research on early warning matrices, flood risk cartographic innovations, and flood morphology-specific strategies.

IV. Discussion and Further Studies

Malaysia's flood risk management literature is complex and multifaceted. Management of flood risks goes beyond infrastructure and drainage systems. A comprehensive approach requires strong policies, legislative frameworks, public education, inter-agency coordination, predictive tools, and hazard mapping. We must also acknowledge localized factors like urban flood risks, environmental exposure, and socioeconomic factors that increase flood vulnerability. GIS and flood hazard and susceptibility models have been shown to improve flood risk management [22] [37]. Developing advanced predictive tools and flood hazard maps is still possible. Financial tools like flood insurance may mitigate flood damage.

Considering the findings presented in Figure 4, which were gleaned from the previous research, potential directions for further investigation include the following:

Figure 4 Findings of the Research

The Malaysian urbanization increases flood risk management challenges. Investigating the delicate balance between urban growth and flood patterns is crucial. We chose seven themes to show how natural disasters and human strategies interact. This discussion illuminates these themes' relationships and possible solutions. Malaysia's approach to assessing urbanization's effects on flood risk and updating its policy framework must be

changed soon. Flood risk management is complicated. Changes in climate and land use are altering the hydrological cycle, increasing flood frequency and intensity [17]. Knowing the delicate balance between urban growth and flooding is crucial.

The research underscores the demand for a cohesive, integrated flood risk assessment framework, as depicted in Figure 5. It is critical to incorporate flood risk mitigation and management into development projects. The process of formulating policies is intricate and involves numerous parties and considerations, all of which must be carefully considered.

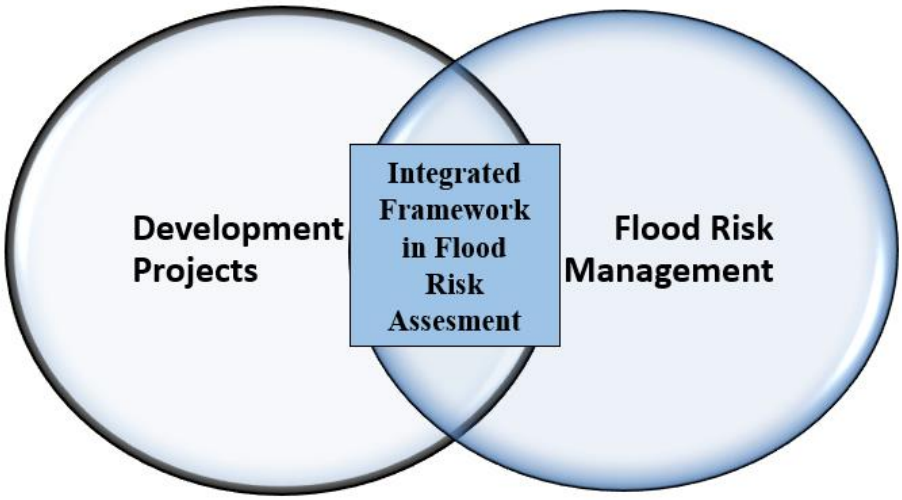

Figure 5 Concept Illustrated for Integrated Framework in Flood Risk Assessment

The research presented here builds upon the foundational understanding set in the introduction, advancing the discourse on the necessity for an encompassing flood risk management strategy in Malaysia. By exploring the interconnection between development and flood risk, this study not only identifies the gaps in current practices but also offers a vision for a holistic management approach. This entails a collaborative effort across multiple sectors and governance levels, ensuring that policy development and implementation are informed by a deep understanding of the socio-economic and environmental landscapes.

V. CONCLUSION

This study fills a significant void in the existing research on flood risk management in Malaysia by highlighting the necessity of an integrated approach that considers the complex nature of flood risks. It highlights the significance of integrating physical, social, economic, and policy aspects to create successful and enduring flood management strategies. Indeed, the results of this study indicate a need for a cooperative strategy involving the federal government, local authorities, urban planners, and developers to collaborate closely. This synergy is crucial for understanding the subtle effects of development on flood patterns and for creating tailored solutions that consider both development requirements and flood risk management.

The proposed integrated framework for flood risk management represents a significant leap forward in addressing the complexities of managing flood risks in the context of rapid urbanization and climate change. It suggests a paradigm shift towards incorporating flood risk assessment into the early stages of planning and development processes, thereby ensuring that new projects enhance, rather than endanger, the community's resilience to floods. Thus, this present study contributes to the goal of sustainable development by promoting a more thorough understanding and approach to flood risk management. Ongoing innovation, validation of advanced predictive models, and commitment to creating resilient, sustainable, and inclusive societies are necessary to address challenges posed by flooding and other climate-related disasters.

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