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# Damages And Losses On Critical Infrastructure From Flooding In Kajang Using PLS-SEM

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**Abstract:** The recurring floods in Kajang, a sub-district of Hulu Langat, Selangor, have significantly affected its critical infrastructure. This study aims to identify the factors and challenges involved, and establishing comprehensive strategies to mitigate the damages and losses experienced by Kajang's critical infrastructure. Using purposive sampling and the G*Power Calculator, a recommended sample size of 43 respondents was determined. Out of these, 36 completed questionnaire surveys were returned, yielding an 84% response rate. Most respondents were aged 26-35, with over 16 years of residency in Kajang. The data collected were analyzed using PLS-SEM, which included Reflective and Formative Path Modeling Analysis, as well as Reflective (Convergent and Discriminant Validity) and Formative Measurement Model Analysis. The results indicated that infrastructure vulnerability is a significant factor contributing to damage and losses. Furthermore, the absence of comprehensive risk assessment and management was identified as a major challenge. Integrating land use planning emerged as a highly effective strategy for enhancing flood resilience in Kajang's critical infrastructure. The findings of this paper are expected to provide valuable insights for policymakers and relevant stakeholders, particularly in evaluating the viability and risk of infrastructure in various localities.

**Keywords:** Flooding; Kajang; Critical Infrastructure; Damages and Losses; and Flood Resilience

## 1. Introduction

Floods, as natural hazards, significantly threaten the resilience and sustainability of critical infrastructure worldwide. Their recurrence, especially due to unpredictable monsoons, causes extensive flooding and severe annual damage [1], [2].

Department of Statistics Malaysia has analyzed the impacts of floods that occurred in Malaysia in 2021. The findings disclosed that economic damages caused by these floods were RM6.1 billion, which equates to 0.40 percent of nominal Gross Domestic Product. Selangor emerged as the state with the most substantial losses, incurring expenses totaling RM 3.1 billion. Among the worst-hit districts, Klang, Petaling, and Hulu Langat recorded the highest damages, amounting to RM 1.2 billion, RM 1.1 billion, and RM 0.4 billion, respectively. Hence, this article focuses on Kajang, a sub-district of Hulu Langat due to its recurrent vulnerability to floods over several decades.

### 1.1 Definition of Flooding, Critical Infrastructure, Damages and Losses and Flood Resilience

Floods are a major natural hazard causing extensive damage and loss across various sectors. Flooding occurs when water rises and overflows onto typically dry land, often due to storms, tidal actions, blockages, or melting ice, which affects critical infrastructure systems [3].

Critical infrastructure, which includes both physical systems (like electricity, water supply, transportation, and communication) and socio-economic elements (such as healthcare and education), is vital for community and economic stability [4]. The management of these infrastructures—whether public or private—affects their resilience to floods. For instance, privately managed infrastructures may have different maintenance practices that influence their vulnerability during disasters.

Floods cause significant damages and losses, which can be divided into economic and non-economic categories [5]. Economic losses include the depletion of tangible assets, income loss, infrastructure damage, and property-related issues. Conversely, non-economic losses encompass human impacts such as loss of life and health, societal losses like the erosion of cultural heritage, territorial loss, and the degradation of indigenous knowledge.

Resilience is crucial for mitigating the impacts of floods and other hazards. Originating from Latin, resilience refers to the ability to bounce back or recover [6]. It describes the capacity of systems and communities to withstand, adapt to, and quickly recover from hazards while maintaining essential functions through effective risk management [7]. Resilience is beneficial when it fosters adaptation and learning, ultimately enhancing sustainability in the face of flooding and other threats [8].

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### 1.2 Factors Contributing to Damages and Losses

Increased rainfall intensity, measured in millimeters per hour, significantly contributes to flood-related damages and losses[3]. Climate change has altered rainfall patterns, resulting in more frequent and intense precipitation events, particularly in Malaysia [9]–[11]. For example, the devastating floods in December 2014 affected over 200,000 people, caused 21 fatalities, and led to damages exceeding RM 1 billion [1], [12].

Flood duration, or the time an area remains submerged, is crucial as it directly correlates with the severity of impacts [13]. In Malaysia, two primary types of floods are observed: monsoon floods and flash floods[1], [9]. Monsoon floods are characterized by their prolonged duration, lasting over a week, with a slow onset and a gradual rise in water levels, typically occurring seasonally during the monsoon seasons. Meanwhile, flash floods resulting from intense rainstorms recede rapidly within a few hours and are not tied to specific seasons. Understanding these types is vital for disaster management, as longer-duration floods require more resources and longer recovery times.

Flood depth is another critical factor affecting damage and losses. Greater water depths indicate larger volumes inundating an area, causing extensive damage [13]. This, combined with water velocity, can result in substantial destruction, similar to shallow water with high velocities [14]. Therefore, considering both flood depth and velocity is crucial when assessing flood-related risks and planning mitigation strategies.

Additionally, the vulnerability of infrastructure—such as roads, railways, and bridges—impacts mobility and safety during floods. If these systems are compromised, the communities that rely on them are also affected [15]. In urban areas like Kuala Lumpur, Selangor, and Kelantan, flooding causes have expanded beyond natural events [2]. Frequent flash floods in these areas are often due to inadequate drainage systems and rapid urbanization, increasing their vulnerability and posing challenges for disaster management and urban planning.

Flooding has significant socio-economic impacts, including loss of lives, property damage, reduced purchasing power, and hindrances to economic growth and development [9], [16], [17]. The post-disaster effects are particularly severe for uninsured communities, as property loss and decreased quality of life hinder recovery. Factors such as age and mental health also play a role in post-flood recovery, highlighting the need for targeted mitigation strategies [1].

### 1.3 Challenges in Managing Damages and Losses

Aging infrastructure presents significant challenges in flood management due to its increasing vulnerability. As infrastructure ages, it becomes more susceptible to flood impacts, especially with changing weather patterns[18], [19]. Older structures, typically over 20 years old, are particularly vulnerable due to outdated flood protection measures and material deterioration, increasing the risk of failures like building collapses [20], [21]. Hence, aging infrastructure poses significant risks during flooding events due to its weakened state.

The rapid growth of diverse infrastructures has led to greater interdependence [22], [23]. For example, healthcare facilities depend heavily on consistent water, power, communication, and transportation for effective patient care and emergency coordination [24]. Managing this interdependence is essential for improving resilience in healthcare and emergency response systems.

Challenges in land use planning, such as permit delays, regulatory non-compliance, uncontrolled land conversion, and poor enforcement, lead to construction in flood-prone areas [25]. Neoliberal priorities can worsen these issues by favoring profit over sustainability and disaster resilience [26]. Thus, sustainable land use planning is vital for mitigating vulnerabilities.

The lack of funding and resources directly affects disaster preparedness, including infrastructure, equipment, training, and community outreach [27]–[30]. Outdated emergency services equipment limits response capabilities, while financial constraints impede training programs for responders and community preparedness efforts. Addressing these funding gaps is crucial for enhancing disaster readiness, especially in flood-prone areas.

The lack of comprehensive risk assessment and management significantly impacts flood resilience and response efforts [31]. This process involves identifying, evaluating, and managing flood risks, providing crucial information for decision-making by governments, city planners, emergency responders, and the public. In Malaysia, authority conflicts among agencies lead to inefficient resource allocation, hindering flood prevention projects and victim assistance[11]. Moreover, lacking a clear risk management plan creates coordination challenges during floods, resulting in delayed responses and greater impacts on communities.

### 1.4 Strategies for Flood Resilience of Critical Infrastructure

Flood management includes two main approaches: structural and non-structural measures [32]. Structural measures include physical solutions like levees and reservoirs, as seen in projects like the SMART project in Kuala Lumpur [11] and along the Kelantan River [33]. Non-structural measures focus on preventive approaches such as policies, public awareness campaigns, training, and educational initiatives to reduce flood risks [34]. For or example, the Kuala Lumpur Multi-Hazard Platform uses innovative tools for hazard mapping and emergency planning. [11]. Well-planned structural measures can reduce flood risks, but their success relies on public cooperation [35]. Non-structural measures are proactive and cost-effective, helping communities respond better during floods and minimizing losses. These measures involve active engagement of individuals, including flood victims, across all stages of the flood disaster cycle.

Integrating land use planning into flood risk management is crucial for proactive flood resilience [36]. This approach emphasizes planning and regulating land use to minimize flood risks, rather than reacting after floods occur. Strict land-use regulations are needed to prevent risky developments in flood-prone areas [37]. For instance, allowing only flood-resilient activities, like parks or parking lots [34] can significantly reduce flood damage.

Emergency response and recovery planning is essential for managing flash floods in three phases: before, during, and after disasters [38]. The pre-disaster phase emphasizes preparations and organizational readiness to respond effectively. Collaboration among various entities is vital during the disaster phase to ensure safe evacuation and sheltering. Post-disaster efforts focus on cleaning, repairing, and restoring affected areas, including public infrastructure. In Malaysia, the National Disaster Management Agency (NADMA) coordinates disaster management and should review flood plans for better efficiency, especially at the local level where immediate response is critical [11].

Education and awareness programs help communities prepare for floods and build resilience. Empowering people during disasters encourages them to follow safety guidelines [11]. These programs align with the Sendai Framework for Disaster Risk Reduction, which aims to improve disaster knowledge for lasting resilience [39]. Various teaching methods around the world make disaster education effective. In Malaysia, Collaboratory uses innovative approaches in elementary schools, like the "Waste Management Awareness Programme: Me & Climate Change," which involves students in hands-on activities and online games to learn about climate change and flooding. They also partner with government agencies, NGOs, and local groups for programs like "Sentuhan Kasih: Disaster Relief," helping communities support first responders during disasters, which speeds up response times and improves effectiveness. Overall, these education programs equip individuals with the skills to understand and respond to flood risks, fostering resilient communities and better disaster management.

Cooperation among sectors is crucial in effective disaster management. This collaboration optimizes resources, minimizes redundancy, and fosters team cohesion, achieving results difficult for a single entity to attain alone [40]. The Sendai Framework's Priority 2 underscores the importance of disaster risk governance and coordination within and between sectors. In Malaysia, collaboration among Disaster Management Organizations (DMOs) is vital. The Department of Social Welfare (JKM) provides essential supplies, helps register victims, and offers support services. Meanwhile, the Ministry of Finance allocates funds and creates policies to streamline financial processes during emergencies. By collaborating across government agencies, NGOs, private sectors, and communities, Malaysia's flood management strategy demonstrates the effectiveness of a unified approach. This teamwork strengthens community resilience and improves disaster response capabilities, ensuring a more effective response to floods and other disasters.

### 1.5 Description of Study Area

According to DID's 2021 Annual Flood Report, Malaysia experienced extensive flooding, affecting various states, with Selangor being one of the hardest hits. The report documented a total of 120 flooding incidents throughout the year 2021, encompassing a range of flood types. Among these, there were 10 instances of monsoon floods, 102 cases of flash floods, and 8 coastal floods. One notable flood event mentioned in the report occurred in Kajang, a populous town in Selangor.

Referring to the Majlis Perbandaran Kajang (MPKj) Selangor Local Plan 2035 (Replacement) Report, Kajang is included in the jurisdiction of the MPKj. It has covered an area of 9,298 hectares, constituting 11.81% of the total land area. The population estimate in Kajang in the year 2020 was approximately 433,300 people with a growth rate of 1.14% [41]. The predominant land use categories in Kajang encompass residential, commercial, industrial, infrastructure, community facilities, and open spaces [42].

Kajang, located at an elevation of 28 m above sea level, experiences a tropical climate [9]. With an average temperature of 25.7°C and annual precipitation of 2960 mm [43], the region is susceptible to flooding, especially during periods of heavy rainfall or monsoon seasons.

### 1.6 Flooding Issues in Kajang

The issue of flooding in Kajang has been a persistent challenge since the 1970s [44]. Flash floods are a common occurrence, with houses along rivers being submerged up to the roof level. Kajang experienced notable flood events in various years including 1971, 1987 and a particularly devastating event took place in December 2011, where the flood caused damages amounting to an estimated RM2.4 million [9]. Appendix A and Appendix B showing the extent of the flooding.

Furthermore, it is reported three flood events in 2014, resulting in the submersion of roughly half of Kajang Town in floodwaters [10]. Water levels reached around 2 m in certain areas, leading to a severe situation. Many shops lots have been inundated by water, cars are floating, and roads are submerged. The consequential losses were substantial, estimated at approximately RM150, 000 per event.

Moreover, floods have been a recurring event in Kajang as documented in the DID's Annual Flood Report 2021 and the Malaysian Flood Report by DID. In 2008, one person died as a result of the prolonged heavy rain on August 27, which lasted for two hours. While on October 15, flooding occurred as a result of the culvert being clogged with garbage. This obstruction hampered water flow, contributing to flooding and potential infrastructure damage. In July 2020, the Langat River faced a critical situation as its water level exceeded the danger threshold. This occurrence led to the overflow of water into nearby areas, specifically affecting the residents of Kg Sungai Sekamat. The consequences were severe, necessitating the relocation of 40 houses in response to the flooding.

Meanwhile in 2021, the Langat River again surpassed its danger level. The Langat River's incapacity to effectively manage the increasing water volume resulted in the upstream river, namely the Jelok River, resuming its flow and subsequently overflowing into residential areas. This, in turn, resulted in flooding for the residents of Taman Sungai Jelok. Furthermore, on May 5, 2021, surface water from Sulaiman Road and Tun Abdul Azizi Road overflowed into the Metro Kajang basement parking area. This event had severe consequences as vehicles, including cars and motorcycles, were unable to be rescued in time and became submerged in the flood.

These events collectively underscore the recurring and severe nature of flooding in Kajang, indicating the need for comprehensive flood management strategies and infrastructure improvements to mitigate future damages and ensure the safety and well-being of residents.

## 2. Research Method

### 2.1 Sampling Technique and Data Collection Method

Purposive sampling was chosen for this study, wherein participants are selected based on specific criteria relevant to the research questions or objectives. The sample size of 43 respondents was determined through analysis using G*Power Calculator.

Data collection is conducted through a questionnaire survey distributed via Google Form to obtain pertinent information directly from primary data sources in the Kajang area. These respondents include individuals from the service sector (such as retail and hospitality), students, and business owners, as well as professionals like engineers, doctors, and teachers.

### 2.2 Data Analysis

Following the collection of survey data, thorough statistical analysis is performed using Partial Least Squares Structural Equation Modeling (PLS-SEM). It is useful for small sample sizes, non-normal data, and complex models with both formative and reflective constructs. The analysis includes:

a. *Path Modeling Analysis*: This technique analyzes relationships between variables in a structural equation model, examining causal relationships between latent constructs and their indicators[45].

b. *Measurement Model Analysis*: This assesses the measurement properties of the constructs in the model. It evaluates factor loadings, indicator reliability, convergent validity, and discriminant validity to ensure the reliability and validity of the measures [22]. Table 1 presents rules of thumb for assessing reflective measurement models.

**Table 1 - Rules of Thumb for Assessing Reflective Measurement Models** [46]–[50]

| Criterion | Recommendation/Rules of Thumbs/Thresholds |
|---|---|
| Indicator loadings (factor loadings) | Not applying Cronbach's alpha; use composite reliability (CR) ≥ 0.708 |
| Internal Consistency Reliability (indicator reliability) | 1) Standardized indicator loadings > 0.70; in exploratory studies, loadings of 0.40 are acceptable<br>2) Minimum 0.70 (or 0.60 in exploratory research)<br>3) Recommended 0.80 to 0.90<br>Maximum of 0.95 to avoid indicator redundancy, which would compromise content validity |
| Convergent Validity | Average variance extracted (AVE) ≥ 0.50 |
| Discriminant Validity<br>1) Cross-loadings<br>2) HTMT | 1) Each indicator should load highest on the construct it is intended to measure<br>2) For conceptually similar constructs: HTMT < 0.90<br>For conceptually different constructs: HTMT < 0.85 |

These rules of thumbs serve as essential benchmarks for assessing the quality and reliability of reflective measurement models, ensuring their robustness in accurately capturing intended constructs and their corresponding indicators. Table 2 presents rules of thumb for assessing formative measurement indicators.

**Table 2 - Rules of Thumb for Assessing Formative Measurement Indicators** [51]

| Criterion | Rules of Thumbs/Thresholds |
|---|---|
| Convergent validity | ≥ 0.70 correlation |
| Multicollinearity | VIF ≤ 5 |

These rules of thumbs provide valuable recommendations for evaluating the quality of formative measurement indicators, emphasizing key aspects that contribute to the overall robustness and validity of formative measurement models. The considerations for this assessment is multicollinearity.

## 3. Result and Discussion

### 3.1 Demographic Analysis

The data for this analysis has been obtained from a diverse group of participants in the Kajang area, including individuals employed in the service sector (e.g., retail and hospitality), students, business owners and also professionals such as engineers, doctors, and teachers (n = 43). 36 participants successfully completed and submitted their data, resulting in a high submission rate of 84%. This robust submission rate indicates a strong level of cooperation and engagement within the sample group.

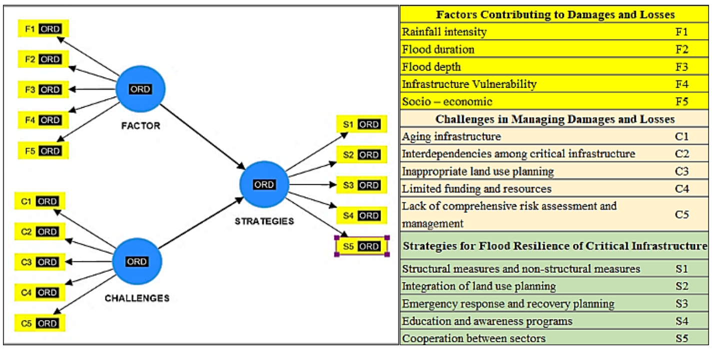
This level of participation provides confidence in the validity and generalizability of the data, supported by prior research such as the study conducted by Oliveri et al. (2004), where 60% (n = 225) of respondents participated out of n = 376 [52]. Therefore, the available data is considered adequate for this analysis.

The study reveals a predominant age group, with the majority falling within 26-35 years. This trend is attributed to the heightened awareness of current issues among individuals in this age range, facilitated by their increased access to technology. Meanwhile, the professional group emerges as the largest occupational category, signifying their high level of knowledge and understanding of the objectives of this survey. Furthermore, a significant portion of respondents has maintained residency in the area for 16 years or more, underscoring their heightened awareness of local conditions and issues.

### 3.2 Path Modelling Analysis

In this analysis, variables are labelled as factors (F1 to F5), challenges (C1 to C5), and strategies (S1 to S5), representing elements within the studied system. Figure 1 illustrates the directional relationships among these variables, demonstrating how they influence each other and providing insights into causal connections.

Additionally, Table 3 offers a comprehensive summary of results for all variables, outlining the strength and nature of their relationships within the model. It enables researchers to uncover unique interactions and effects within the system, leading to a more profound understanding of its complexities.



| Factors Contributing to Damages and Losses | |
|---|---|
| Rainfall intensity | F1 |
| Flood duration | F2 |
| Flood depth | F3 |
| Infrastructure Vulnerability | F4 |
| Socio – economic | F5 |
| **Challenges in Managing Damages and Losses** | |
| Aging infrastructure | C1 |
| Interdependencies among critical infrastructure | C2 |
| Inappropriate land use planning | C3 |
| Limited funding and resources | C4 |
| Lack of comprehensive risk assessment and management | C5 |
| **Strategies for Flood Resilience of Critical Infrastructure** | |
| Structural measures and non-structural measures | S1 |
| Integration of land use planning | S2 |
| Emergency response and recovery planning | S3 |
| Education and awareness programs | S4 |
| Cooperation between sectors | S5 |

**Fig. 1 - Directional Relationships among Variables**

**Table 3 - Result of Path Modelling Analysis**

| | Item | Direction of causality | Characteristics of item | Verdict |
|---|---|---|---|---|
| Factors Contributing to Damages and Losses | | | | |
| Rainfall intensity | F1 | Arrow pointing from | Each item adequately reflects the | Reflective |
| Flood duration | F2 | | | |
| Flood depth | F3 | | | |

| | | | | |
|---|---|---|---|---|
| Infrastructure Vulnerability | F4 | construct to item | intended construct | |
| Socio – economic | F5 | | | |
| Challenges in Managing Damages and Losses | | | | |
| Aging infrastructure | C1 | Arrow pointing from construct to item | Each item adequately reflects the intended construct | Reflective |
| Interdependencies among critical infrastructure | C2 | | | |
| Inappropriate land use planning | C3 | | | |
| Limited funding and resources | C4 | | | |
| Lack of comprehensive risk assessment and Management | C5 | | | |
| Strategies for Flood Resilience of Critical Infrastructure | | | | |
| Structural measures and non-structural measures | S1 | Arrow pointing from construct to item | Each item adequately reflects the intended construct | Reflective |
| Integration of land use planning | S2 | | | |
| Emergency response and recovery planning | S3 | | | |
| Education and awareness programs | S4 | | | |
| Cooperation between sectors | S5 | | | |
| Strategies | | Arrow pointing from item to construct | Item are influencing or shaping the construct. | Formative |

The Path Modeling Analysis results indicate a combination of both Reflective and Formative approaches. Reflective relationships, shown by arrows from constructs to items, signify a strong connection where each item, such as rainfall intensity (F1), aging infrastructure (C1), and structural measures (S1), accurately reflects the underlying construct. This ensures reliable measurements aligned with the intended construct, enhancing the analysis's validity.

Conversely, arrows from items to constructs signify a formative relationship, where each item actively shapes the underlying construct. For example, changes in items related to flood duration (F2) or socio-economic factors (F5) can significantly impact the definition of damages and losses. Understanding these formative relationships adds depth to the analysis, acknowledging that items are dynamic contributors shaping the construct.

This comprehensive approach, integrating both Reflective and Formative aspects, leads to meaningful and consistent insights, ultimately enhancing the credibility and robustness of the research findings.

## 3.3 Measurement Modelling Analysis

### 3.3.1 Reflective Measurement Model

The findings displayed in Figure 2 illustrate the reflective measurement model, focusing on convergent and discriminant validity.

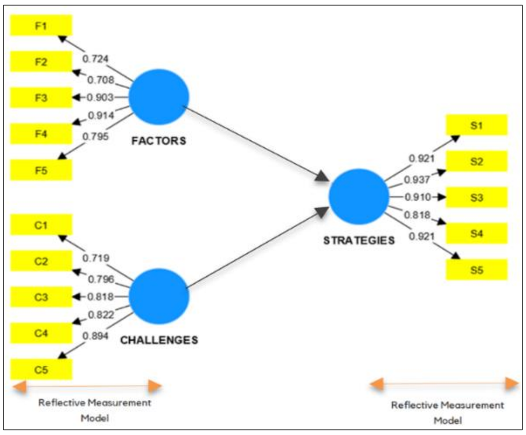


**Fig. 2 - Reflective Measurement Model**

#### 3.3.1.1 Convergent Validity

Based on Table 4, analysis of the factor loadings column, it unanimously all the item surpassing or equal to the threshold of 0.708. This indicates a strong and robust relationship between these items and the construct. The item reliability score within the threshold signifies a reasonable level of internal consistency. This reliability metric provides confidence in the stability and coherence of the construct's measurement, bolstering the overall reliability of the analytical model.

AVE value being above the 0.50 threshold. It indicates good convergent validity, suggesting that the observed variables in the model effectively converge or measure the intended latent construct.

**Table 4 - Result of Convergent Validity**

| | **Item** | **Factor Loadings ≥ 0.708** | **Indicator Reliability Min 0.70 Max 0.95** | **AVE ≥ 0.50** |
|---|---|---|---|---|
| Factors Contributing to Damages and Losses | | | | |
| Rainfall intensity | F1 | 0.724 | 0.906 | 0.662 |
| Flood duration | F2 | 0.708 | | |
| Flood depth | F3 | 0.903 | | |
| Infrastructure Vulnerability | F4 | 0.914 | | |
| Socio –economic | F5 | 0.795 | | |
| Challenges in Managing Damages and Losses | | | | |
| Aging infrastructure | C1 | 0.719 | 0.906 | 0.659 |
| Interdependencies among critical infrastructure | C2 | 0.796 | | |
| Inappropriate land use planning | C3 | 0.818 | | |
| Limited funding and resources | C4 | 0.822 | | |
| Lack of comprehensive risk assessment and Management | C5 | 0.894 | | |
| Strategies for Flood Resilience of Critical Infrastructure | | | | |
| Structural measures and non-structural measures | S1 | 0.921 | 0.941 | 0.814 |
| Integration of land use planning | S2 | 0.937 | | |

| | | |
|---|---|---|
| Emergency response and recovery planning | S3 | 0.910 |
| Education and awareness programs | S4 | 0.818 |
| Cooperation between sectors | S5 | 0.921 |

***Factors Contributing to Damages and Losses***

The analysis indicates that infrastructure vulnerability (F4) stands out as the predominant factor, demonstrating a robust correlation coefficient of 0.914. This underscores that the vulnerability of infrastructure, such as buildings, bridges, and other critical components, significantly amplifies the impact of floods, leading to heightened damages and losses.

The factor of Flood depth (F3) with a noteworthy correlation coefficient of 0.903. This specific focus on flood depth highlights its crucial role in exacerbating the consequences of flooding. Deeper floods correlate strongly with increased damage, emphasizing the need for strategies that consider and mitigate the effects of varying flood depths.

Furthermore, the socio-economic factor (F5) emerges as a significant contributor, showcasing a correlation coefficient of 0.795. This indicates that societal and economic aspects, such as population density, economic activities, and community resilience, play a substantial role in influencing the overall impact of floods. Understanding the socio-economic dynamics becomes imperative for developing comprehensive flood mitigation plans that address both physical and societal vulnerabilities.

***Challenges in Managing Damages and Losses***

Three significant hurdles have come to the forefront. Foremost among them is the “Lack of comprehensive risk assessment and management” (C5) with a substantial correlation coefficient of 0.894. The high correlation coefficient suggests that the lack of a thorough risk assessment and effective management framework is a major impediment. This implies that without a comprehensive understanding of potential risks and a well- defined strategy for managing them, efforts to mitigate damage and losses are likely to be less effective. Addressing this challenge involves implementing robust risk assessment protocols and establishing proactive management practices.

Additionally, “Limited funding and resources” (C4) emerges as a noteworthy challenge, revealing a correlation of 0.822. The substantial correlation indicates that a shortage of financial and operational resources poses a significant challenge. In practical terms, this could hinder the implementation of preventive measures, timely responses, and the overall resilience of systems. To overcome this challenge, strategies for securing additional funding, optimizing resource allocation, or seeking alternative solutions should be explored.

The third identified challenge is “Inappropriate land use planning” (C3), marked by a correlation coefficient of 0.818. Poorly planned land use can exacerbate the effects of natural events, contributing to increased vulnerability. Mitigating this challenge involves enhancing land use planning processes, considering environmental factors, and ensuring that developments are resilient to potential hazards.

***Strategies for Flood Resilience of Critical Infrastructure***

The analysis unveils key insights into effective measures. The integration of land use planning (S2) emerges as a highly impactful strategy, displaying a substantial correlation coefficient of 0.937. This underscores the critical role of thoughtful and integrated land use planning in bolstering the resilience of critical infrastructure against floods. Effective land use planning can mitigate the vulnerability of infrastructure by strategically locating and designing structures in flood-prone areas.

Structural and non-structural measures (S1) present another significant strategy with a noteworthy correlation coefficient of 0.921. This suggests that a combination of physical infrastructure enhancements (such as dams or levees) and non-physical strategies (such as early warning systems or community education) collectively contributes to increased flood resilience for critical infrastructure.

Additionally, the cooperation between sectors (S5) stands out as a vital strategy, demonstrating a correlation coefficient of 0.921. This emphasizes the importance of collaboration and communication across various sectors, such as government agencies, private industries, and community organizations. A coordinated effort among different sectors enhances the overall effectiveness of flood resilience strategies.

#### 3.3.1.2 Discriminant Validity

**Table 5 - Result of Heterotrait-Monotrait (HTMT) Ratio**

| | Heterotrait-Monotrait (HTMT) Ratio |
|---|---|
| Factors <-> Challenges | 0.717 |
| Strategies <-> Challenges | 0.786 |
| Strategies <-> Factors | 0.667 |

Based on Table 5, all the HTMT ratios are below the threshold of 0.90, indicating satisfactory discriminant validity between conceptually similar constructs. Adhering to the rule of thumb for conceptually different constructs (HTMT < 0.85), these ratios comfortably meet this criterion as well. The findings suggest that the "Factors," "Challenges," and "Strategies" constructs are reasonably distinct from each other, supporting the validity of the measurement model.

### 3.3.2 Formative measurement model

#### 3.3.2.1 Multi Collinearity

**Table 6 - Results of Formative Measurement Model**

| Formative indicator | Multi- collinearity VIF (≤ 5.00) |
|---|---|
| Factor | 1.728 |
| Challenges | 1.728 |

Based on Table 6, the provided VIF values for "Factor" and "Challenges" are both below the recommended threshold value is less than 5.00. It suggests that the formative indicators within these constructs are not highly correlated with each other. The absence of high correlation indicates that multi-collinearity is not a concern in the analysis of these constructs. This strengthens the reliability of the analysis, as it signifies that the formative indicators contribute unique information without redundancy among constructs.

## 4. Conclusion

In conclusion, the repeated flooding in Kajang underscores the urgent need for enhanced flood protection measures to address ongoing challenges. Integrating land use planning (S2) has emerged as a highly impactful strategy, emphasizing its crucial role in enhancing the resilience of critical infrastructure against floods. Strategic land use planning can significantly reduce infrastructure vulnerability by carefully locating and designing structures in flood-prone areas.

Future research should focus on a comprehensive approach to flood mitigation in Kajang, addressing various aspects such as finance, technology, social factors, and policies related to resilience. By exploring these dimensions, it is possible to develop more effective and sustainable flood management strategies. Additionally, fostering collaboration among government agencies, NGOs, private entities, and communities will be essential in enhancing disaster response capabilities and community resilience. This holistic approach will ensure that Kajang is better prepared to withstand and recover from future flood events, ultimately safeguarding both infrastructure and the well-being of its residents.

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## References

[1] F. S. Buslima, R. C. Omar, T. A. Jamaluddin, & H. Taha, “Flood and Flash Flood Geo-Hazards in Malaysia,” 2018.

[2] M. Y. Safiah *et al.*, “Understanding urban flood vulnerability and resilience: a case study of Kuantan, Pahang, Malaysia,” *Nat. Hazards*, vol. 101, no. 2 , pp. 551–571, 2020.

[3] Jabatan Pengairan dan Saliran Malaysia, “Government of Malaysia Department of Irrigation and Drainage. DID Manual. Volume 1-Flood Management,” 2009.

[4] C. Bach, A. K. Gupta, S. S. Nair, and J. Birkmann, “Training Module: Critical Infrastructures and Disaster Risk Reduction (in the Context of Natural Hazards),” 2013.

[5] V. Panwar, E. Wilkinson, and L. Weingärtner, “Financial arrangements for addressing losses and damages A Disaster Risk Reduction Primer,” 2023.

[6] C. Malalgoda, D. Amaratunga, and R. Haigh, “Challenges in Creating a Disaster Resilient Built Environment,” *Procedia Econ. Financ.*, vol. 18, pp. 736–744, 2014.

[7] UNISDR, “United Nations International Strategy for Disaster Reduction Secretariat (UNISDR), 2017.Report of the Open-Ended Intergovernmental Expert Working Group on Indicatorsand Terminology Relating to Disaster Risk Reduction. The United Nations GeneralAssembly on February 2nd, 2017. https://www.preventionweb.net/terminology/resilience. Accessed 8/08/22.,” 2017.

[8] IPCC, “IPCC, 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. AContribution of Working Group II to the Fifth Assessment Report of theIntergovernmental Panel on Climate Change. World Meteorological Organization,Geneva, Switzerland, p. 190,” Alistair Woodward, 2014.

[9] A. Bari, L. Alam, M. M. Alam, & Labonnah, F. Rahman, and J. J. Pereira, “Estimation of losses and damages caused by flash floods in the commercial area of Kajang, Selangor, Malaysia,” 2021.

[10] S. . Blenkinsop, L. . Muniz Alves, and A. J. P. . Smith, “Sciencebrief Review: Climate Change Increases Extreme Rainfall and the Chance of Floods. In: Critical Issues in Climate Change Science, Edited By C. Le Quéré, P. Liss & P. Forster. https://doi.org/10.5281/Zenodo.4779119,” 2021.

[11] H. S. Rosmadi, M. F. Ahmed, M. Bin Mokhtar, and C. K. Lim, “Reviewing Challenges of Flood Risk Management in Malaysia,” *Water (Switzerland)*, vol. 15, no. 13, pp. 1–21, 2023.

[12] M. Othman, C. . Chang, N. . Zakaria, and A. Ab Ghani, “Trends Of Extreme Rainfall Events: A Case Study In Sungai Pahang River Basin,” 2015.

[13] D. Wagenaar, “The significance of flood duration for flood damage assessment. Master Thesis Water Management, TU Delft,” 2012.

[14] FEMA, “Federal Emergency Management Agency (2023). Unit 1: Floods and Floodplain Management. Retrieved from https://www.fema.gov/pdf/floodplain/nfip_sg_unit_1.pdf,” 2023.

[15] S. E. Chang, “Socioeconomic Impacts of Infrastructure Disruptions,” in *Oxford Research Encyclopedia of Natural Hazard Science*, Oxford University Press, 2016.

[16] O. I. Lawanson, D. Proverbs, and R. L. Ibrahim, “The impact of flooding on poor communities in Lagos State, Nigeria: The case of the Makoko urban settlement,” *Journal of Flood Risk Management*, vol. 16, no. 1. John Wiley and Sons Inc, 01-Mar-2023.

[17] M. G. Winter, D. Peeling, D. Palmer, and J. Peeling, “Economic impacts of landslides and floods on a road network,” *Acta Univ. Carolinae, Geogr.*, vol. 54, no. 2, pp. 207–220, Dec. 2019.

[18] Ganguly, Bhatia, and Flynn, “Critical Infrastructures Resilience Policy and Engineering Principles,” 2018.

[19] Saleh, *Climate Change and Infrastructure Resilience. In: National Academy of Engineering. Frontiers of Engineering: Reports on Leading-Edge Engineering from the 2018 Symposium. Washington (DC): National Academies Press (US).* National Academies Press, 2019.

[20] M. N. Fatemi, S. A. Okyere, S. K. Diko, M. Kita, M. Shimoda, and S. Matsubara, “Physical vulnerability and local responses to flood damage in peri-urban areas of Dhaka, Bangladesh,” *Sustain.*, vol. 12, no. 10, May 2020.

[21] L. Capacci, F. Biondini, and D. M. Frangopol, “Resilience of aging structures and infrastructure systems with emphasis on seismic resilience of bridges and road networks: Review,” *Resilient Cities Struct.*, vol. 1, no. 2, pp. 23–41, Jun. 2022.

[22] S. N. Jonkman and R. J. Dawson, “Issues and challenges in flood risk management-Editorial for the special issue on flood risk management,” *Water (Switzerland)*, vol. 4, no. 4. pp. 785–792, 2012.

[23] A. Pamidimukkala, S. Kermanshachi, N. Adepu, and E. Safapour, “Resilience in water infrastructures: A review of challenges and adoption strategies,” *Sustainability (Switzerland)*, vol. 13, no. 23. MDPI, 01-Dec-2021.

[24] F. C. Nick, N. Sänger, S. van der Heijden, and S. Sandholz, “Collaboration is key: Exploring the 2021 flood response for critical infrastructures in Germany,” *Int. J. Disaster Risk Reduct.*,vol. 91, Jun. 2023.

[25] J. C. Tasantab, “Beyond The Plan: How Land Use Control Practices Influence Flood Risk In Sekondi-Takoradi,” *Jamba J. Disaster Risk Stud.*, vol. 11, no.1, pp. 1–9, 2019.

[26] N. Z. A. Norizan, N. Hassan, and M. M. Yusoff, “Strengthening flood resilient development in malaysia through integration of flood risk reduction measures in local plans,” *Land use policy*, vol. 102, Mar. 2021.

[27] K. Charalambous, A. Bruggeman, E. Giannakis, and C. Zoumides, “Improving public participation processes for the Floods Directive and flood awareness: Evidence from Cyprus,” *Water (Switzerland)*, vol. 10, no. 7, Jul. 2018.

[28] E. Mavhura, “Learning from the tropical cyclones that ravaged Zimbabwe: policy implications for effective disaster preparedness,” *Nat. Hazards*, vol. 104, no. 3, pp. 2261–2275, Dec. 2020.

[29] E. Munsaka, C. Mudavanhu, L. Sakala, P. Manjeru, and D. Matsvange, “When Disaster Risk Management Systems Fail: The Case of Cyclone Idai in Chimanimani District, Zimbabwe,” *Int. J. Disaster Risk Sci.*, vol. 12, no. 5, pp. 689–699, Oct. 2021.

[30] L. Nahayo *et al.*, “Early alert and community involvement: approach for disaster risk reduction in Rwanda,” *Nat. Hazards*, vol. 86, no. 2, pp. 505–517, Mar. 2017.

[31] Y. Alabbad and I. Demir, “Urban Flood Impact Assessment and Hazard Vulnerability Analysis: Iowa Case Study,” 2022.

[32] J. S. Nanditha and V. Mishra, “On the need of ensemble flood forecast in India,” *Water Security*, vol. 12. Elsevier B.V., 01-Apr-2021.

[33] I. Yusoff, A. Ramli, N. A. Mhd Alkasirah, and N. Mohd Nasir, “Exploring the managing of flood disaster: A Malaysian perspective,” *Malaysian J. Soc. Sp.*, vol. 14, no. 3, pp. 24–36, Aug. 2018.

[34] P. Sayers *et al.*, *Flood risks management : A strategic approach*. Asian Development Bank, 2013.

[35] N. W. Chan, A. A. Ghani, N. Samat, N. N. N. Hasan, and M. L. Tan, “Integrating Structural and Non-structural Flood Management Measures for Greater Effectiveness in Flood Loss Reduction in the Kelantan River Basin, Malaysia,” in *Lecture Notes in Civil Engineering*, vol. 53, Springer, 2020, pp. 1151–1162.

[36] M. Rubinato *et al.*, “Urban and river flooding: Comparison of flood risk management approaches in the UK and China and an assessment of future knowledge needs,” *Water Sci. Eng.*, vol. 12, no. 4, pp. 274–283, Dec. 2019.

[37] J. Saifulsyahira, M. A. Endre, A. Farhan, and M. H. Juni, “Governance Of Flood Disaster Management: Malaysian Case Study,” 2016.

[38] P. F. M. Tamyez, N. C. I. Gerth, A. R. Zahari, and M. N. A. Rashid, “Analyzing The Critical Factors for Humanitarian Response on Flood-Related Disaster,” *Int. J. Ind. Manag.*, vol. 10, pp. 99–112, Mar. 2021.

[39] V. How, E. S. Azmi, H. Abdul Rahman, and K. Othman, “The Way Forward: Opportunities and Challenges of Sustainable School Disaster Education in Malaysia,” *Int. J. Acad. Res. Bus. Soc. Sci.*, vol. 10, no. 15, Dec. 2020.

[40] W. Teo and N. Sulaiman, “Multi-Agency Collaboration in Flood Disaster Management in Sarawak, Malaysia,” 2019.

[41] Department of Statistics Malaysia, “Population of Housing Census of Malaysia Dashboard (MyCenDash),” 2023. [Online]. Available: https://www.dosm.gov.my/mycendash/.

[42] Majlis Perbandaran Kajang, “Rancangan Tempatan Majlis Perbandaran Kajang Selangor 2035 (Penggantian): Jilid I (Strategi Pembangunan),” 2020.

[43] N. Muhamad and H. A. Shaidin, “The Assessment of Flood Events in Selangor,” 2022.

[44] N. Muhamad and H. A. Shaidin, “The Assessment of Flood Events in Selangor,” *Malaysia. J. Adv. Geospatial Sci. Technol.*, vol. 2, no. 2, pp. 42–55, 2022.

[45] J. F. Hair, G. T. M. Hult, C. M. Ringle, and M. Sarstedt, “A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM) Third Edition,” 2022.

[46] R. R. Bagozzi and Y. Yi, “On the Evaluation of Structural Equation Models.”

[47] G. A. Churchill, “Measure and Construct Validity Studies,” 1979.

[48] Y. Grégoire and R. J. Fisher, “The effects of relationship quality on customer retaliation,” *Mark. Lett.*, vol. 17, no. 1, pp. 31–46, Jan. 2006.

[49] J. F. Hair, J. J. Risher, M. Sarstedt, and C. M. Ringle, “When to use and how to report the results of PLS-SEM,” *European Business Review*, vol. 31, no. 1. Emerald Group Publishing Ltd., pp. 2–24, 14-Jan-2018.

[50] J. Hulland, “Use Of Partial Least Squares (PLS) In Strategic Management Research: A Review Of Four Recent Studies,” 1999.

[51] J. F. Hair, G. T. M. Hult, C. M. Ringle, and M. Sarstedt, “A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM) Second Edition,” 2017.

[52] R. S. Oliveri, C. Gluud, and P. A. Wille-Jørgensen, “Hospital doctors’ self-rated skills in and use of evidence-based Medicine – A Questionnaire Survey,” Journal of Evaluation in Clinical Practice, vol. 10, no. 2, pp. 219–226, May 2004.

[53] Jabatan Pengairan dan Saliran Malaysia, Rekabentuk Terperinci Saliran Mesra Alam Bagi Bandar Kajang, Selangor Darul Ehsan, December 2014