UNIVERSITI TEKNOLOGI MARA

A SYSTEMATIC EVALUATION OF POST-FLOOD BUILDING DAMAGE ASSESSMENT IN MALAYSIA

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MSc

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CONFIRMATION BY PANEL OF EXAMINERS

I certify that a Panel of Examiners has met on 13 March 2026 to conduct the final examination of Muhammad Naziem Bin Mohd Salehen on his Masters of Science thesis entitled "A Systematic Evaluation of Post-Flood Building Damage Assessment In Malaysia" in accordance with Universiti Teknologi MARA Act 1976 (Akta 173). The Panel of Examiners recommends that the student be awarded the relevant degree. The Panel of Examiners was as follows:

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I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

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ABSTRACT

Flooding remains one of the most frequent and destructive natural disasters in Malaysia causing substantial damage to buildings, infrastructure and communities. However, post-flood damage assessment in Malaysia is still constrained by subjective visual inspection, limited integration of flood-related attributes and the absence of a systematic framework for consistent classification. This study aimed to identify the most significant attributes influencing post-flood damage classification, determine the appropriate damage-level assessment and develop a conceptual framework for systematic post-flood damage assessment in the Malaysian context. A mixed-methods approach was adopted, involving a questionnaire survey of 94 disaster management practitioners and semi-structured interviews with experts from relevant disaster management and technical agencies, followed by an expert validation exercise. Quantitative data were analysed using descriptive statistics, validity and reliability tests, variable ranking and canonical correlation analysis, while qualitative data were analysed thematically. The findings identified four principal domains influencing post-flood damage assessment, namely building attributes, flow and hydraulic factors, environmental factors and non-structural components. Canonical correlation analysis further confirmed a significant relationship between damage frequency and severity. Among the most influential findings, mold growth, wall damage and electrical system damage recorded the highest combined damage-priority scores. These results informed the development of the Post-Flood Damage Assessment (PFDA) framework, which was positively evaluated by validation experts in terms of clarity, alignment with existing guidelines and practical applicability. Overall, the study demonstrates that the proposed framework offers a more systematic, consistent and locally relevant approach to post-flood damage assessment, with potential to support repair prioritisation, resource allocation and recovery planning in flood-prone regions of Malaysia. The study also contributes to Sustainable Development Goal 11 (Sustainable Cities and Communities) by supporting resilient settlement recovery and improved disaster preparedness and to Sustainable Development Goal 13 (Climate Action) by strengthening local capacity for climate-related disaster response and adaptation.

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LIST OF SYMBOLS

Symbols

σ^2	Population Variance
σ	Population Standard Deviation
μ	Population Mean
N	Population Size / Total Number of Observations in the Population
S^2	Sample Variance
S	Sample Standard Deviation
x_i	Value of the i-th Observation in the Population / for Variable X
$\bar{x}$	Sample Mean
y_i	Value of the i-th Observation for Variable Y
n	Sample Size / Required Sample Size
p	Proportion of the Population (Typically 0.5 When Unknown)
e	Acceptable Margin of Error
X^2	Chi-Square Value for 1 Degree of Freedom at the Desired Confidence Level
r	Pearson's Correlation Coefficient Between Variables X and Y
j	Number of Canonical Functions in Canonical Correlation Analysis (CCA)
c	Canonical Correlation for the i-th Canonical Function
λ	Wilks' Lambda Statistic Used in Canonical Correlation Analysis

X	Absolute Value of the Original Canonical Loading Value
Xmin	Smallest Loading Value in the Dataset
Xmax	Largest Loading Value in the Dataset
w_1	Weight Assigned to the Normalised Frequency Score
w_2	Weight Assigned to the Normalised Severity Score
α	Significance Level (Alpha), Used When Comparing P-Values with the Preset Threshold

LIST OF ABBREVIATIONS

Abbreviations

AHP	Analytic Hierarchy Process
ATC	Applied Technology Council
B40	Bottom 40% Income Group
BBB	Build Back Better
BCA	Building Condition Assessment
BNM	Bank Negara Malaysia
CCA	Canonical Correlation Analysis
CI	Critical Infrastructure
COVID-19	Coronavirus Disease 2019
DOSM	Department of Statistics Malaysia
EM-DAT	Emergency Events Database
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
GIS	Geographic Information System
HVAC	Heating, Ventilation and Air Conditioning
IBM SPSS	International Business Machines – Statistical Package for the Social Sciences

ICT	Information and Communication Technology
IDA	Initial Damage Assessment
JKR	Jabatan Kerja Raya (Public Works Department Malaysia)
JPS	Jabatan Pengairan dan Saliran (Department of Irrigation and Drainage Malaysia)
MARA	Majlis Amanah Rakyat
MAXQDA	MAX Qualitative Data Analysis Software
MKN	Majlis Keselamatan Negara (National Security Council Malaysia)
NADMA	National Disaster Management Agency (Agensi Pengurusan Bencana Negara)
PBT	Pihak Berkuasa Tempatan (Local Authority)
PDA	Preliminary Damage Assessment
PDNA	Post-Disaster Needs Assessment
PFDA	Post-Flood Damage Assessment
RC	Reinforced Concrete
SCR	Structural Condition Rating
SMART	Special Malaysia Disaster Assistance and Rescue Team
SPSS	Statistical Package for the Social Sciences

LIST OF NOMENCLATURE

Nomenclatures

N	Population Size / Total Number of Observations in the Population
n	Sample Size / Required Sample Size
S^2	Sample Variance
S	Sample Standard Deviation
x_i	Value Of The i-th Observation in the Population / for Variable X
$\bar{x}$	Sample Mean
y_i	Value of the i-th Observation for Variable Y
r	Pearson's Correlation Coefficient Between Variables X and Y
p	Proportion of the Population (Typically 0.5 When Unknown)
e	Acceptable Margin of Error
X^2	Chi-Square Value for 1 Degree of Freedom at the Desired Confidence Level (3.841 in This Study)
j	Number of Canonical Functions in Canonical Correlation Analysis (CCA)
c	Canonical Correlation for the i-th Canonical Function
X	Absolute Value of the Original Canonical Loading Value
Xmin	Smallest Loading Value in the Dataset
Xmax	Largest Loading Value in the Dataset
w_1	Weight Assigned to the Normalised Frequency Score ($W_1 = 0.5$ in This Study)

w_2	Weight Assigned to the Normalised Severity Score ($W_2 = 0.5$ in This Study)

CHAPTER 1
INTRODUCTION

1.1 Research Background

Over the past two decades, the frequency of major floods has increase almost 50% worldwide, driven by increasing rainfall intensity and climate change (E360 Digest, 2020). Floods are among the most frequent and contribute to devastating natural disasters globally, accounting for 85% of all natural disasters in Malaysia since 2000 (BNM, 2023). This trend stresses the urgent need for Malaysia to enhance their disaster management capacities. The increasing frequency and severity of floods emphasizes the growing influence of climate change and the urgent need for effective preparedness, response, recovery and mitigation strategies. As shown by EM-DAT (2024), data in Figure 1.1 indicates a significant rise in flood frequency which has increased the impact on communities and the extent of damage after 2018. In 2021, floods in Malaysia increased rapidly with eight occurrences affecting 4.90% of the population. These floods caused RM6.1 billion in economic losses, equivalent to 4.39% of the country's GDP. The floods destroyed or severely damaged over 20,000 homes and displaced more than 71,000 residents across several states such as Selangor and Pahang (NADMA, 2024b). Effective post-flood damage assessment is critical for ensuring structural safety and guiding decisions on repairs or demolition (Building Performance, 2024). The tangible damage included RM2 billion in public assets and infrastructure, RM1.6 billion in residential properties. These impacts emphasise the need for effective post-flood damage assessments to enhance effective preparedness, response, recovery and mitigation strategies.

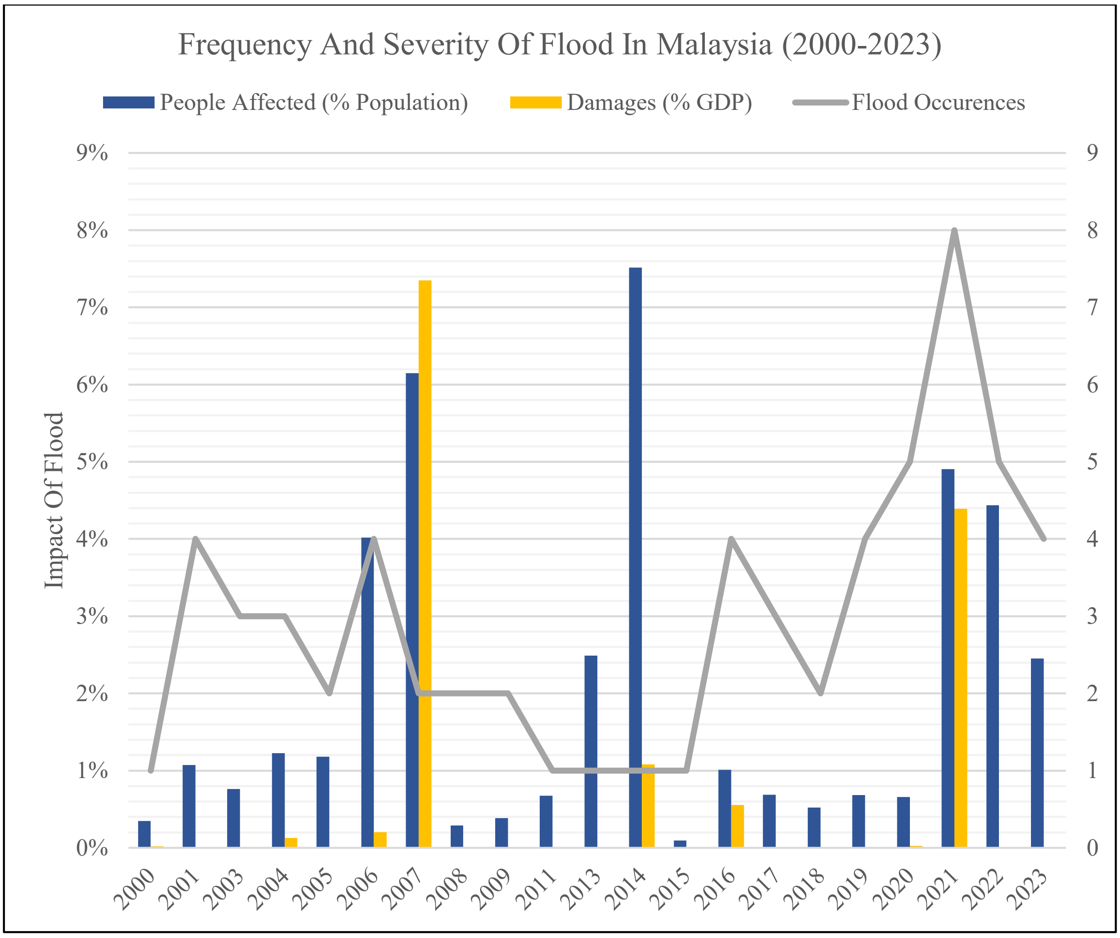

Figure 1.1 Frequency and Severity of Flood in Malaysia from 2000-2023 (EM-DAT, 2024)

Floodwaters can cause a range of damage, such as cracks, wall shifting and weakened foundations. However, current disaster management practices lack clear frameworks for systematically classifying post-flood damage (Del Zoppo et al., 2022). Traditionally, authorized and experienced personnel rely on visual assessments to evaluate building damage after floods, a practice that is widely used but often constrained by their experience and time requirements. Until now, the Applied Technology Council-45 (ATC-45) field manual provides guidelines for professionals to assess building safety after floods, focusing on rapid categorization of damage severity (ATC, 2004). While this approach allows for direct observation of damage, it can be dangerous and time-consuming, requiring 30 minutes to 4 hours per building and required knowledge of damage or understanding particularly in large-scale disaster scenarios. These methods also have limitations, as assessments can be influenced by personal experience, varying levels of expertise and cognitive biases, leading to inconsistent results (Khajwal & Noshadravan, 2021; Zhang & Pan, 2022).

To address these challenges, a few studies have proposed frameworks to improve post-flood damage assessment and support continuous decision-making processes. Currently in Malaysia, Osman (2023) evaluates the Building Condition Assessment (BCA) method, developed by the Malaysian Public Works Department (JKR). This method aims to systematically assess flood damage and prioritize maintenance actions through a standardized matrix system. Yet, the BCA lacks an integrated approach that accounts for critical flood dynamics, such as depth, duration and velocity, all of which significantly impact structural integrity. The Post-Disaster Needs Assessment (PDNA) is another commonly used framework. It uses an integrated, multi-sectoral approach to assess physical damages, economic losses and the costs required to address recovery needs following a natural disaster (European Union et al., 2013). While the PDNA provides structured methodologies for rapid response and recovery planning, it typically categorizes buildings under general sectors such as "housing" or "infrastructure" without conducting the level of detailed assessment necessary. This gap can lead to underestimation of damage level incurred to the structures and infrastructure.

Therefore, by developing a conceptual framework for post-flood damage assessment, this will enable effective assessments and improve the analysis of disaster-related data. This study aims to identify significant key attributes, integrate damage level and establish a comprehensive framework that integrates damage level assessment, contributing a systematic approach to post-flood evaluations. The framework can benefit agencies such NADMA, JKR, MKN and JPS by improving coordination, resource allocation and decision-making during disaster recovery efforts. This research will also contribute to disaster management planning in Malaysia, shaping policies under the National Security Council Directive No. 20 to enhance disaster resilience. It aligns with Sustainable Development Goal (SDG) 13, aiming to strengthen resilience and response capabilities to climate hazards and natural disasters.

1.2 Problem Statement

Flood events in Malaysia have resulted in substantial damage losses, affecting various sectors and urge the need for effective damage assessment strategies. An analysis of the sectoral distribution of flood losses in Malaysia reveals an important pattern. Although the number of recorded flood events decreased from 2021 to 2023, the proportion of damage attributed to public assets and infrastructure increased significantly reaching 48% in 2023 as illustrated in Figure 1.2 (DOSM, 2023). This indicates that flood impacts are becoming increasingly concentrated on critical infrastructure systems. Similarly, residential living quarters constitute a major portion of the losses (26%) in 2021 and remaining significant in subsequent years. These losses amounted to approximately 0.4% of Malaysia's nominal GDP in 2021, with further GDP reductions of 0.13% to 2.28% estimated depending on flood severity (Ashizawa et al., 2022). This shift in damage distribution suggests the need for a more effective and systematic post-flood damage assessment approach. A reliable assessment is important to accurately evaluate the extent of damage and to support better decision-making in recovery planning and resource allocation.

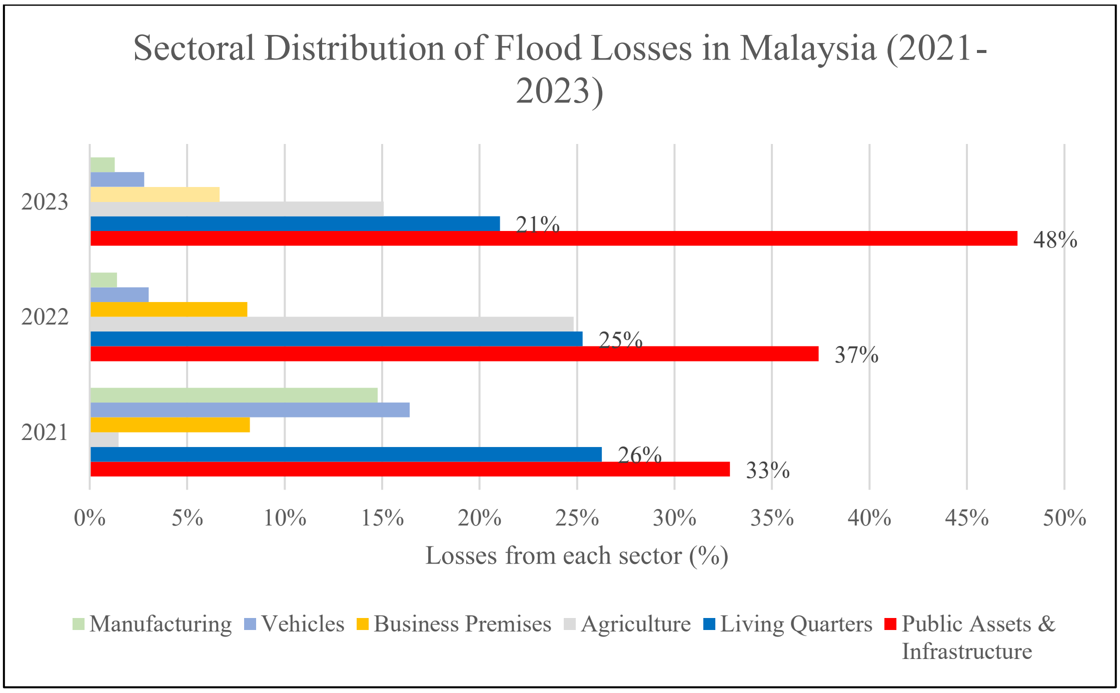

Figure 1.2 Sectoral Distribution of Flood Losses in Malaysia Based on Data from 2021-2023

In practice, post-flood damage assessment is primarily focused on buildings and related infrastructure, where evaluation is conducted based on observable and measurable attributes. These include physical damage to structural and non-structural components, disruption of building function and other indicators that can be assessed by agencies and practitioners during post-flood inspections. In Malaysia, tools such as the Building Condition Assessment (BCA) and MyFloodRAS are currently used to support flood-related assessments. After flood, the BCA, conducted by the Public Works Department of Malaysia (JKR) systematically evaluates the physical condition of government buildings to identify structural defects and maintenance requirements, ensuring the safety and durability of public assets (Mat Nasir, 2022; Rahman & Manan, 2020). Similarly, MyFloodRAS, a GIS-based web application developed by the Department of Irrigation and Drainage (JPS), supports flood damage assessment and early warning systems. It calculates both direct and indirect damages caused by floods and provides a structured approach to flood risk assessment (JPS, 2013).

Even though these tools serve specific operational purposes such as flood risk assessment (MyFloodRAS) and building condition evaluation (BCA) they operate independently and emphasise different aspects of assessment. The key limitation lies in the lack of integration between these tools where there is no shared damage taxonomy, no integrated workflow and no standardised classification scale linking structural condition assessment with flood hazard and loss evaluation. Buildings assessed under the BCA framework often face maintenance buildups due to inadequate funding and the prioritization of other repair needs (Mat Nasir, 2022; Rahman & Manan, 2020). Also, the BCA fails to comprehensively consider environmental factors such as soil conditions, which significantly influence building performance during disasters (Yusoff, 2020). This lack of linkage between structural assessments and flood damage evaluations creates a critical gap, as it delays the ability to produce a complete, attribute-based assessments of post-flood damage. Current frameworks lack a systematic approach to damage categories, resulting in inconsistencies in damage assessment during recovery planning.

To address these gaps, this research proposes a conceptual framework for post-flood damage assessment, focusing on addressing significant key attributes and their corresponding damage level. The proposed conceptual framework includes significant key attributes such as building characteristics, flow and hydraulics environmental factors and non- structural component. Focusing on flood-prone areas in Malaysia, the framework aims to standardize post-flood damage assessment practices, ensuring consistency and replicability. By aligning this framework with national policies and international guidelines, it bridges the gap between the operational tools and strategic disaster risk reduction, contributing to more effective recovery and resilience-building efforts.

1.3 Research Objectives

This study conducts an in-depth investigation aimed at enhancing our understanding of post-flood damage assessment. The following research objectives outline specific areas of focus, establishing the understanding for a thorough and impactful study.

a) To identify the most significant key attributes that significantly influence the classifications of post-flood damage assessment

b) To identify the appropriate damage level assessment for assessing attributes identified

c) To develop a conceptual framework for systematic damage assessment at post-flood event by integrating significant key attributes and damage level identified

1.4 Research Question

i) What are the most significant key attributes that are related to classifications damage assessment?

ii) What is the appropriate damage level for assessment of damage in the context of post-flood damage assessment?

iii) What component and methodologies can contribute to the development of a conceptual framework for assessing damage in post-flood events?

1.5 Scope of Study

The study draws on documented Malaysian flood events, official reports and existing national and state-level guidelines. The scope of this study includes input from NADMA staff and experts from NADMA, JPS, JKR and MKN, who are directly involved in disaster management and post-flood assessment. The selection of respondents is based on specific criteria including relevant working experience in flood-related management, direct involvement in post-flood assessment activities and professional knowledge of building and infrastructure damage evaluation. The proposed framework is intended to be applicable across flood-affected regions in Malaysia and is not limited to a single case study area. The outcome of this study is to provide a practical reference for post-flood damage assessment that can be applied by stakeholders at federal, state and local levels.

1.6 Limitation of Study

This study acknowledges several limitations, particularly related to the scope, generalisability and focus on specific types of damage. Although the proposed framework is intended for application across Malaysia, it is mainly developed based on literature, official reports and expert inputs from agencies that are more actively involved in major flood events in selected states such as Kelantan, Terengganu, Pahang, Johor and Selangor. Therefore, certain findings may reflect the characteristics of these more frequently affected regions in terms of building typology, governance structure and availability of data. When applied to other areas with different socio-economic, geographic, or construction characteristics such as rural settlements or East Malaysia, some adjustment or calibration may be required. In addition, the study focuses primarily on tangible and observable damage to buildings and related infrastructure. Intangible impacts such as psychological distress, social disruption and long-term livelihood losses are not explicitly covered, in order to allow a more detailed and structured analysis of physical damage that is directly relevant to post-flood recovery planning. Future research could integrate multiple data sources, a wider range of regional contexts and a broader set of damage dimensions to enhance the robustness and applicability of the framework.

Another significant limitation is the potential bias of participants' responses, as the professionals interviewed were selected based on their expertise and seniority within their respective agencies. Their responses may reflect a preference for their own practices or organization priorities, which potentially overlooking alternative approaches or gaps in addressing flood-related damage. Future research could conduct a community-level surveys to provide a local perspective, which can give real life situations and identify challenges that may not be visible at the organizational level. Additionally, the reliance on participants' recollections of past flood events introduces the risk of memory bias, which may result in incomplete or wrong interpretations of critical issues. To address these limitations, future studies could include multiple case studies in separate settings, include real-time flood data and applying advanced technologies such as GIS and IoT sensors to validate and refine the proposed framework.

1.7 Significance of Research

The significance of the research is as follows:

a) This research focuses on identifying significant attributes for damage classification within a localized context to make sure precise and measurable criteria. These attributes refer to the characteristics of damage components such as structural and non-structural elements that can be observed and assessed after flood events.
b) The study also identifies appropriate damage level assessments to support the development of a conceptual framework for post-flood damage assessment.
c) This research provides a practical tool for disaster management and building assessment professionals in Malaysia. The proposed framework incorporates the significant key attributes to enable a more systematic, consistent and reliable approach to post-flood damage assessment. Centred on the Malaysian context of recurrent flood events, this research has the potential to contribute to the development of informed and resilient strategies for post-flood recovery and reconstruction throughout the country.

1.8 Thesis Layout

This thesis is organized into five (5) chapters, each with a particular purpose to ensure a systematic arrangement of the research. Chapter 1 introduces the study by providing the background, context and significance of the research. The chapter includes the problem statement, research objectives, questions and scope, emphasising the focus on post-flood damage assessment within flood-prone areas in Malaysia. In Chapter 2, it focuses on the theoretical and empirical foundations of post-flood damage assessment. This chapter discusses the classification of key attributes such as flood damage methodologies, building vulnerability factors and existing disaster management frameworks.

Chapter 3 outlines the systematic approach used to achieve the research objectives through a mixed-methods methodology. Quantitative data was gathered via structured questionnaires distributed to disaster management professionals in NADMA, while qualitative insights were collected from semi-structured interviews with experts from NADMA, JPS, JKR and MKN. The empirical context covers flood-prone areas across Malaysia, drawing on experience from recent major flood events to provide a locally grounded basis for analysis. Data analysis techniques include descriptive statistics, variable ranking, canonical correlation and thematic analysis to ensure the reliability and validity of the findings. The chapter also addresses ethical considerations and presents a detailed research timeline.

Chapter 4 presents the findings of the study, focusing on identifying significant attributes influencing post-flood damage. The analysis combines frequency and severity data of damage types and explores the statistical relationship between damage frequency and severity through canonical correlation analysis. Expert interview data were thematically analysed to validate and contextualize the survey results. This chapter provides insights into the most frequently and severely occurring types of damage and the key attributes influencing them. Expert feedback was used to refine the framework to improve its practicality and alignment with real-world disaster management practices in Malaysia.

Lastly, Chapter 5 concludes the study by summarizing the main findings aligned with each research objective and offering practical recommendations for policy makers, practitioners and future research.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction to the Literature

This literature review focuses on the mechanisms of damage, existing assessment methodologies and gaps in current practices. This chapter aims to establish the theoretical foundation to enhance post-flood damage assessment. By addressing the limitations of current methodologies, the understanding from this chapter will contribute to the development of a more effective and standardized framework.

2.2 Classification of Tangible and Intangible Damage

Previous studies conducted by KTA Tenaga Sdn. Bhd. and the Department of Irrigation and Drainage (JPS) have established categories for assessing flood damages (JPS, 2003). These assessments are generally classified into direct or indirect and tangible or intangible categories (Merz et al., 2010; Parker et al., 1987). Direct damages include physical harm to buildings, infrastructure, or injuries to people, while indirect damages involve disruptions like traffic jams, trade interruptions and health-related issues (Merz et al., 2010). The difference between tangible and intangible damage lies in whether the impact can be measured in monetary terms (Sulong & Romali, 2022). Tangible damage can be quantified easily, such as the cost to repair a building, while intangible damage refers to more difficult-to-quantify effects, such as emotional distress or loss of quality of life (Pellicani et al., 2018; Romali & Yusop, 2021). Table 2.1 shows the details of the damage categories.

Table 2.1
Flood Damage Categories (Sulong & Romali, 2022)

	Tangible		**Intangible**
	Primary	**Secondary**	
Direct	Damage to buildings, infrastructure, agriculture (e.g., soil erosion, crop	Cost for cleanup, reconstruction and	Loss of life, psychological distress, cultural heritage and ecosystems.

	destruction), business assets and livestock.	environmental restoration.	
Indirect	Disruption to business in public services/utilities (e.g., communication networks), production losses for suppliers outside affected areas, traffic delays and loss of tax revenue from business relocation after floods.	Broader impacts on regional and national economies.	Traumatic experience, loss of trust in authorities, declining health and emotional distress.

2.3 Damage Assessment

One of the most critical steps in promoting resilience is assessing post-flood damage that helps authorities understand the degree of destruction and plan necessary recovery actions (Jiang et al., 2023; Liu et al., 2023). A well-conducted assessment provides data for making informed decisions about disaster declarations, resource distribution and financial assistance. If the damage is severe, local and state governments may request federal support that is often only granted after official damage reports confirm the need (FEMA, 2020). As emergency response transitions from evacuation and life-saving measures to damage evaluation and resource allocation, damage assessments help determine the full extent of destruction and its impact on structures and infrastructure. One of the primary functions of post-flood damage assessment is to determine whether a structure is habitable or not.

2.3.1 Types of Damage Assessment

Damage assessments are primarily divided into three (3) types, which are rapid assessment, preliminary assessment and technical assessment (McEntire, 2022). Each of the assessments is different in terms of the stages of the response and recovery process. The first type is rapid assessment that is also known as an Initial Damage Assessment (IDA). It is conducted immediately after a disaster to provide a quick overview of the extent of damage and human impact (European Union et al., 2013). This assessment is typically carried out by emergency personnel, government agencies or humanitarian organizations. The goal is to estimate the number of affected buildings, infrastructure damage and casualties. This information is essential for making urgent decisions involving evacuation, emergency aid and resource allocation (Osman, 2023). However, according to Chen and Ji (2021), rapid assessments can sometimes be inaccurate due to time constraints and limited access to affected areas. It also relies on incomplete data sources such as hazard tracking maps and social media that introduce bias and inaccuracies.

Preliminary assessment is generally referred to as a Preliminary Damage Assessment (PDA). According to the FEMA Preliminary Damage Assessment Guide (Draft 1.1), the PDA process takes place after the Initial Damage Assessment (IDA) that is conducted by local governments or tribal nations (FEMA, 2024). The timing of the preliminary assessment varies depending on factors such as the severity of the disaster, accessibility of affected areas and the urgency of federal assistance. According to Washington Military Department (2025), the PDA process usually takes 30 days in general, including the damage reporting, damage verification and disaster aid. This type of assessment provides a more detailed evaluation of the damage and is usually performed by government officials, disaster response agencies and insurance assessors. The purpose of a preliminary assessment is to determine whether federal or state disaster assistance is required. In some cases, a disaster declaration may be made in advance based on predicted damage, but a preliminary assessment is still necessary to verify the extent of the losses and guide resource allocation (FEMA, 2020). Figure 2.1 shows recovery personnel from FEMA, the Small Business Administration, Iowa's Homeland Security and Emergency Management Division and the City of Manchester during a Preliminary Damage Assessment (PDA) conducted on July 28, 2010, in response to the failure of the Delhi Dam.

Figure 2.1 Preliminary Damage Assessment (PDA) Team Evaluates Flood Impact near Delhi Dam Failure, Iowa (July 28, 2010)

Lastly, technical assessment is conducted to determine the precise cost of damages and to develop recommendations for rebuilding. This assessment is carried out by engineers, insurance agents and other professionals who evaluate structural integrity, safety risks and potential repair strategies. Technical assessments may take weeks or months to complete depending on the complexity of the damage. The findings from technical assessments play a key role in post-disaster reconstruction planning and infrastructure resilience (McEntire, 2022). Figure 2.2a, Figure 2.2b and Figure 2.2c illustrates technical assessments conducted evaluate structural, moisture-related and content damage.

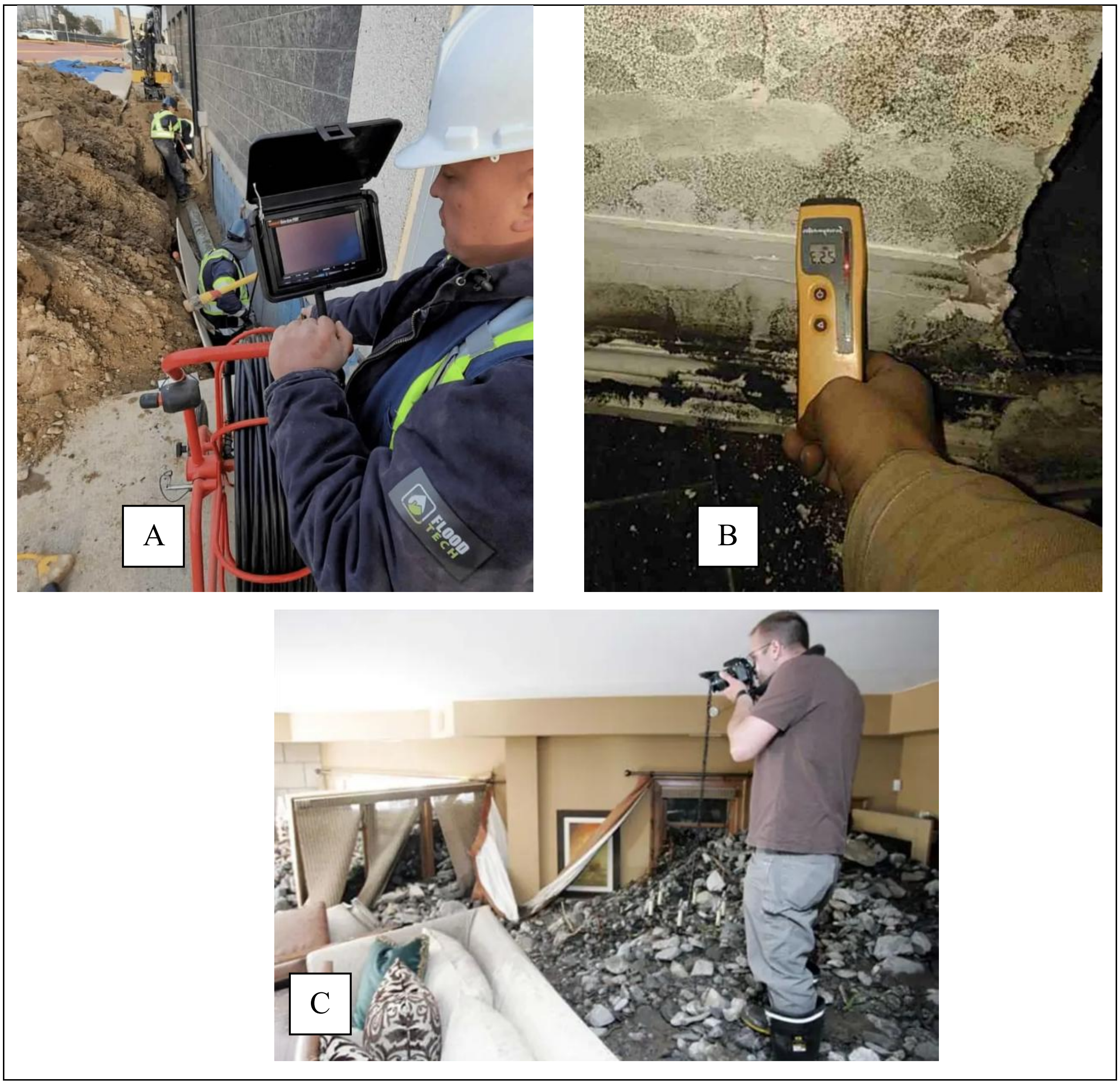

Figure 2.2 Post-Flood Technical Assessment: (A) Structural Inspection Using a Pipe Camera, (B) Moisture Level Measurement in a Flood-Damaged Wall, (C) Content Damage Inspection

2.3.2 Methods of Conducting Damage Assessment

There are three (3) widely used methods for conducting damage assessments. These methods are commonly known as windshield assessments, aerial assessments and walkthrough assessments. Each method has a different purpose and is utilized based on accessibility and scale of damage (McEntire, 2022). In windshield assessments, it is conducted immediately after a disaster by observing damage from a vehicle (Cheng et al., 2022). This approach allows assessment teams to quickly scan impacted neighbourhoods, identify the most severely affected zones and allocate resources efficiently. The team assigned will periodically stop to verify initial observations through brief interviews with survivors, collecting additional information such as insurance coverage and property ownership status (FEMA, 2020). This method helps to identify the most affected areas and determine where to direct immediate assistance. It is useful in the first hours or days after a disaster when a broad overview is needed to prioritize resources (FEMA, 2024). However, this method has its limitations such as blocked roads, floodwaters or debris. These limitations can prevent access to certain areas making it impossible to get a full picture of the damage. Despite these challenges, windshield assessments remain as one of a fast and practical way to gather initial damage information.

Aerial assessments, or also known as virtual sensing involve surveying disaster-affected areas from aircraft, helicopters or Unmanned Aerial Vehicles (UAVs) (Munawar et al., 2021) . These assessments are necessary when roads are inaccessible or when officials need a large-scale overview of the damage. The assessment provide a rapid and large-scale overview of affected regions making them especially useful for Preliminary Damage Assessments (PDA) (Singh & Hoskere, 2023). Aerial imagery helps emergency management teams and policymakers make quick, informed decisions about resource allocation and response strategies. This method is also widely used for media coverage to provide with real-time updates on disaster impacts. For instance, Figure 2.3 illustrates an aerial assessment conducted after the severe flooding in Pengkalan Chepa, Malaysia on December 27, 2014.

Figure 2.3 Aerial Assessment After Flood in Pengkalan Chepa, Malaysia (Sutchiewcharn, 2023)

Walkthroughs, also known as site visits involve physically inspecting areas affected by disasters to assess the extent and type of damage. This method typically includes on-the-ground evaluations of homes, businesses, roads, schools and public infrastructure. This method play an important role in verifying reported damage and in gathering detailed information for formal damage assessment reports (Alam et al., 2020). In Malaysia, the Department of Statistics Malaysia (DOSM) carried out walkthroughs as part of its Special Report on the Impact of Floods in 2024. The purpose of these visits was to ensure data accuracy and to better understand the real conditions faced by affected communities (DOSM, 2025).

This method is essential for identifying the specific types of assistance required by individuals, communities and government agencies following a disaster. They help determine whether reconstruction support or technical intervention is necessary. To conduct effective walkthrough assessments, evaluators often require technical knowledge in areas such as structural engineering, demolition procedures and construction standards (Zheng et al., 2021). This ensures that the assessments are both accurate and aligned with safety regulations and rebuilding priorities.

2.4 Damage Assessment Procedure

A systematic damage assessment procedure is essential following any disaster event to ensure an accurate understanding of the impacts, guide effective resource allocation and support informed recovery planning. According to Nkombi and Wentink (2022), damage assessment procedure typically consists of clearly defined phases, beginning with pre-assessment preparations and continuing through structured damage evaluations. This comprehensive approach not only ensures consistency and accuracy but also maximizes safety for assessment teams and affected populations. Each stage involves carefully planned activities from initial team coordination and access preparation to standardized evaluation protocols using established classification systems and assessment codes (ATC, 2004; FEMA, 2024). The following subsections explain the stages in detail including the specific tasks, data requirements and standardized parameter involved in each phase.

2.4.1 Pre-Assessment Activities

Once a disaster occurs, all individuals involved in the damage assessment process will conduct a meeting to make sure a coordinated and effective response. This meeting is done to clarify the assessment process and ensure that all team members understand how to complete assessment forms accurately (McEntire, 2022; Nkombi & Wentink, 2022). Standardized forms and reporting templates revied with detailed explanations on how to document structural damage, categorize hazards and record other critical observations accurately. If access to damaged buildings become challenging, key distribution should be arranged in advance to facilitate a thorough inspection (Hauashdh et al., 2024). Additionally, coordinators work with local business owners, property managers or municipal authorities to gather necessary keys and ensure that teams can enter structures safety without delays (Nkombi & Wentink, 2022). Therefore, a clear instruction should be given on how to handle situations where access is restricted due to structural instability or legal restrictions (FEMA, 2016, 2024).

The meeting also identifies access routes and designates specific locations rescued within the disaster area. Environmental hazards resulting from the disaster must also be assessed to prevent routing through high-risk zones, even though this may increase the travel distance for rescue vehicles and still not fully guarantee safety (Xu et al., 2021). Priority is often given to routes that connect essential staging areas such as hospitals, evacuation shelters and supply distribution centres with the disaster site. In cases where the road network is damaged or inaccessible, alternative transportation methods such as highways and railways should be explored to maintain connectivity.

2.4.2 Damage Assessment Parameter

When conducting damage assessment, the involved parties must follow a standardized parameter to ensure accuracy. This includes properly documenting damage, marking buildings with appropriate notices, securing hazardous areas and informing the public about the meaning of assessment codes. For example, commonly used system is the color-coded tagging scheme as outlined in ATC-20 and ATC-45 field manuals (ATC, 2004). This scheme classifies buildings into three categories as illustrated in Table 2.2.

Table 2.2
Color-Coded Classification System for Evaluating Damage after Flood (ATC, 2004)

Color	Classification	Description
Green	Inspected	No visible hazards were identified. While some minor repairs may be necessary, the building's original lateral load capacity remains largely unaffected. The structure is safe for normal use and occupancy without restrictions.
Yellow	Limited entry/restricted use	The building is believed to pose certain safety risks. Entry is allowed only for emergency purposes and solely at the owner's own risk. Continuous occupation or use is not permitted. Public access is strictly prohibited due to potential danger.
Red	Unsafe	The structure presents an extreme safety hazard and is at risk of imminent collapse. It is deemed unsafe for occupancy or entry. Only authorized personnel, as determined by the relevant authorities, may access the premises under controlled conditions.

Alphanumeric coding systems are also used to provide more detailed information on the damage type, evaluation status and recommended actions. These codes help complement the visual indicators from ATC-20 and ATC-45. For example, FEMA's damage assessment codes use combinations of letters and numbers such as A1, B2, or C3 to signify specific impacts to public infrastructure, utilities, habitability or debris-related concerns (FEMA, 2024). Each letter resembles to a damage category such as "A" for debris clearance, "B" for protective measures and "E" for public buildings. The number indicates severity or priority level based on established damage indicators.

2.5 Methods for Estimating Flood Damage

According to Marvi (2020), the methods to estimate post-flood damage are generally divided into two categories, which are historical data and analytical or simulation-based models. The first method relies on historical data from previous flood events, assuming the damage patterns observed in the past will be similar to the future events. The second method uses simulation models to explore how water affects building materials, these models often include simplified assumptions. Both methods involve a degree of uncertainty that require analysts to be aware of the limitations and uncertainties in their chosen approach (Marvi, 2020). The following subsections explore both methods in more detail to explain their applications, data requirements and limitations.

2.5.1 Historical Data

One way to estimate flood damage is by examining damage data from past floods. The concept is that assets or sectors of similar types are likely to experience similar damage when exposed to the same conditions. For example, if a three-story single-family home lost 50% of its structural value in a recent flood with 1.5m of water, it is expected that similar buildings in the area might face about the same loss in value if flooded with 1.5m of water. Damage is typically quantified in monetary terms, however various methods are used to estimate this financial impact (Mobini et al., 2021; Olmez & Deniz, 2023).

In some cases, damage is calculated based on the cost of repair or replacement (Marvi, 2020). The way damage is estimated can vary depending on whether depreciation is included. Depreciation can be defined as economic depreciation as a decrease in an asset's value over time, influenced by factors such as building age, quality and technological advancements (Yoshida, 2020). Without depreciation, the estimate reflects the economic impact, while with depreciation, it shows the loss to households. After a flood event, damage analysis commonly relies on two primary data sources which are post-flood data and insurance claims.

Post-flood data is available with different levels of detail and collection. Damage databases for natural hazards such as floods are typically specific to each event (Kellermann et al., 2020). This suggests that the collected and stored data is often gathered at a higher level such as by state or country for each event. For example, well-known databases such as EM-DAT provide information on total damages, insured losses and fatalities for natural disasters worldwide (EM-DAT, 2024). In Malaysia, the database can be obtained thru The Official Web Of Public

InfoBanjir by JPS (JPS, 2024). The collected data is helpful for analyzing trends and studying total losses over time (Marvi, 2020).

2.5.2 Simulation Model

Flood loss models in the literature mainly aim to predict the direct economic costs of repairing physical flood damage (Olmez & Deniz, 2023). According to Lonetti and Maletta (2018) common method for assessing damage involves estimating repair costs as a proportion of the market value. Alternatively, synthetic vulnerability models can be created using expert-based approaches that rely on damage data gathered through hypothetical "what-if" scenarios. The model involves the creation of probabilistic models, such as Monte Carlo simulation that evaluate damage by establishing empirical relationships between flood characteristics (such as depth or velocity) and the estimated damage (Olmez & Deniz, 2023; Paulik et al., 2023).

Analytical models rely on structural analysis and simulations to study how water interacts with buildings. First, the pressure of the floodwater on the building is measured. Then, the impact on each part of the structure is analysed using structural analysis methods. Finally, repair costs are allocated to each damaged part and the total cost is determined by summing the costs of all components.

2.6 Damage Assessment Challenges

Damage assessments are expected to provide an accurate representation of the extent and severity of damages. However, conducting an effective and timely damage assessments after disasters presents a few challenges. According to McEntire (2022), the primary issues typically involve problems related to accuracy, coordination among stakeholders, accessibility to affected areas and safety during assessments. These limitations can delay the reliability of data collected and delay necessary recovery actions. The following subsections explore each of the challenges in detail.

2.6.1 Accuracy

One of the biggest challenges in damage assessment is the issue of accuracy. Damage assessments are often prone to inaccuracies for several reasons. In Malaysia, one of the major contributing factors is the performance of the flood warning system itself. A worth mentioning example is the National Flood Forecasting and Warning Programme (PRAB) Phase 1 (2015-2022), which was criticized for its low accuracy, with a forecast accuracy rate of only 5.6% (Tan, 2023). This low accuracy was partly due to issues such as inadequate maintenance of equipment and data collection problems. As a result, the system struggled to provide timely and reliable flood warnings, which in turn affected the accuracy and preparedness of subsequent damage assessments.

In some situations, delays in reporting also contribute to the inaccuracies. The 2021–2022 flood event in Malaysia gave example to this issue as the reporting phase were complained for being slow and inefficient (Tzu Chi, 2022). Errors in data collection such as omissions, duplicate entries or misclassifications can also distort the accuracy of damage assessments. This is a major issue in Malaysia where damage assessments are still largely carried out through manual data collection methods which are more vulnerable to human error (JPS, 2024). Furthermore, historical data on flood damage is also often scarce in Malaysia that led to challenges in conducting comprehensive assessments (Balasbaneh et al., 2020; Romali et al., 2019). As a result, additional surveys are often needed to gather essential data, but the efforts can be time-consuming and may not adequately cover all affected areas especially in remote or rural regions.

Moreover, damage assessments are often repeated multiple times following a disaster that affected the accuracy. Multiple rounds of damage and inundation assessments also produced deviation in the estimates. For instance, initial figures from Malaysian government agencies estimated total losses at around RM 5.3 billion. However according to Tew et al. (2022), later independent studies using satellite-based mapping and fine-resolution digital elevation models (DEMs) reported a flooded area of approximately 77 km^2 and estimated losses as high as RM 6.1 billion.

2.6.2 Inter-Agency Collaboration and Coordination

Another major challenge in conducting post-disaster damage assessments is the involvement of multiple agencies and organizations. Each organization have differences in their objectives, methodologies and reporting formats. In the Malaysian context, damage assessments typically involve a wide range of stakeholders including government departments such as NADMA, JPS, JKR, local authorities, private engineering consultants, non-governmental organizations (NGOs) and emergency responders. This variety of agencies becomes difficult to coordinate and harmonize assessment activities, especially after disaster. The absence of a unified assessment protocol or central coordination mechanism often results in overlapping responsibilities, delayed reporting and inconsistencies in data collection (NADMA, 2024b). Table 2.3 summarizes the government agencies involved in disaster operations and their respective roles and responsibilities during disaster response (Mohammed Zain et al., 2023).

Table 2.3
Government Agencies Involved in Disaster Operations (Mohammed Zain et al., 2023)

Agency	Functions and Responsibilities After Disaster
JKM	• Responsible for distributing essential food supplies, clothing and necessities to individuals affected by disasters. • Manage and operate evacuation shelters for displaced victims during disaster events.
RELA	• Support the preparation and distribution of food to disaster victims and emergency response teams.
APM	• Responsible for delivering aid and supplies to disaster zones and coordinating land and sea transport for evacuation operations. • Oversee the management of temporary shelters for evacuees and assist in supplying food to disaster victims.
JKR	• Provide equipment, vehicles and skilled workers to assist with site clean-up operations following a disaster. • Establish temporary accommodation such as tents and shelters at disaster sites. • Ensure the provision of water supply services and increase water pressure in areas requiring emergency water access.
ATM	• Provide transport services by land, sea and air during disaster response operations. • Deploy and manage machinery and equipment needed for

	emergency response efforts.
DBKL	• Assist with the operation and maintenance of evacuation centres for disaster victims. • Provide vehicles to support logistical operations during disaster response.

2.7 Global Perspective on Post-Flood Damage Assessment

Recent studies have increasingly focused on tangible flood damage, particularly to infrastructure. For example, Shrestha et al. (2021a) and Sen et al. (2022) stresses the importance of accurately assessing damage in residential areas which they emphasize that variations in house types can significantly influence outcomes. To support rapid response, Tan and Schultz (2021) introduced a practical, on-site data collection method for regional flood mitigation Meanwhile, Zheng et al. (2021) applied image-based classification techniques to assess building damage and Harris et al. (2022) examined future damage scenarios under evolving land use and flood conditions. In addition, Komatsuzaki et al. (2022) demonstrated that dwelling type and building height are key factors in flood vulnerability , which shows that taller buildings tend to experience less severe damage. The current literature, as summarized in Table 2.3 demonstrates a growing recognition of the importance of damage assessments in international disaster discourse.

Table 2.4
Current Research with Emphasize on Tangible and Intangible Damage

Reference Authors	**Method considerations in research**	**Direct**			**Damage assessment**
		Tangible Damage		**Intangible Damage**	
		Infrastructure	**Damage in building**		
(Mobini et al., 2022)	Data mining + rank	✓			Relationship between the reason for flooding, sewer type and the type of claimant
(Dabaj et al., 2022)	Document analysis + questionnaire survey data	✓		✓	Framework for optimal risk reduction
(Sen et al., 2021, 2022)	Document analysis	✓			Framework to quantify time-

	interview				varying resilience
(Williams et al., 2022)	Document analysis + impact assessment	✓			Framework for estimating road and electricity network
(Urlainis et al., 2022)	Document analysis	✓			Framework of multi-hazards risk assessment
(Senapati, 2022)	Document analysis	✓			Identify vulnerability in society
(Alabbad & Demir, 2022)	Document analysis + observation data			✓	Comprehensive insight into the vulnerability of communities
(Edamo et al., 2022)	Document analysis + questionnaire survey data			✓	Flood modelling and risk assessment
(Li et al., 2022)	Observation data			✓	Flood risk assessment
(Komatsuzaki et al., 2022)	Document analysis + questionnaire data		✓		Damage effects in household
(Harris et al., 2022)	Document analysis + observation data		✓	✓	Damages for the agricultural, residential and industrial
(Zheng et al., 2021)	Document analysis + observation data		✓		Building damage assessment
(Tan & Schultz, 2021)	Document analysis + observation data	✓	✓	✓	Framework for rapid and updated damage assessment and recovery
(Shrestha et al., 2021a)	Questionnaire survey data		✓		Damage rate

Despite an increasing number of studies on infrastructure damage, there is a significant gap in the classification of building damage assessments. Many studies focus on broader impacts, such as people affected, agricultural area damage and critical infrastructure evaluation rather than a more focused post flood building related framework. This study aims to address this gap by offering technical perspectives on post-flood damage assessments during the initial recovery stages of disasters. This variation in research activity is further illustrated in Figure 2.4, which presents the distribution of flood-induced damage studies across different countries.

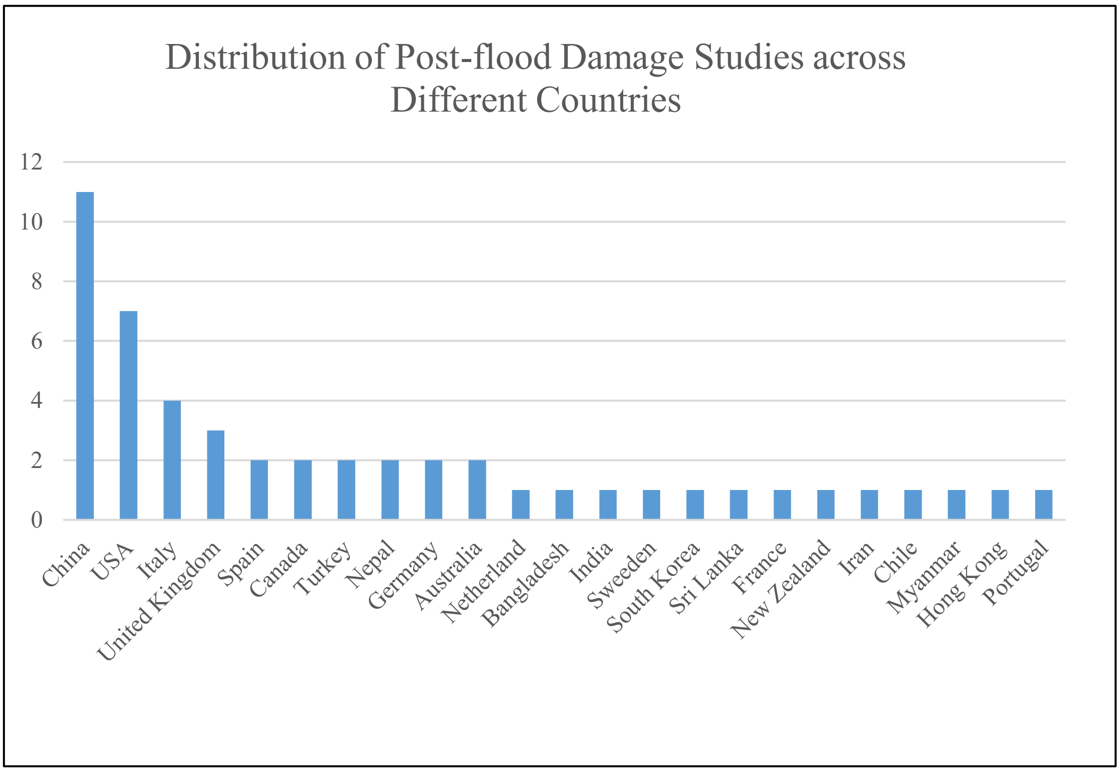

Figure 2.4 Distribution of Post-Flood Damage Studies across Different Countries

Globally, the impact of floods on buildings varies depending on geographic location, infrastructure conditions and climate characteristics (Kundzewicz et al., 2019; Najibi & Devineni, 2018). These differences also influence how countries approach flood damage assessment, particularly in terms of research focus and data availability. Some countries such as China have produced a large volume of research on post-flood damage assessment. This research focus is likely determined by the country's frequent exposure to natural disasters, which was over 500 events between 2000 and 2019 (Lu et al., 2023). Chinese studies often examine specific structural factors such as the role of building orientation and window placement in increasing horizontal flood forces as well as the relationship between building shape and flood dynamics (Zhen et al., 2023; Zhou et al., 2022).

In contrast, research in the United States adopts a broader perspective that were aiming to mitigate the country's annual flood losses, which average $2.4 billion and account for more than 75% of federal disaster declarations (Li & van de Lindt, 2012). U.S.-based studies include the development of fragility curves, automated damage detection using machine learning and cost-benefit analyses for adaptation planning (Han & Mozumder, 2021; Nofal et al., 2020; Wang et al., 2022). The

Netherlands stands out in Europe as a notable case study, with over two-thirds of its land at risk of flooding due to its low elevation (Fulmer, 2024).

However, research output on post-flood damage remains uneven across countries. Many flood-prone regions, particularly in the Global South, face data limitations. In countries such as Bangladesh and India, comprehensive records on structural damage and flood characteristics are scarce (Haque et al., 2023). Jia et al. (2023) argues in assessing flood risk at cultural heritage sites due to limited regional data. It is further supported by (Lin et al., 2021) which states that data limitations include building function and drainage system upgrade plans. Similarly, in Germany, post-disaster assessments are not mandatory by law, which limits the availability of data on the severity of losses and damages caused by extreme flood (Birkmann et al., 2023).

2.8 Damage Attributes

The attributes influencing flood damage are generally classified into two categories, impact (hazard) and resistance (vulnerability) parameters (Lazzarin et al., 2022; Sulong & Romali, 2022; Thieken et al., 2005). Impact factors include hydrological elements such as flood depth, duration and velocity. On the other hand, resistance factors involve the physical properties that affect the ability to withstand stress (Sulong & Romali, 2022). This classification is widely used in building-scale flood damage modelling, where exposure is typically assumed as analysis is conducted on structures already affected by flooding. However, at larger such as spatial scales, exposure becomes a critical independent factor. For example, as illustrated in Figure 2.5, Zhou et al. (2017) proposed a conceptual framework in which hazard, exposure and vulnerability jointly influence flood damage. Using U.S. state-level data, their study demonstrated that including indicators such as GDP, population density and land use improved model performance, with up to 76% of flood damage variation explained in certain states.

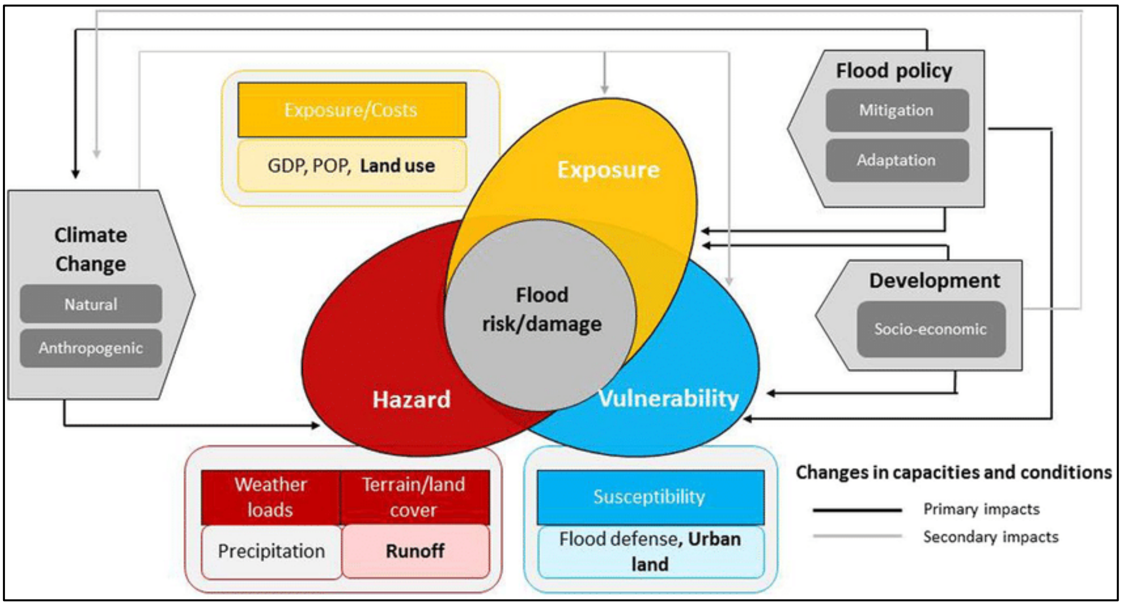

Figure 2.5 Conceptual Framework for Analyzing Flood Damage Variation Including Hazard, Exposure and Vulnerability Components (Zhou et al., 2017)

Based on the literature contexts, exposure is considered a precondition, which is the building under analysis is already exposed to flooding. Therefore, the focus shifts to how the intensity of the flood event (impact) interacts with the structural capacity (resistance) to produce observable damage. This approach allows for a more direct examination of the damage mechanism without including higher-level spatial or socio-economic considerations typically associated with exposure (Sulong & Romali, 2022).

Recent studies have made efforts to group the factors to be used in flood assessment. However, there is still no clear agreement on which attributes are most critical and how to integrate them consistently across different assessment frameworks (Birkmann et al., 2023; Figueiredo et al., 2021). This disagreement has led to different methods and variable choices across studies. For example, Çal and Ciravoğlu (2025) proposed a framework that included 51 building-scale indicators including physical attributes such as foundation height, construction material, external openings and roof type. In contrast, Paulik et al. (2024) from an empirical study in New Zealand concluded that hydraulic factors such as flood depth were significantly induced more damage than structural factors which they found a limited correlation between story count or frame type and observed flood damage. Other studies, however focused on more concise sets of building indicators such as material, elevation, size, opening, height and number of floors. Their conclusion remains different which the attributes were argued as a more critical role hydraulic factors (Capparelli et al., 2023; Santos et al., 2024).

A review by Ziari et al. (2023) further supports the notion as the author argued that many flood resilience models miss essential technical indicators at the building scale which are critical to accurately assessing damage. To bridge these gaps and guide the development of a clearer and more applicable post-flood assessment frameworks, this review organizes the relevant variables into four key categories: building attributes, hydraulic and flow factors, environmental influences and non-building attributes. The categories provide a structured basis to evaluate how different attributes contribute to overall flood damage. The following sections will explore each of these groups in more detail, with a focus on their relevance to post-flood damage assessment.

2.8.1 Building Attributes

Building response to flooding depends on factors such as structure, design and materials context. Recent research shows that specific features of a building can significantly influence the extend of the damage. For instance, multi-story buildings may buckle under the uneven pressures of floodwaters (Dalgic et al., 2023), or window openings may amplify damage by allowing flood forces to enter (Bertsch et al., 2022; Feng et al., 2022). Even aspects like floor design can increase a building's susceptibility to damage (Oubennaceur et al., 2019). The vulnerability of a building also depends on factors such as the number of stories a building has (Izquierdo et al., 2021; Shrestha et al., 2021a), the materials used (Haque et al., 2023; Shrestha et al., 2021a) and even the age of the building (Capparelli et al., 2023; Paulik et al., 2023). Understanding these factors allows us to categorize the attributes into three (3) main categories: structural components, design and layout and building materials.

2.8.1.1 Structural Components

A building's structural components are the physical elements that support its weight, as well as any additional loads the building carry (Team, 2024). These structural components are divided into two categories. The superstructure, located above ground (floors, walls, roofs, columns) and the substructure (foundation, basement), which is situated below ground (Govalkar, 2024). Substructure damage from floods is primarily related to foundation instability and water penetration below ground (Toll et al., 2012) while superstructure damage typically involves water-related deterioration of the building's visible elements above ground (Custer & Nishijima, 2015). Figure 2.6 illustrates a typical cross-section of a house, including superstructure and substructure components relevant to load transfer and flood exposure.

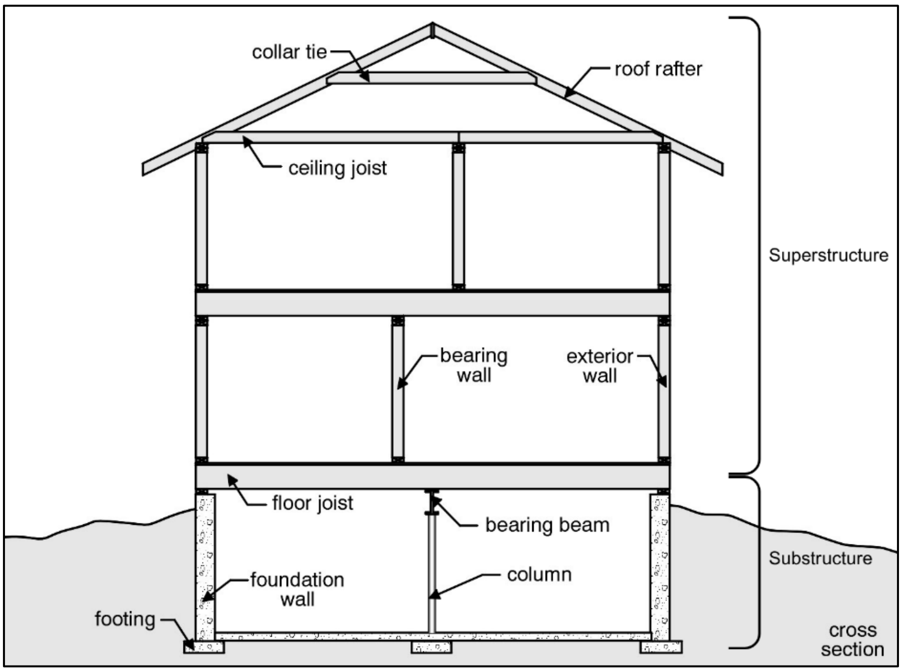

Figure 2.6 Cross-Sectional Diagram of a Typical House Structure

The way these structural components are designed such as the number of stories, framing system and foundation type give an important role in how a building responds to stress. For example, Izquierdo et al. (2021) demonstrated through analytical fragility modelling that certain configurations, particularly one or two-story reinforced concrete (RC) frames with concrete block infill or regular-shaped multi-story RC structures show reduced susceptibility to structural failure. On the other hand, Macuha (2023) through their empirical assessment of school buildings in Metro Manila found that structural damage was largely absent even during high flood depths (up to 10 m). Instead, non-structural components and internal finishes were damaged the most with the damage ratio decreasing as building height increased from 23.6% for one-story buildings to 15.02% for four-story structures. Dalgic et al. (2023) offer a more complex perspective by analysing component level fragility particularly on floor systems. Their studies found that floors in timber buildings displayed a 100% failure probability at 2.5 m flood depth and even concrete floor systems showed 50-80% probability of failure at 3.0 m depending on detailing and floor to wall connection.

Taken together, these studies concluded that although building structural components influence is highly context-dependent, it is still one of the most important components for assessing flood damage and essential for understanding building's resilience. Some of the attributes that were consistently used across different studies were noted, particularly number of stories. Studies such as Macuha (2023) and Dalgic et al. (2023) consistently show that taller buildings generally have lower damage ratios due to their reduced exposure to floodwater on upper floors. Research by Del Zoppo et al. (2022), Lonetti and Maletta (2018) and Luo et al. (2020) emphasizes the critical importance of the framing system even though each studies adopts distinct analytical approaches and scopes. The attributes and other notable one are summarized in Table 2.5.

2.8.1.2 Design and Layout

The design and layout of a building in determining flood damage has been well-documented. However, scholarly opinions vary regarding its overall significance and relative weight compared to other structural or environmental attributes. Wüthrich et al. (2020) and Zhen et al. (2023) strongly emphasize that building orientation significantly affect how floodwaters flow around the structure and influencing hydrodynamic forces. Wüthrich et al. (2020) used computational fluid dynamics (CFD) simulations and found that a building rotated 30° from the main flow direction experienced 1.2 to 1.4 times higher horizontal forces compared to a building aligned parallel to the flow. Similarly, Zhen et al. (2023) conducted flume experiments on scaled building models and reported that peak hydrodynamic pressure increased from 1.8 kPa to 2.4 kPa as building orientation shifted from 0° to 45° relative to the incoming flow. Both studies concluded that buildings aligned parallel to the flood direction are subject to reduced resistance and lower impact while angled or perpendicular configurations significantly increase the lateral forces.

This is further supported by Zhu et al. (2023) who showed that urban block arrangements and building clusters influence the direction and depth of water flow, inducing that certain layout types more prone to internal water intrusion. Figure 2.7

illustrates five (5) typical urban layout configurations in Beijing, China that were used by the study to analyse the influence of building arrangement on floodwater behaviour. According to Zhu et al. (2023), the New Hybrid layout (bottom right) was found to be the most vulnerable to flood impacts due to its dense building arrangement and obstructed drainage paths.

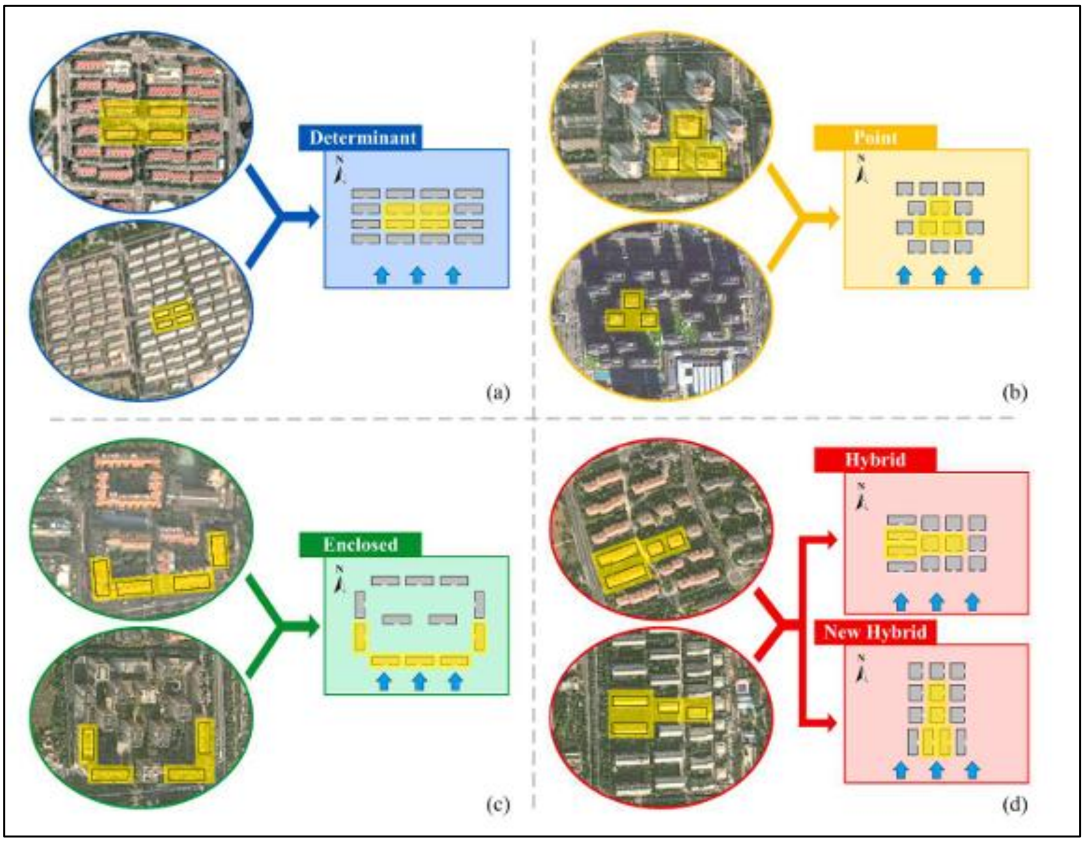

Figure 2.7 Classification of Typical Urban Residential Layout Types and Their Influence on Floodwater Movement. The Layouts Include (A) Determinant, (B) Point, (C) Enclosed and (D) Hybrid and New Hybrid (Zhu et al., 2023)

However, some researchers argue that while design and layout do influence flood behaviour, their effect may be secondary to other dominant factors. Jansen et al. (2020) in a controlled study of three residential building types in the Netherlands found that wall thickness and reinforcement type were more decisive than layout in determining structural performance. Similarly, Del Zoppo et al. (2022) emphasized the importance of accurate geometric input in structural failure analysis. The study notes that variations in exterior infill wall thickness from 120 mm to 200 mm changed collapse probabilities by up to 42%, even when building orientation and layout were held constant.

The placement of structural openings such as windows and doors has also been studied as a factor in determining internal flood damage. The height and placement of openings can act as entry points for floodwaters and effecting the amount of internal damage (Bertsch et al., 2022; Dalgic et al., 2023; Feng et al., 2022). Bertsch et al. (2022) reported that buildings with ground-level openings experienced 30-45% greater internal water depths, while Dalgic et al. (2023) demonstrated that unreinforced openings could lead to a 30-50% reduction in wall strength, thus increasing the risk of structural failure. Similarly, Feng et al. (2022) showed that openings placed within 0.3 m of ground level and aligned with flow direction could result in up to 70% higher inflow velocity that accelerates internal inundation.

Wüthrich et al. (2020) expanded on these findings by experimentally analysing the effects of façade permeability and building orientation on hydrodynamic forces. Figure 2.8 shows the test setup using different cube configurations and their relative exposure to flood. Specifically, cubes with 60% opening ratio at 45° orientation experienced up to a 30% reduction in drag force compared to sealed cubes but with significantly higher internal flow complexity and greater risk of local structural instability.

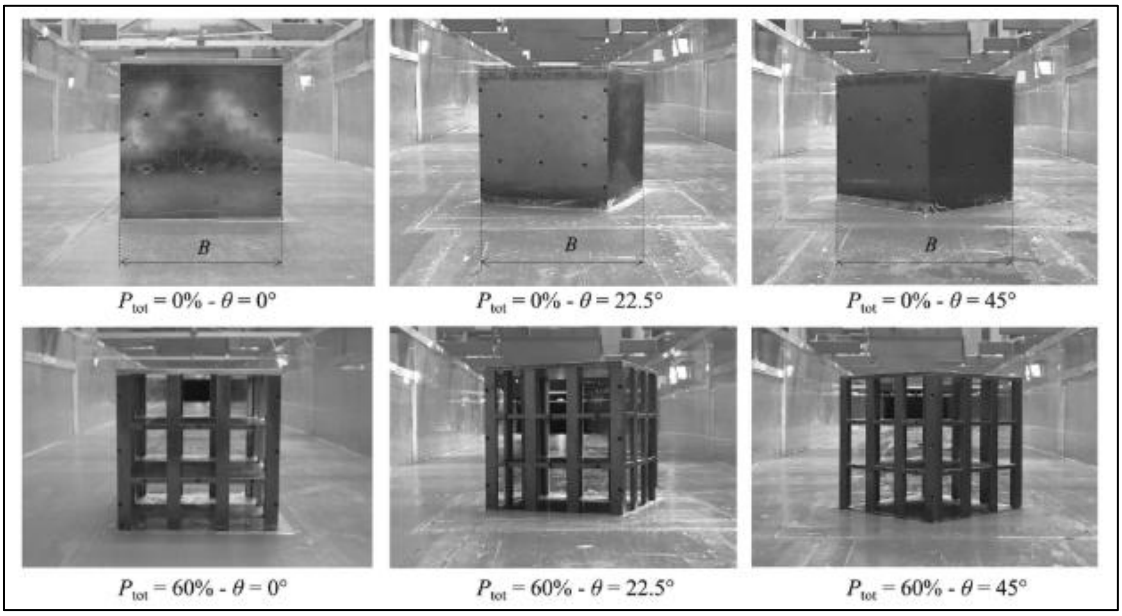

Figure 2.8 Experimental Setup from Wüthrich et al. (2020) Using Six Cube Models Tested at Different Façade Opening Ratios (Ptot) and Orientation Angles (θ) Relative to Flood Flow Direction

Although all three studies agree that opening is an important attribute in flood damage assessment, they all differ on the mechanism of damage. Dalgic et al. (2023)

argue that the structural role of openings as a stress concentrator is more critical than the water entry function. However, study by Bertsch et al. (2022) don't explore how opening affect the strength of a building structure at all. Feng et al. (2022) on the other hand suggests that water entry function can induce damage even if the building itself remains structurally strong. These suggests that opening influence varies depending on the methodological perspective and the specific mechanisms being analysed.

2.8.1.3 Building Material

One of the most important attributes considered in this study is the analysis of construction materials as their physical and mechanical properties significantly influence a structure's flood resilience (Izquierdo et al., 2021). The study explores how different materials, from wood to concrete respond to flood conditions. Various research response of different construction materials to flood conditions provides valuable insights into their specific weaknesses and how they affect the structural integrity of buildings (De Iasio et al., 2023; Figueiredo et al., 2021). Most research focuses on materials such as wood (Nofal et al., 2020; Xing et al., 2023), concrete (Del Zoppo et al., 2022; Tiwari et al., 2023; Xing et al., 2023) and masonry (Luo et al., 2020) to analyse their behaviour when exposed to waterborne debris impacts and high strain rates.

For example, wood is highly susceptible to moisture-induced swelling, that can go up to 30% loss in compressive strength and significant dimensional distortion when exposed to high humidity or standing water for prolonged periods (Capparelli et al., 2023). In the case of masonry walls, Figueiredo et al. (2021) found that masonry walls with a height more than 20 times their thickness could start to collapse under water pressure as low as 1.5 kPa. Lonetti and Maletta (2018) also found that as floodwaters velocity reach from 1.0 to 3.0 m/s, the pressure on buildings can increase by more than 40%, especially if the materials used are weak or poorly connected. Therefore, the selection and proper use of building materials are essential in minimizing flood damage and improving overall flood resilience.

Structures constructed with substandard materials such as poles, daga (mud-mixed plaster), plastics, tents and wooden or metal boards are at a higher risk of being swept away or heavily damaged by floodwaters (Mudefi, 2023). This is demonstrated by Haque et al. (2023) and Izquierdo et al. (2021) who assessed flood vulnerability that includes building materials as primary attributes. Haque et al. (2023) found that 86% of flood-affected households in the sample area were built using low-durability materials such as tin sheets, bamboo and unreinforced timber. Similarly, Izquierdo et al. (2021), demonstrated that informal or substandard urban dwellings had a 50% probability of moderate-to-severe damage at just 0.5–1.0 m of flood depth, whereas engineered reinforced concrete buildings showed far greater resilience, with similar damage only occurring beyond 1.5 m depth. Figure 2.9 shows four typical residential house types in the floodplain areas of the Teesta River Basin, Bangladesh. These include (a) BB type - bamboo structure with bamboo cladding, (b) BBC type- bamboo frame with bamboo and corrugated iron cladding, (c) BC type- bamboo frame with full corrugated iron sheet cladding and (d) MC type- timber frame with metal cladding.

Figure 2.9 Typical Residential House Types in the Teesta River Floodplain, Bangladesh: (A) BB, (B) BBC, (C) BC and (D) MC Type (Izquierdo et al., 2021)

In contrast, masonry walls with double brick thickness are widely used in residential and commercial buildings due to their enhanced load-bearing strength and structural stability, with up to 40% higher resistance to lateral forces than normal thickness (Asad et al., 2024). The Concrete Damage Plasticity (CDP) model is often used to analyse the behaviour of concrete and masonry materials during floods (Capparelli et al., 2023). Studies by De Iasio et al. (2023) emphasize how material properties such as tensile strength and strain rates directly impact a building's susceptibility to the structural response due to flood damage. Collectively, these findings show that analysing specific behaviours of masonry and concrete under flood stress allows for the development of more accurate models and better material choices.

All the significant building-related attributes discussed in the literature have been synthesized and presented in Table 2.5. The table summarizes the key attributes from the literature that are most important for building resilience to flooding. These attributes were selected not only based on the frequency of their appearance across relevant studies but also on the depth of empirical evidence and analytical validation supporting their impact. The table organizes the attributes into three categories: structural components, building design and layout and building materials. This structured classification offers a better understanding of how various attributes operate independently, thus provide a foundational framework for a better damage assessment strategy.

Table 2.5
Building Characteristics Significant Attributes

Significant attributes	Attribute Class	Description	Subcategory	References
Building Attributes	Structural attributes	Physical characteristics of a building that contribute to its ability to withstand stress	Number of Stories	(Capparelli et al., 2023; Dalgic et al., 2023; Del Zoppo et al., 2022; Guo et al., 2022; Oubennaceur et al., 2019; Shrestha et al., 2021a; Xing et al., 2023; Ziari et al., 2023)
			Framing system	(Del Zoppo et al., 2022; Lonetti & Maletta, 2018; Luo et al., 2020)
			Foundation type	(Del Zoppo et al., 2022; Guo et al., 2022; Nofal & van de Lindt, 2020; Nofal et al., 2020; Olmez & Deniz, 2023)
			Wall thickness	(Asad et al., 2024; Capparelli et al., 2023; Dalgic et al., 2023; Del Zoppo et al., 2022; Jansen et al., 2020; Postacchini et al., 2019)
			Building age and condition	(Mobini et al., 2021)
	Building Design	Overall arrangement and configuration of a structure's physical	Orientation	(Jansen et al., 2020; Wüthrich et al., 2020; Zhen et al., 2023)
			Building Opening	(Dalgic et al., 2023; Haghighatgou et al., 2022; Wüthrich et al., 2020; Zhen et al., 2023; Zhu et al., 2023)
			Building dimension	(Haque et al., 2023; Zhu et al., 2023)

		features		
	Building Material	Substances used in the construction of a building's elements	Material type	(Figueiredo et al., 2021; Haque et al., 2023; Paulik et al., 2023; Postacchini et al., 2019; Shrestha et al., 2021a; Xing et al., 2023; Ziari et al., 2023)

2.8.2 Flow and Hydraulics

Floodwater behaviour is fundamental to determine the type, location and extent of damage. The attributes are different to building characteristics which represent external forces acting on structures (Zhou et al., 2017). The nature of moving water with a combination of sediment, debris and contaminants impose complex loads that affect both structural stability and material degradation. Recent studies have emphasised that not all water-related damage is due to depth alone. Factors such as flow velocity, turbulence and debris impact also critically influence flood severity (De Iasio et al., 2023; Del Zoppo et al., 2022; Luo et al., 2020). Based on careful categorization, this section groups flow and hydraulic attributes into three (3) main subcategories: hydraulic factors, solid and contamination loads and hydrological factors. The following subsections examine each group in depth to provide insight into their mechanisms and the influence on building damage.

2.8.2.1 Hydraulic Factors

Hydraulic factors involve the behaviour of water as it flows through channels or systems (Gupta, 2016). These include characteristics such as flow depths, velocities and the interaction of water with physical boundaries, which are analysed through equations involving conservation of mass and momentum. Hydraulic factors include variables such as flow velocity, pressure and turbulence which alter the hydraulic forces experienced by buildings during flooding. In the context of post-flood damage, higher flow velocities are often associated with increased erosive forces (Del Zoppo et al., 2022). Water depth and flow velocity are commonly adopted from previous experiments to calculate the impact force on the building model (Del Zoppo et al., 2022; Zhen et al., 2023).

Previous research has demonstrated a positive correlation between increased flow velocities and the severity of damage to building foundations and structural components (Luo et al., 2020). In one of the studies, the characterization of extreme flash flooding in Europe reported that flash flooding can reach maximum velocities of up to 10 km/h, with the most common velocity range falling between 2 km/h and 6 km/h (Asad et al., 2024). The pressure exerted by flowing water plays a crucial role in influencing the structural response of buildings. Particularly during peak flow periods, elevated pressure has the potential to induce structural deformations and threaten the integrity of building materials, as indicated by studies (Zhou et al., 2022). Lonetti and Maletta (2018) explained the role of pressure in the context of pressure distributions applied to the structural system due to fluid-structure interaction.

Some variation however exists based on the role of pressure distribution in damage assessment. Zhou et al. (2022) argue that elevated pressure up to 2.5 kPa is a primary factor in inducing material deformation during peak flows. Their numerical simulations emphasize pressure as a standalone hazard, even in the absence of high velocities. In contrast, Lonetti and Maletta (2018) suggest that pressure-related damage becomes significant only when coupled with turbulent conditions or specific structural geometries. Their fluid structure interaction models show that uniform pressure alone does not always produce substantial damage unless flow turbulence or oscillation is introduced. Moreover, Luo et al. (2020) adds a structural focus by showing how hydraulic variables affect foundation behaviour. They note that higher velocities at 2.0 m/s led to foundational instability and base cracks. This contrasts with Zhen et al. (2023), who focus more on superstructure interaction with water. These differing focus shows that authors diverge on which building components are most at risk and how different hydraulic conditions interact with structural variables.

2.8.2.2 Solids and Contaminants

Damage assessment from the perspective of solid properties focuses on two key factors which are sediment transport and debris movement. Research conducted by Contreras and Escauriaza (2020) used a coupled hydraulic and sediment transport model to estimate sediment deposition patterns during a flood event in Santiago, Chile. The results showed that areas with sediment concentration above 40% were particularly prone to long-term obstruction of drainage systems and increased structural vulnerability. Figure 2.10 illustrates the spatial distribution of sediment transport probability where red zones indicate a 60% probability of sediment deposition. As floodwaters recede, sediment accumulation not only clogs water pathways but also increases the density and viscosity of the water during peak flow (Contreras & Escauriaza, 2020; Croke et al., 2013).

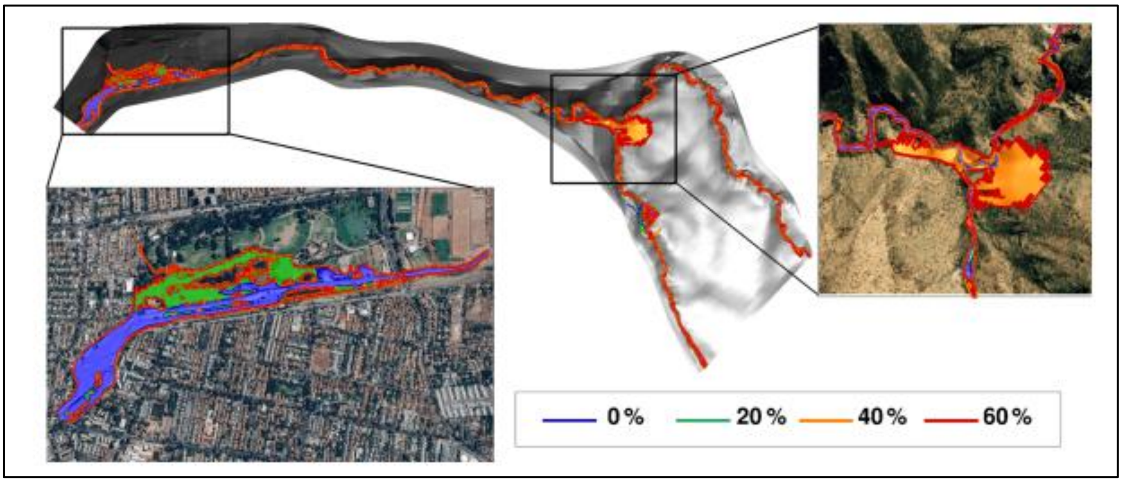

Figure 2.10 Spatial Distribution of Sediment Transport and Deposition Probability in a Floodplain along the Mapocho River, Chile (Contreras & Escauriaza, 2020)

In contrast to the nature of sediment which are predictable as indicated by studies, debris often produce unpredictable outcome. Objects such as logs, furniture and vehicles carried by the current can act as forces and can even create makeshift dams. Luo et al. (2020) quantified this by showing that debris impacts can exert concentrated loads sufficient to cause cracks in reinforced concrete and masonry walls, especially when debris velocity exceeds 2.5 m/s. Similarly, De Iasio et al. (2023) emphasized that localized stress can lead to severe out-of-plane failures in masonry, particularly in older or unreinforced walls. They documented crack propagation patterns correlating with impact energy, noting that walls without confinement measures suffered more damage under the same debris force. Additionally, debris has the potential to obstruct drainage channels and inlets, leading to high change for another flood occurrence (Izquierdo et al., 2021).

2.8.2.3 Hydrological Factors

Hydrological factors refer to aspects related to the movement, distribution and transformation of water within the hydrological cycle (Gupta, 2016). It explains the origin of flood, intensity and potential effects on structures. From analysis of previous research, three essential components that involvedly contribute to the hydrological factors, namely precipitation, river discharge and pressure distribution. Lin et al. (2021) emphasized that in densely populated regions, extreme rainfall events are becoming more frequent and intense, driven by climatic changes. They reported that high-intensity rainfall in urbanized areas can exceed 80 mm/hr, significantly increasing runoff potential and overwhelming drainage systems. Their study emphasizes that in areas with high population density, heavy rainfall events are more frequent, intense and prolonged. This assertion is further supported by (Piyumi et al., 2021) whose study explores into the variations of precipitation in using seven precipitation scenarios to show that rainfall variability increases flood risk by as much as 35% under intensified climate models.

Monitoring river discharge and predicting potential surges is also necessary for anticipating floods and implementing strategies to protect vulnerable buildings. The interaction between discharge through buildings and surrounding water flow can cause consistently high flow depths on the downstream side (Wüthrich et al., 2020). Additionally, research highlights how the design and structure of buildings can affect water discharge (Zhou et al., 2022). Pressure distribution, especially in the context of fluid-structure interactions, describes how hydraulic forces are spread across building elements. Lonetti and Maletta (2018) studies exemplify this, underscoring the spatial distribution of pressures and their role in inducing damage to structures.

All relevant flow and hydraulic attributes identified from the literature have been compiled and outlined in Table 2.6. The table highlights the most critical factors affecting building vulnerability to flooding, selected based on their frequency of discussion in previous studies and the robustness of empirical and analytical evidence supporting their relevance. These attributes are grouped into three main categories: hydraulic factor, solid properties and hydrological factors. This categorization provides a clearer understanding of the mechanisms through which water dynamics contribute to flood damage and aids as a foundational reference for developing more structured and holistic post-flood damage assessment approaches.

Table 2.6
Flow and Hydraulics Significant Attributes

Significant attributes	Attribute Class	Description	Subcategory	References
Flow and hydraulics attributes	Fluid Flow	Movement of water during flood event	Flow velocity	(Capparelli et al., 2023; Del Zoppo et al., 2022; Haque et al., 2023; Jansen et al., 2020; Lonetti & Maletta, 2018; Luo et al., 2020; Olmez & Deniz, 2023; Peng et al., 2021; Postacchini et al., 2019; Wüthrich et al., 2020; Zhen et al., 2023; Zhu et al., 2023)
			Pressure distribution	(Asad et al., 2024; Capparelli et al., 2023; De Iasio et al., 2023; Del Zoppo et al., 2022; Jansen et al., 2020; Lonetti & Maletta, 2018; Luo et al., 2020; Olmez & Deniz, 2023; Postacchini et al., 2019; Tien Bui et al., 2019; Zhen et al., 2023; Zhu et al., 2023)
			Turbulence	(Lonetti & Maletta, 2018; Peng et al., 2021; Zhu et al., 2023)
	Solid Properties	Characteristics and behaviours of sediment and debris carried by floodwaters	Sediment transport	(Capparelli et al., 2023; Izquierdo et al., 2021)
			Debris movement	(Capparelli et al., 2023; De Iasio et al., 2023; Del Zoppo et al., 2022; Izquierdo et al., 2021; Olmez & Deniz, 2023; Zhen et al., 2023)
	Hydrological Parameter	Measurable	Precipitation	(Izquierdo et al., 2021; Jia et al., 2023; Kim & Kang, 2023; Lin et

	characteristic of water within hydrological cycle	Intensity	al., 2021; Piyumi et al., 2021; Zhang et al., 2023)
		Flood discharge	(Izquierdo et al., 2021; Oubennaceur et al., 2019; Thapa et al., 2020; Wüthrich et al., 2020; Zhu et al., 2023)
		Duration	(Haque et al., 2023; Lu et al., 2023; Nofal & van de Lindt, 2020; Nofal et al., 2020; Piyumi et al., 2021; Zhou et al., 2022)

2.8.3 Environmental Factors

Although hydrological and hydraulic factors have received considerable attention, there is a growing suggestion for more research into other potentially significant contributors to flood damage. (Spekkers et al., 2015). A building's ability to withstand flooding is largely determined by its own characteristics, but the surrounding environment also plays a crucial role. For instance, buildings located near water bodies such as lakes or rivers are more vulnerable to flooding (Xing et al., 2023). The proximity of a structure to a possible source of floodwater directly correlates with the likelihood of being flooded (Hossain & Meng, 2020).

2.8.3.1 Topography

Topography is also an important factor in assessing flood risk (Jia et al., 2023) as it is considered as one of the common drivers in flood risk analysis (Lin et al., 2021; Marín-García et al., 2023; Thapa et al., 2020). Guo et al. (2022) highlighted that low-lying areas and coastal regions are particularly at risk of flood damage, while higher-altitude locations tend to be less susceptible, although severe floods can still impact these areas. In mountainous regions, the stability of slopes can be affected by floods, resulting in landslides and harm to buildings (Luo et al., 2020). Although not completely reliable, (Hossain & Meng, 2020) propose that structures situated at higher altitudes are often less susceptible to floods in comparison to those located closer to sea level or in floodplains. Still, severe occurrences and concentrated inundation can still affect buildings at greater heights. The height of a structure in relation to its surroundings might still be significant, even within a certain location. Buildings located at the base of slopes or in low-lying areas are more prone to the pooling and buildup of floods (Yang et al., 2021).

2.8.3.2 Flood Zones

Several areas are assigned flood zones according on past flood occurrences and evaluations of risk. Buildings situated in flood-prone areas, as classified by United States. Federal Emergency Management (2008), are statistically more prone to floods and damage. Flood zones are commonly classified according to the extent and regularity of floods they encounter. For instance, regions labelled as "100-year flood zones" have a 1% annual probability of experiencing a flood of a specific magnitude (United States. Federal Emergency Management, 2008). Dalgic et al. (2023) highlight that the depth and speed of floods have a direct effect on the kind and extent of harm that a structure might experience. Increasing flood elevation can result in heightened structural pressures, while swifter currents can induce erosion and the effect of debris.

2.8.3.3 Site-Specific Factors

Another significant environmental factor is site specific factor, which include land use and soil type variables. According to Bertsch et al. (2022) there is an increase in impermeable surface area such as city street due to urban growth. Paved surfaces significantly heighten the risk of flooding in urban locales by overwhelming drainage systems. The prevalence of impervious surfaces leads to urban flooding, placing a strain on drainage infrastructure (Hossain & Meng, 2020). On the other hand, green areas function as natural absorbers, taking in water and reducing its effects. Soil types can increase or decrease flood risk levels. Impermeable rocks for example contribute to surface runoff, while permeable formations enhance water infiltration (Hossain & Meng, 2020). Climate and weather pattern also contribute to damage, which has led to increased frequency and height of extreme floods (Birkmann et al., 2023; Capparelli et al., 2023). Severe weather events can also interrupt the regular functioning of important facilities. Critical infrastructures (CIs) are built to endure climatic or weather-related stresses, but climate change might result in more frequent or severe potential failures, as well as exposure to new or unfamiliar dangers (Vamvakeridou-Lyroudia et al., 2020).

All key environmental attributes affecting flood risk, such as distance to water bodies, elevation, flood-prone zoning, land use patterns and soil composition have been carefully reviewed and summarized in Table 2.7. These attributes were selected based on their consistent appearance in existing studies and the strength of evidence supporting their role in influencing flood-related damage. The structured presentation of these factors provides a clearer perspective on how environmental conditions contribute to flood vulnerability and serves as a critical reference for enhancing spatial flood risk analysis and informing targeted mitigation planning.

Table 2.7
Environmental Factors Significant Attributes

Significant attributes	**Attribute Class**	**Description**	**Subcategory**	**References**
Environmental Factor	Environmental Factor	Surrounding environment that influence the susceptibility of structures	Proximity to water bodies	(Oubennaceur et al., 2019; Qin et al., 2023)
			Flood zone	(Guo et al., 2022; Haque et al., 2023; Lin et al., 2021; Oubennaceur et al., 2019; Ziari et al., 2023)
			Climate	(Birkmann et al., 2023; Han & Mozumder, 2021; Hossain & Meng, 2020; Jia et al., 2023; Kim & Kang, 2023; Nkeki et al., 2022; Piyumi et al., 2021; Zhang et al., 2023; Zhou et al., 2022; Zhu et al., 2023; Ziari et al., 2023)
			Soil type	(Guo et al., 2022; Hossain & Meng, 2020; Jia et al., 2023; Nkeki et al., 2022; Piyumi et al., 2021; Zhang et al., 2023; Ziari et al., 2023)
			Surface permeability	(Bertsch et al., 2022; Birkmann et al., 2023; Han & Mozumder, 2021; Jia et al., 2023; Kim & Kang, 2023; Zhang et al., 2023; Zhu et al., 2023)
			Site-specific factors	(Hossain & Meng, 2020; Jia et al., 2023; Kim & Kang, 2023; Lin

				et al., 2021; Lu et al., 2023; Nkeki et al., 2022; Piyumi et al., 2021; Zhang et al., 2023; Ziari et al., 2023)
	Topography	Overall shape and features of a land surface	Altitude	(Bertsch et al., 2022; Hossain & Meng, 2020; Kim & Kang, 2023; Nkeki et al., 2022; Piyumi et al., 2021; Zhang et al., 2023; Zhou et al., 2022; Ziari et al., 2023)
			Slope	(Haque et al., 2023; Hossain & Meng, 2020; Jia et al., 2023; Kim & Kang, 2023; Lin et al., 2021; Lu et al., 2023; Oubennaceur et al., 2019; Piyumi et al., 2021; Zhang et al., 2023; Ziari et al., 2023)

2.8.4 Non-Structural Components

Non-structural components refer to elements of a building that do not contribute to its load-bearing capacity but still experience significant damage after floods. Interior components such as movable furniture, equipment and personal belongings form an important attribute of "building content". These items are located inside the building and are physically separate from the permanent structure, yet they often represent a substantial share of total loss during flood events.

Several studies highlighted that damage to interior contents can be severe even when the main structure remains standing. (Figueiredo et al., 2021) show that in many buildings interior contents are highly exposed to water, sediment and contaminants once floodwaters enter the premises Similarly, in terms of monetary impact Shrestha et al. (2021a) estimate expected annual damage (EAD) without any adaptation at about 2.27 billion kyats for buildings and 1.73 billion kyats for assets, meaning that contents contribute roughly 43% of direct residential losses at basin scale. Olmez and Deniz (2023) also shows that when interior components such as machinery, production-line equipment, interior finishes and services are damaged, total repair costs can reach up to 28% of the building's replacement cost with repair and recovery requiring on average up to 165 working days.

Although the structural frame may continue serviceable, damage to interior non-structural components can drive long business interruption and high indirect losses. The vulnerability of building contents is closely linked to their location and material properties. Items placed at ground-floor level or in basements are directly exposed to rising water levels, while porous materials such as upholstered furniture, paper records or textiles tend to absorb water and deteriorate quickly (Shrestha et al., 2021b). Electrical and electronic equipment are also sensitive to moisture and contamination, leading to functional failure even after limited water contact. These patterns are consistent with the evidence that non-structural components often account for much of the observable post-flood damage.

From a post-flood assessment perspective, treating interior contents as a distinct attribute is important for two reasons. First, contents losses are strongly associated with indirect impacts, such as loss of livelihood, disruption of essential services and loss of cultural or sentimental value. Second, including building content as a separate subcategory under non-structural components, as summarised in Table

2.8 helps to capture damage that is not reflected by structural indicators alone. Accordingly, this study adopts "Building content" as a significant non-structural attribute for post-flood damage classification and subsequent framework development.

Table 2.8
Non-Structure Component Significant Attributes

Significant attributes	Attribute Class	Description	Subcategory	References
Non-Structure Component	Interior Component	Movable furnishings, equipment and personal belongings located within a building, separate from the permanent structure	Building content	(Figueiredo et al., 2021; Olmez & Deniz, 2023; Shrestha et al., 2021a)

2.9 Post-Flood Damage-Assessment Frameworks

Several established international frameworks have been widely applied to guide post-event evaluation. The ATC-45 provides one of the most operationally relevant approaches for building evaluation following hazard events (ATC, 2004). ATC-45 establishes a tiered inspection protocol, beginning with rapid exterior and ground-level observations (e.g., erosion, scour and visible structural distress), followed by detailed engineering evaluations where necessary (Alam et al., 2025). At the initial stage, inspectors conduct exterior and ground-level checks to identify measurable damage indicators such as foundation scour or erosion, differential settlement cracks structural tilting and flood inundation levels (e.g., above 1.0 m, often associated with material degradation). Where significant damage is observed, further evaluation considers structural integrity and material performance, including reductions in strength due to prolonged water exposure (e.g., timber strength loss up to 30–50% after 48–72 hours of saturation).

The assessment outcome is then communicated using a standardised tagging system, namely Safe (Green), Restricted Use (Yellow) and Unsafe (Red) (ATC, 2004). Its criteria were developed for U.S. building types and permits direct numeric thresholds (crack widths, scour depths) may need local calibration and its placard system assumes formal building oversight. For Malaysia, ATC-45's procedures could guide field tagging system using the same logic. However, while ATC-45 provides strong engineering-based judgement at building level, it does not support multi-sector recovery planning or national-level coordination, which are present in broader frameworks such as the Post-Disaster Needs Assessment (PDNA) and the National Flood Emergency Framework (Environment & Affairs, 2014; European Union et al., 2013).

Another example is the FEMA's PDA framework that establishes a standardised damage documentation process for disasters (FEMA, 2020). Damaged buildings are classified using simple categories such as affected, minor, major or destroyed that tied to threshold criteria such as repair cost as a percentage of value (e.g. Minor = <50% loss, Major = 50–100%, Destroyed = total loss) (Alam et al., 2025). For instance, the PDA guidance suggests counting houses "Major" if heavy structural damage makes them unsafe to occupy. This common taxonomy means that damage tallies from different counties or disasters can be aggregated and compared consistently, which is vital for validating aid requests and identifying hotspots. However, survey methods are flexible from surveys to satellite imagery as long as the results fit the standardized template (FEMA, 2019). In practice, PDA data often populate GIS layers or spreadsheets that show damage gradients and cost estimates (Singh & Hoskere, 2023). The PDA process does not specify engineering-level detail or safety ratings such as two houses might both be "Major" even if one failed from foundation scour and another from a collapsed wall. Thus, FEMA PDA complements ATC-45 by capturing impact extent but lacks depth in hazard-mechanism interpretation. Table 2.9 shows the comparison of these frameworks in terms of their purpose, scope, key components and applicability in post-flood damage assessment.

Table 2.9
Comparative Table of Core Frameworks

Framework	Purpose	Scope	Key Components	Strength	Limitations	Typical Use Cases
Preliminary Damage Assessment Guide (FEMA, 2020).	Standardizes how officials collect, validate, quantify and document damage/impacts to support assistance/declaration decisions.	Early post-event covers households and public infrastructure impacts.	Structured process and emphasizes documenting cause, location and details of damage and validating observations.	Strong "minimum dataset" discipline for comparability and aggregation across jurisdictions.	Primarily program/assistance oriented, not a structural engineering inspection manual.	Rapid flood impact documentation of damaged homes and public assets to prioritize resources and justify support requests.
ATC-45 Field Manual (ATC, 2004)	Enables rapid decisions on whether flood/wind-affected buildings are safe for use or require restricted/prohibited entry.	Building-level safety evaluation for windstorms and floods. Designed for field deployment by building officials/inspectors/engineers.	Two core procedures: Rapid Evaluation and Detailed Evaluation; rapid steps include exterior survey, ground/geotechnical checks. Limited entry if necessary, criteria-based judgement, then posting.	Flood-specific mechanisms are explicit supporting repeatable field judgement under time pressure.	Does not produce sectoral "needs" outputs by itself; needs linkage to PDA/PDNA-style aggregation for recovery planning.	Post-flood building tagging for controlled re-entry. Prioritizing detailed engineering inspections and communicating restrictions to occupants/responders.
Sendai Framework for Disaster Risk	Global DRR framework that requires risk understanding,	Policy-level, multi-hazard, national-to-local strategies and monitoring.	Four priorities for action and targets. Priority 4 emphasizes preparedness for effective response and BBB in	Provides the standardizing justification for designing damage	Not operational: does not specify inspection forms, safety thresholds,	BBB and DRR monitoring to motivate standardized damage/impact

Reduction 2015–2030 (UNDRR, 2020)	governance, risk investment and preparedness.		recovery/rehabilitation/reconstruction.	assessments as reusable DRR evidence	or engineering procedures and requires translation into methods and datasets.	datasets.
Post-Disaster Needs Assessment Guidelines: Volume A (European Union et al., 2013)	Harmonizes post-disaster assessment for damages, losses and recovery needs, producing a recovery strategy and costed recovery framework.	Multi-sector, national/large-event scale. Sits after immediate life-saving response and designed to reduce fragmented parallel assessments.	Core elements include baseline information, disaster effects, disaster impact and recovery strategy. Emphasizes participation/coordination and BBB without becoming a general development plan.	Clear, examiner-legible “handoff” logic from damage evidence to prioritized recovery needs and costing across sectors, compatible with BBB.	Resource- and data-intensive. Typically slower than rapid field screening and requires strong coordination capacity.	Major floods requiring structured recovery planning, inter-ministerial coordination and credible costing/priority setting.
The National Flood Emergency Framework for England (Environment & Affairs, 2014)	Strategic framework for flood emergency planning/response; emphasizes impact reporting and shared situational awareness to prioritize scarce resources.	England; flooding from multiple sources; multi-agency coordination and information flow (not an engineering inspection manual).	Defines reporting roles and timing, provides working definitions and emphasizes that early reporting enables prioritization and targeted support.	Useful governance benchmark for standardizing impact reporting and data pipelines across agencies and infrastructure operators.	Limited component-level damage-state guidance. Not designed for structural safety tagging or engineering diagnosis.	Flood impact reporting for national/local situational awareness, resource prioritization and transition into recovery management.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Introduction

This study focuses on developing a conceptual framework for post-flood damage assessment. The primary objectives are to identify the most significant classification attributes, determine appropriate damage level assessment and establish a conceptual framework for post-flood damage assessment. The variables were carefully selected based on findings from previous research to ensure their relevance and applicability. A detailed flowchart illustrates the entire research process, including the methodological framework. Overall, this chapter provides a comprehensive overview of the research methodology employed to achieve the objectives of the study issue.

3.2 Research Philosophy

A research philosophy is a set of basic ideas that guide how a research study is planned and carried out. Different research philosophies provide different ways of understanding and conducting research (Tamminen & Poucher, 2020). It depends on the suitable concepts, techniques and assumptions for use and data collecting. The choosing of specific research philosophies is influenced by the practical implications. In fact, it has the potential to yield novel and trustworthy insights into the subject of study. Put simply, it defines the study topic, methodology, data gathering, processing and analysis.

Philosophy is important because it provides a framework for understanding and making sense of the world (Williamson, 2021). It allows researchers to critically analyze and evaluate the research technique that is usable and the approach that can be applied. In order to select the methodology, the researcher must initially comprehend the objective of the research. Referring to (Bleiker et al., 2019), ensuring coherence between the philosophical stance adopted and the methodologies employed in a study is a crucial element of research quality. Nevertheless, a multitude of researchers argue that adopting more radical methods might impose limitations. Therefore, this study will be conducted using the explanatory approach in philosophy.

3.3 Research Process

In order to facilitate productive and efficient research, a medium guide was developed. This guide takes the form of a flowchart that outlines a methodological framework to aid researchers in their procedures. The research technique was designed to streamline initial planning and precisely establish the study goals. A methodological framework is a tool that guides developers through a series of steps to complete a process or task (McMeekin et al., 2020). Based on (Reed et al., 2021), methodological frameworks provides a systematic and organized way to assess the significance and reach of both positive and negative effects of research. This enables them to select an appropriate evaluation design that aligns with the particular objectives and circumstances of the assessment (Reed et al., 2021). Utilizing methodological frameworks offers a multitude of benefits. It elevates research quality, standardizes methodologies (Squires et al., 2016), optimizes result validity (Kallio et al., 2016) and enhances the consistency, reliability and accuracy of actions (Rodgers et al., 2016). Consequently, this section underscores the significance of the research's methodological framework. Figure 3.1 illustrates a comprehensive research process flowchart tailored to the methodological framework applicable to the subject of this research.

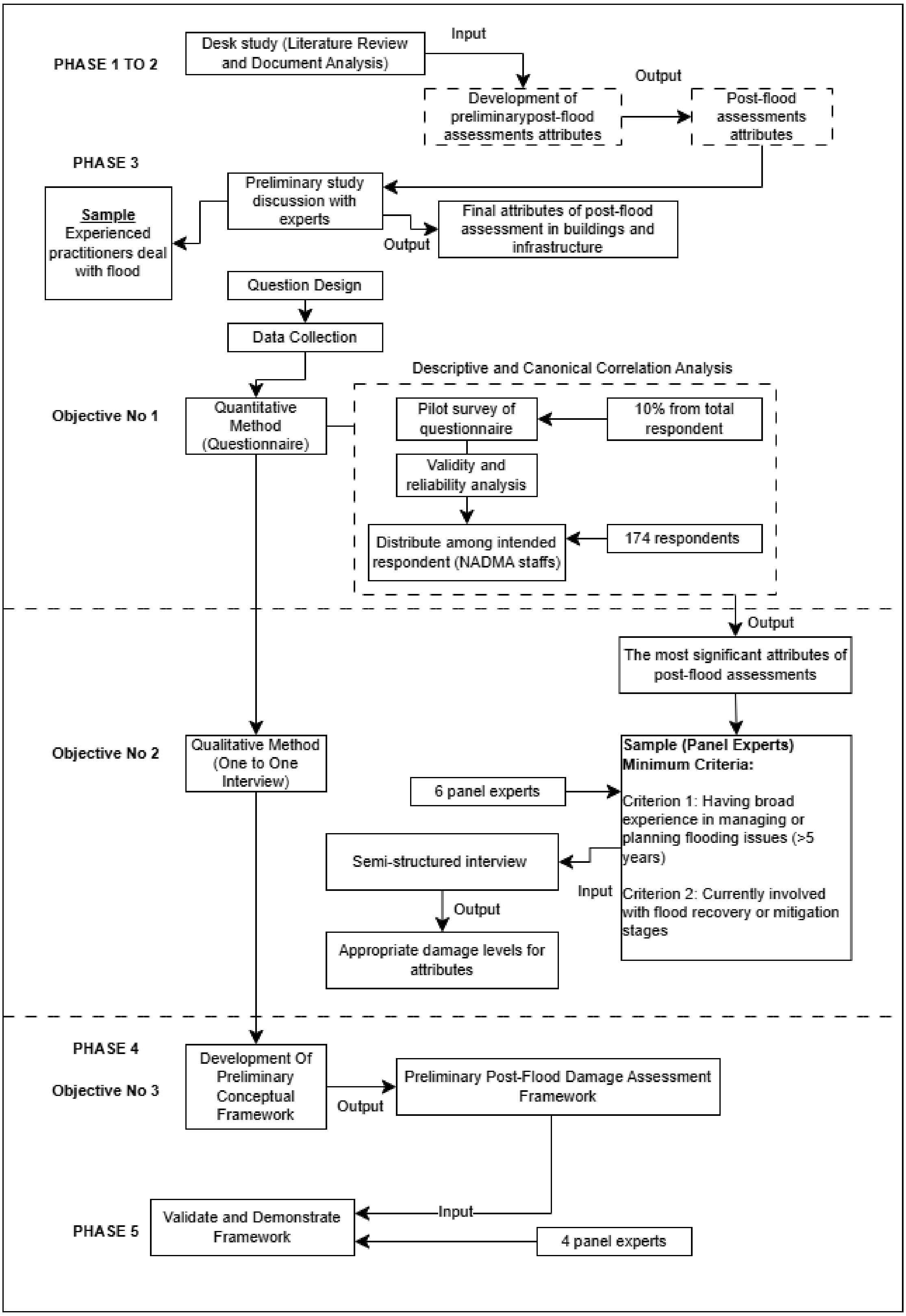

Figure 3.1 Research Process Flowchart for the Methodological Framework

The research process is divided into five (5) phases, with detailed activities outlined in each phase to achieve the research objectives. These phases are identified as Phase 1, Phase 2, Phase 3, Phase 4 and Phase 5 are explained as follows:

- Phase 1 – Desk study includes reviewing existing literature related to flood damage assessment, mitigation strategies and socio-economic factors. This includes analysing published articles, reports and case studies, as well as examining official documents such as government policies and disaster management guidelines. Papers relevant to data in specifically damage assessments, damage level, flood management and guidelines in flooding were considered. Namely Journal of Hydrology, Climate Risk Management Journal, Journal of Cleaner Production, International Journal of Disaster Risk Reduction, Progress in Disaster Science Journal, Journal of Cleaner Production, Journal of Environmental Management and Sustainable Cities and Society Journal.
- Phase 2 - Involves determination of objectives, defining scope and the limitations of the research, which focuses on the attributes in post-flood damage assessments in buildings. Based on the findings from the desk study, the study identified and organised the attributes that significantly influence post-flood damage assessment. These attributes were derived from recurring factors reported in the literature and were grouped into meaningful categories relevant to the Malaysian flood context. In this study, the assessment attributes were not selected arbitrarily but were developed through a process of literature synthesis in which related variables were reviewed, compared and consolidated into broader analytical groups. Through this process, the attributes were organised into four principal categories, namely building attributes, flow and hydraulics, environmental factors, and non-structural components. Each category represented a set of observable and assessable factors considered relevant to the classification of post-flood damage. This phase also involved aligning the identified attributes with the research objectives, particularly Objective 1, which sought to determine the most significant attributes influencing post-flood damage classification.
- Phase 3 - The questionnaire was developed directly from the assessment attributes identified in Phase 2. Each section of the questionnaire was

structured to measure the perceived significance, frequency or severity of the identified attributes in relation to post-flood damage assessment. The questionnaire design was attribute-driven where each item was constructed to represent a specific variable or attribute category established during the desk study and attribute development phase. The questionnaire was divided into sections covering respondent background, frequency of damage occurrence, severity of damage, building attributes, hydraulic factors, environmental factors and non-structural components. The design of the questionnaire was intended to ensure content relevance and logical correspondence between the literature-derived attributes and the empirical data collected from respondents. Before the actual survey was administered, a pilot study was conducted to assess the clarity, relevance and internal consistency of the instrument. The revised questionnaire was then distributed to disaster management practitioners in NADMA. The responses were analysed using SPSS Statistics to determine the significance and ranking of the attributes.

To achieve Objective 2, the framework was validated using the face validity approach which involves a semi-structured interview method. Face validity relies on subjective judgment and includes the opinions of non-researchers about the validity of the study. For instance, a specific matrix can be considered to have face validity if experts in the relevant field analyse the model and confirm that its output closely represents real-world scenarios.

- Phase 4 - In achieving Objective 3 (i.e. developing post-flood damage assessments in buildings framework), the findings from the previous phases will be integrated to structure the framework. This study adopted a mixed-method approach in which quantitative and qualitative methods were used in a complementary manner. The quantitative phase consisted of the questionnaire survey, while the qualitative phase involved semi-structured interviews with experts from NADMA, JKR, JPS and MKN. The mixed-method approach was operationalised sequentially, where the quantitative findings first identified the important assessment attributes and damage-related tendencies, and the qualitative findings were subsequently used to explain, refine and contextualise those results. This research method was important because the questionnaire alone could identify significant attributes, but it could not sufficiently explain how those attributes should be interpreted and applied in actual post-flood assessment practice. Therefore, expert interviews were conducted to obtain professional judgement on the practical meaning, relevance and usability of the identified attributes and damage levels. The findings from both methods were then integrated to develop the preliminary conceptual framework.

- Phase 5 - The validation process will evaluate the framework's functionality, key attributes, associated measures and identify areas for improvement. The validation process was carried out only after the preliminary framework had been developed, in order to assess whether the framework accurately reflected the assessment attributes and damage level considerations identified in the earlier phases. This validation was conducted through semi-structured interviews with experts from NADMA, JKR, JPS and MKN. The purpose of the validation was to evaluate the framework in terms of clarity, relevance, comprehensiveness and practical applicability for post-flood damage assessment in Malaysia. More specifically, the experts were asked to examine whether the proposed framework adequately represented the main assessment attributes, whether the attribute categories were logically organised, whether the suggested damage level assessment was appropriate and whether the framework could realistically support field-based assessment and decision-making. Feedback obtained from the experts was then used to refine the structure, content and presentation of the framework. Therefore, the validation step in this study refers to expert review of the preliminary framework, rather than validation of a statistical model or software output. This process ensured that the final framework was conceptually sound, practically relevant and consistent with the real needs of post-flood damage assessment practice in Malaysia.

3.4 Research Design

The research design serves as the comprehensive approach guiding the investigation, outlining the systematic methodology for addressing specific research issues through data collection, analysis, interpretation and presentation. This framework establishes clear parameters within which the researcher operates, employing specified methodologies and techniques.

The primary research employed questionnaire surveys and expert interviews as research methodology. The ensuing discussion outlines the research activities undertaken:

- Questionnaire Survey - This method involves collecting data from large groups of individuals that were involved in flood events, seeking their opinions, judgments, attitudes, beliefs and behaviours. Participants from NADMA respond to a set of research-related questions through various platforms such as email, WhatsApp, or Telegram. The collected data is then evaluated based on respondent answers, providing easily comprehensible insights.
- Expert Interview - Conducted with individuals possessing over ten years of experience in the disaster management, including from NADMA, JKR, JPS and MKN. This qualitative data collection method involves virtual or in-person conversations. The aim is to gather expert opinions and insights within the research scope, enriching the study with valuable perspectives from seasoned professionals. These experts played a crucial role in gathering comprehensive data for the case study area, validating variables and contributing to the development of the proposed frameworks.

Primary research involves direct engagement by the researchers. However, secondary research focuses on summarizing, collating and synthesizing previously conducted research. In contrast to primary research, secondary data is gathered from published sources that were initially collected for different purposes (Taherdoost, 2021). An example of secondary research is a systematic review, where the methodology involves a thorough analysis and assessment of current literature reviews on a specific subject, synthesizing findings relevant to the research work. For this study, secondary research data was gathered from diverse sources, including academic publications, journals, articles, books, websites, blogs, encyclopaedias, project documents, statistical databases and historical records. Secondary research materials come in various formats, such as published datasets, reports, survey findings and information from internet, library and institutional sources. Researchers, therefore, collected, evaluated, analysed and integrated secondary research to validate the research objectives.

3.4.1 Formulation of Review Question

Shaping a well-defined research question stands as a foundational requirement for initiating a successful research project, a practice commonly undertaken at the project's inception. Modern research guidelines emphasize the research question's pivotal role, positioning it as the starting point and underscoring its utmost significance (Goldschmidt & Matthews, 2022). This step is crucial as the formulation and planning of a framework pivot on the unique research problem that has been identified. This article is guided by the following questions: What most significant attributes of classifications damage assessment? What is the most appropriate damage level assessment for assessment of damage? How can a conceptual framework assist the assessment damage at post-flood event? The analysis of these questions can be effectively conducted by employing the population, concept and context framework as stated in Table 3.1.

Table 3.1
PCC (Population, Concept and Context) Framework

Criteria	**Element(s)**	**Descriptions**
Population	Disaster management practitioners in Malaysia	The individuals and groups directly involved in or affected by post-flood damage practitioners in Malaysia assessment across Malaysia. This includes federal and state agencies such as NADMA, JPS, JKR, MKN and experts with experience in flood damage assessment and disaster management operations
Concept	Post-flood damage Assessment Framework	A conceptual framework designed to evaluate and categorize the damage to buildings following a flood. This framework includes attributes, classifications and appropriate damage level assessment contributing to disaster management.

Context	Flood occurrences in Malaysia	The research is centred around major flood events that have occurred in Malaysia particularly in frequently affected states such as Kelantan, Terengganu, Pahang, Johor and Selangor. It specifically focuses on disaster management activities and post-flood damage assessment conducted after these flooding incidents.

3.4.2 Establishment of Inclusion and Exclusion Criteria

From the insights gained through an in-depth review of existing academic publications, this research first established criteria for inclusion and exclusion in regard to flood-induced damage in the Malaysian context. All information sources related to the concept within this context, particularly those highlighting the various forms of damage resulting from floods, were meticulously considered for inclusion in the review. The authors intentionally established inclusion and exclusion criteria in order to confine the scope of the search to publications written in the English language and specifically targeting the document type of “article”. A conscious decision was made to prioritise research papers and exclude other types of documents such as novels, book chapters, reports, or grey literature. The choice to refrain from imposing temporal limitations on the search was indicative of an acknowledgment of the interdisciplinary character of the subject matter. Furthermore, the search was not limited to a particular geographic region or a certain selection of academic journals, thereby enabling a thorough and extensive investigation.

Moreover, as emphasised in the section on idea and keywords, these criteria were customised to identify scholarly articles that expressly explore the occurrence of floods or disasters in which flooding acts as a secondary consequence. As a result, scholarly articles focusing on various categories of catastrophic events, such as earthquake activities, were deliberately skipped over. Consequently, the information sources selected must set firmly to addressing these specific questions. Furthermore, the study incorporated pertinent literature focusing on data related to damage assessments, damage levels, flood management and guidelines in flooding.

3.4.3 Development of Search Strategy

To encompass a broad spectrum of records, the research opted for widely used electronic databases renowned for their extensive publication sources. These comprised ScienceDirect, Scopus, Google Scholar, ResearchGate and Google. Ensuring the bibliographic extraction's reliability and accuracy involves the utilisation of a source or database that possesses high standards of identification (Herrera-Franco et al., 2020). The search strategy was established through generating a collection of terms and phrases derived from the research questions of the study. The phrases contained: Building-to-building damage, Flood building opening, Flood structural Integrity, Waterborne to structure post-flood damage, Flood building assessment. Notably, this encompassed publications from distinguished journals such as the Journal of Cleaner Production, Journal of Hydrology, Climate Risk Management Journal, Progress in Disaster Science Journal, International Journal of Disaster Risk Reduction, Journal of Environmental Management and Sustainable Cities and Society Journal. The search strategy focused on English-language records dated from January 2018 to October 2023. The author exclusively reviewed records obtained through their institution and the retrieval of these records from all databases occurred between October 1 and October 23, 2023. 49 records were retrieved from Science Direct, from Google Scholar, ResearchGate from Scopus, culminating in a total of 49 potentially suitable records.

3.4.4 Screening and Selection of Relevant Evidence

The records that were identified underwent a thorough screening and selection process that corresponded to established parameters for inclusion and exclusion. At the outset, the inclusion criteria for analysis were limited to 'journal articles' leading to the deletion of 8 records that did not satisfy these requirements. After the refining process, a total of 66 records remained for additional examination and analysis. Following this, a thorough process of deleting duplicate entries was carried out, resulting in the removal of 18 records and ultimately leading to a more refined collection of 48 entries. The third phase entailed the implementation of a crucial eligibility criterion, which required that records explicitly address the three research objectives of the study as indicated in section 2.2.1. The process of selecting records and determining their inclusion in the study is outlined in the chart depicted in Figure 2.1. The next step involved categorizing the identified records based on their respective damage influences and corresponding authors. The damage influence categories specified in the records were thoroughly reviewed to confirm their alignment with the specific elements outlined in the research framework.

To assure the credibility and accuracy of the study, a screening process was created. The procedure encompassed an analysis of the factors employed in the existing literature in order to construct vulnerability indices. Moreover, an additional measure was undertaken to assess and confirm the reliability of these variables in the context of the case study. Through the implementation of this selection methodology and the integration of information from both the scientific community and our own experiential knowledge, our objective was to generate outcomes that are deemed trustworthy and dependable.

The factors documented in the literature were discerned based on the ones accessible in databases. After identification, factors that were irrelevant to the study and variables that exhibited overlap with others were subsequently deleted. Furthermore, many irrelevant variables, such as building architectural style, were consolidated due to their lack of relevance in relation to the study.

3.5 Data Collection

The data collection process involves gathering and analysing information on specified variables within a predefined framework, enabling the exploration of pertinent issues and the assessment of results. This research adopts a mixed-method approach, recognizing that the study's objectives necessitate the analysis of both quantitative and qualitative data. Using an exploratory descriptive approach, the research initiates with the collection of quantitative data through a selected case study and questionnaire surveys. Subsequently, qualitative data is gathered through semi-structured interviews to complement or elucidate the quantitative findings. This explanatory method is chosen to leverage the comprehensive perspective offered by quantitative data, facilitating a more profound and thorough analysis of the research subjects.

The research process comprises crucial steps, including problem formulation, literature analysis, methodology design and simultaneous data collection and analysis.

This qualitative research employs multiple techniques, such as preliminary research, questionnaire surveys and interviews. Simultaneous use of various approaches, such as preliminary research, questionnaire surveys, interviews and other sources, to gather comprehensive and diverse perspectives on the research subject is called triangulation. It was utilised to minimize biases and increase the overall robustness of the research outcomes (Natow, 2020). Reliable data collection is vital for accurate, trustworthy research findings, preventing errors and ensuring the validity and integrity of results (Taherdoost, 2021).

3.5.1 Questionnaire Survey

A questionnaire is a research tool consisting of a series of questions designed to gather information from respondents through surveys or statistical analysis. Taherdoost (2021) stated that questionnaires are used in a variety of circumstances to obtain information. It comprises a set of questions with predefined response options that individuals from a specific demographic complete, providing researchers with the data needed for the study (Taherdoost, 2021). Researchers often employ the questionnaire technique to gather information. This method enables them to systematically collect both organised and unstructured data from respondents, either through structured interviews or self-completion.

This study utilised a questionnaire-based survey to gather useful data from disaster management practitioners involved in flood response and post-flood damage assessment in Malaysia. This data gathering methodology relies on Google Forms and is distributed to the specifically identified target audience of the case study. The questionnaire was prepared in alignment with the specified study objectives and distributed to locals that had first-hand experience with the specific challenges posed by flooding in the region accompanied with a comprehensive elucidation of the research's context and purpose. It is hereby confirmed that the respondents had a comprehensive understanding of the questionnaire prior to providing their answers. When constructing a questionnaire, it is critical to keep certain aspects in mind to ensure that it best satisfies the assessment criteria of a certain project or activity.

The way a questionnaire is designed and administered will also influence the pace at which individuals respond and the accuracy of the data collected. It is necessary to undertake pilot tests in order to determine if these scenarios may be deemed successful or not (Taherdoost, 2021). In order to guarantee the accuracy and consistency of the questionnaire, a preliminary survey was carried out representing the disaster management practitioners involved in recent flooding events. This was done before the official surveys were distributed. The feedback and insights obtained from the pilot survey were employed to complete the questionnaire set.

The research questionnaire is structured into four (4) sections to ensure that the survey is given to the target respondents in a coherent and brief manner. Therefore, the survey has been organised in the following manner:

1) Section A: The respondent's demographic and profile information including their email, gender, age, highest qualification, type of organisations, professional discipline, experience to flood and location. The respondents were evaluated using a multiple-choice question.
2) Section B: Frequency and severity of different types of building damage following a flood event. Respondents were asked to evaluate a set of 14 specific types of damage (e.g., foundation damage, wall cracks, electrical system damage, mold growth, etc.). The questions are structured in two parts, how often the types of damage are encountered (with response options ranging from "Never" to "More than 10 times"), while the second part assesses how severe the damage is using a 5-point Likert scale (1 = least severe, 5 = most severe).
3) Section C: Structural variables that influence a building’s resilience to flood damage. Respondents were asked to rate the importance of ten (10) building characteristics (e.g., number of storeys, framing system type, foundation type, material type, building age) on a 5-point Likert scale, where 1 = least critical and 5 = most critical.
4) Section D: Fluid dynamics variables and their potential impact on flood damage to buildings. Respondents were asked to rate the significance of each eight (8) of the following fluid dynamics factors on a 5-point Likert scale from 1 (least critical) to 5 (most critical).
5) Section E: Environmental conditions and non-structural building attributes. Respondents are asked to evaluate the importance of each factor using the same 5-point Likert scale from 1 (least critical) to 5 (most critical). This section identifies influences (like climate, geography and land use) and

building content that can either mitigate or exacerbate the impacts of floods on buildings. Eight (8) environmental factors and three (3) non-structural factors were asked in the section.

The major research methodology employed in this study was the use of an online survey administered using Google Forms. The survey consisted of a carefully constructed questionnaire that included both closed-ended and open-ended questions. The researcher employed the (Krejcie & Morgan, 1970) sampling procedure to determine the appropriate number of respondents for this study. Johnson and Shoulders (2019) tate that the Krejcie and Morgan (1970) formula, or tables derived from it, is a widely used and cited method for estimating sample size. However, this approach is specifically designed for calculating sample sizes to predict population proportions (or percentages) with a specified level of confidence. Quantitative survey design imposes determining the optimal sample size to mitigate biases and sampling mistakes utilising the relevant mathematical equation (Mweshi & Sakyi, 2020). Hennink and Kaiser (2022) argued that the growing demand for statistically representative samples in empirical research has created a need for efficient methods to determine appropriate sample sizes. They referenced Krejcie and Morgan's (1970) table as an early tool developed to simplify the estimation of sample sizes for specific populations, which remains relevant in addressing this methodological challenge. The table was created by the actual Krejcie and Morgan (1970, p. 607) formula, resulting in the sample size table shown in equation 3.1.

$$n = \frac{(x^2)(N)(P)(1-P)}{[(d^2)(N-1)+(x^2)(P)(1-P)]} \tag{3.1}$$

Where:

n = the sample size required

X = the chi-square value for 1 degree of freedom at the desired confidence level (usually 95%)

N = the size of the population

P = the population proportion (typically set at 0.50 to maximize the sample size)

d = the margin of error

Table 3.2
Sample Determination by Krejcie and Morgan

N	S	N	S	N	S
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

3.5.2 Expert Interview

The research utilized a semi-structured interview approach to investigate the perspectives of participants from disaster experts from NADMA regarding development of the proposed conceptual framework. This method involved a set of key questions that covered various aspects of the regions under investigation, providing the researcher with a slightly greater flexibility in exploring the subject. The interviewees were carefully selected, focusing on individuals with over five (5) years of experience in the disaster management, who were considered experts in the field. One-on-one interviews were conducted with these selected candidates based on their credentials, competence and extensive experience in flood damage assessment. The purpose of these in-depth interviews was to validate the findings from the questionnaire survey and to support the third objective, which involves developing a conceptual framework for post-flood damage assessment.

The semi-structured questions for this research are systematically organized into four (4) parts, ensuring that the session effectively engages respondents in a clear, concise and thoughtful manner. This meticulous structuring of the interview script is evident in the following aspects:

1) Part I: The interview session commenced with a brief introduction, during which the researcher gathered information on the expert's background and their specific roles and responsibilities.
2) Part II: The expert's insights on the most significant attributes influencing classifications in post-flood damage assessment. The experts are encouraged to share their experiences and observations related to damage classifications.
3) Part III: The appropriate damage level assessment for assessing damage after a flood. Expert were asked provide examples or scenarios where specific damage level assessment proved effective in their experience.
4) Part IV: Expert's perspectives on developing a conceptual framework for post-flood damage assessment. A detailed discussion was initiated about the elements they consider crucial for an effective conceptual framework in the context of flood management.

A focused one-on-one interview discussion was conducted with key experts as part of the validation phase for the proposed conceptual framework. This serves as a valuable guide decision-making, preparedness and planning and enhancing response coordination. The comprehensive responses obtained from the interview session were meticulously analysed and organized in a concise and precise table format.

3.5.3 Other Resources

The research study utilised various data sources to ensure a comprehensive and well-informed investigation. Primary sources include published materials such as books, articles and journals that contribute authoritative insights to the study. Furthermore, the study also employed organizational archives and databases as valuable sources of documents and reports. The research also taps into contemporary and readily accessible data channels. Reliable information sources, such as newsletters, media outlets, magazines and reputable websites, are essential for enriching the research dataset, thereby enhancing the credibility and depth of the study's findings.

3.6 Questionnaire Survey Data Analysis

An online questionnaire survey was distributed to all staff members of the National Disaster Management Agency (NADMA), identified through the staff directory available in the internet search database (NADMA, 2024a). As noted by Turner (2020), sampling involved selecting a subset of a population of interest for research purposes, which stated that it is essential to select population directly related to the research objectives. In this context, the population of interest included NADMA's disaster management staff, specifically targeting employees who had practical experience in disaster management in Malaysia. NADMA staff working in disaster response units, risk mitigation teams, and emergency management departments were invited to participate from March to May 2024. The required sample size was estimated using formula by Krejcie and Morgan (1970) to calculate the sample size value based on the population size. The population is the number of NADMA staffs, and the sample size determined based on the desired level of confidence of 95% and margin of error of 5%. Based on the total staffs working inside NADMA agency, the total population is determined to be 316, thus the total number of sample size needed is 174.

$$n = \frac{X^2 Np(1-p)}{e^2(N-1) + X^2 p(1-p)} \quad (3.2)$$

Where:

n= Required sample size
N= Total population size
e= Acceptable margin of error
X^2= Chi-square value for 1 degree of freedom at 95% confidence (3.841)
p= Proportion of the population (if unknown, typically 0.5)

Generally, studies often report response rates between 40% and 60% as acceptable for most research contexts (Sharma, 2022). According to Wu et al. (2022), the average response rate for online surveys in education-related fields is 44.1%, while earlier studies, such as Shih and Xitao (2008) and Cook et al. (2000) reported averages of 34% and 39.6% respectively. When contextualized, the response rate of this study reflects a good survey design and sufficient engagement from respondents. This rate surpasses averages reported in other studies and demonstrates strength in terms of participation.

3.6.1 Validity and Reliability Analysis

Validity and reliability hold immense significance for researchers engaged in the conduct and/or evaluation of empirical research. While the concepts of validity and reliability are closely intertwined, they convey distinct properties of the measuring instrument (Sürücü & Maslakci, 2020). Validity refers to the extent to which a measuring instrument accurately and effectively assesses the specific behaviour or quality it is designed to measure. It evaluates how well the instrument fulfils its intended purpose. (Anastasi & Urbina, 1997). In accordance to (Gates et al., 2018), Validity is a characteristic influenced by the measuring instrument, the subjects involved, and the conditions under which it is administered. In contrast, reliability refers to the stability of the instrument and its ability to produce consistent results over time (Sürücü & Maslakci, 2020).

Validity analysis gauges the extent to which test scores align with the intended variables, ensuring precise measurement of the target criteria. Correlation analysis, a fundamental component of validity testing, identifies relationships between two variables. The correlation coefficient is a crucial statistical measure used in this analysis to quantify the strength and direction of the relationship. The Statistical Package for the Social Sciences (SPSS) software is employed to perform this analysis. In this research, correlation analysis was employed to evaluate the relationship between each individual questionnaire item and the overall values. This approach served a dual purpose: evaluating the survey's validity and measuring the degree of correlation between linearly related variables. Correlation analysis was applied to assess the strength of relationships among variables, particularly in the context of developing a conceptual framework for flood damage assessment. While reliability focuses on consistency, validity focuses on accuracy. It's crucial to recognize that reliability doesn't inherently ensure validity; a test can be consistent but lack accuracy (Rajput, 2020). In the study of measurement, classical theory underscores the significance of both reliability and validity as benchmarks of measurement quality (O'Connor et al., 2023).

The validity and reliability tests are conducted upon the completion of the questionnaire, bridging the interpretive gap between the researcher and the respondent. In this research, both tests were applied to the questionnaire survey designed for disaster management practitioners involved in flood response and post-flood damage assessment in Malaysia. The purpose of these analyses is twofold: first, to verify the reasonableness and consistency of the data, and second, to validate the accuracy of the findings.

Table 3.3
Cronbach's Alpha Range

Cronbach's Alpha	**Internal consistency**
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable

$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

3.6.1.1 Validity Analysis

The validity of the questionnaire designed specifically for participant from NADMA has been evaluated in this research. Validity indicates how accurately the collected data aligns with the research objectives and measures the intended concept (Ranganathan & Caduff, 2023). Validity analysis ensures that the survey captures the desired variables effectively. In this study, correlation analysis served as a validity test to examine the relationships among the variables. This statistical method, performed using SPSS software, evaluates both the strength and direction of the relationship between two variables.

The analysis evaluated how strongly individual questionnaire items were related to their overall scores by examining correlation coefficients. A high correlation indicates a strong relationship between two variables, whereas a low correlation signifies a weak relationship. A positive correlation occurs when both variables increase together, whereas a negative correlation occurs when one variable decreases as the other increases. To determine whether these correlations were statistically significant, p-values were compared to the preset significance level (α or alpha).

To ensure the questionnaire's comprehensiveness and applicability, a pilot study was conducted from twenty-one (21) staffs from NADMA prior to distribution to relevant participants. The pilot sample represented approximately 12.1% of the intended main sample of 174 respondents, which exceeds the commonly cited 10% guideline for pilot studies and is also within the range of 10 to 30 participants frequently recommended for questionnaire pretesting (Connelly, 2008). The critical values for Pearson's r are shown Appendix C. The obtained p-value correlation coefficient from the analysis was compared to the α or alpha on critical values given in the table, accounting for degrees of freedom (df= number of pairs of scores minus 2) which this analysis has tested the significance of the correlation.

3.6.1.2 Reliability Analysis

Reliability analysis is a measurement tool to consistently gives stable results. Cronbach's Alpha is a popular way to check how reliable survey instruments are. (Tavakol & Dennick, 2011). Alpha, developed by Cronbach (1951) is a measure of the internal consistency of a test or scale, expressed as a value between 0 and 1 (Forero, 2023). It measures how well the items in a questionnaire work together to assess the intended concepts. In this research, Cronbach's Alpha was calculated using IBM SPSS Statistics 29 software (IBM. Corp, 2024) to determine the internal consistency of the questionnaire survey.

According to Amirrudin et al. (2020) and Imasuen (2022), Cronbach's Alpha value of 0.7 or higher is considered acceptable for most research purposes. Values between 0.70 and 0.79 indicate acceptable reliability, while values above 0.80 are considered strong. Values above 0.90 indicate excellent internal consistency. Both author states that larger sample sizes and greater variability in the data, such as higher variance and standard deviation, contribute to more stable and accurate Alpha values.

3.6.2 Descriptive Statistics Analysis

Descriptive statistics involve the quantitative characterization of data properties. This type of data analysis seeks to clarify, illustrate, or summarize data points in a meaningful way, enabling the identification of patterns that align with the inherent conditions of the data. It stands as a crucial procedure in statistical data analysis, offering a method to rationally simplify extensive datasets. Descriptive statistics summarize large amounts of data into simple and clear information. When combined with visual tools like graphs or charts, they become an important part of analysing numerical data.

To assess and interpret the data, this research employed the statistical software SPSS, addressing research problems and scrutinizing data collection and findings. Descriptive statistics were important in this research to help to understand the data and analyse the results from questionnaire surveys and case studies. Descriptive statistics commonly include measurements such as range, interquartile range, central tendency (mean, median, mode), standard error and coefficient of variation. Ong and Puteh (2017) emphasized that SPSS statistical software is highly effective for conducting correlational and comparison tests within univariate, bivariate and multivariate analyses, utilizing both parametric and non-parametric techniques.

3.6.2.1 Frequency Distribution Analysis

Descriptive statistics implicate frequency analysis, which involves examining the occurrence of values in a dataset. In statistical terms, frequency refers to the number of times an event or value occurs. The distribution summarizes how often specific values or ranges of values occur for a given variable. A fundamental distribution includes each variable value along with the corresponding count of individuals possessing that value. Thus, frequency analysis is a statistical branch that delves into the count (frequency) of occurrences, evaluating parameters such as central tendency, dispersion, percentiles and more. Frequency distributions are typically presented either in tabular form or graphically, with the latter discussed in the subsequent chapter.

3.6.2.2 Mean, Standard Deviation and Variance Analysis

The standard deviation measures the average distance of each data point from the mean, showing the spread of the data. Variance represents the average squared deviation of each point from the mean. The standard deviation is the square root of the variance, while the variance reflects the overall spread of data points within the group. The standard deviation is a single statistic that indicates the variability of a dataset. It demonstrates the relationship between that set of scores and the sample mean. Standard deviation analysis in research shows how much individual responses to a question deviate from the mean. This research used standard deviation to evaluate the collected data. A large standard deviation indicates that values are often far from the mean, while a small standard deviation suggests that values are clustered around the mean. It reflects the average distance of each data point from the mean. Smaller values indicate consistent data points close to the mean, while larger values show greater variability and dispersion. As the dataset becomes more diverse, extreme values are more likely to occur.

The arithmetic mean is a fundamental concept of central tendency in statistics. It serves as a measure of the typical or average value within a dataset. The mean, also known as the average, is calculated by summing up all the data points in a collection and then dividing the sum by the total number of data points. (King & Eckersley, 2019) acknowledged that the standard deviation, serving as a measure of variability, is not only computationally demanding but also challenging to validate. In this context, an essential concept is the distribution, which necessitates defining a variable and determining the accumulated frequency of its different values. Therefore, all techniques involving regression, correlation and variance analysis rely on the assumption of normally distributed data. Equation 3.3, 3.4, 3.5 and 3.6 illustrates the formulas for standard deviation and variance for both the population and the sample dataset as stated by (King & Eckersley, 2019).

Population variance and standard deviation formula:

$$\sigma^2 = \frac{\sum_{i=1}^{N}(x_i - \mu)^2}{N} \tag{3.3}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \mu)^2}{N}} \tag{3.4}$$

Where:

σ^2 = Population variance
σ = Population standard deviation
N = Total number of observations in the population
x_i = The value of the ith observation in the population
μ = Population mean

Sample size variance and standard deviation formula:

$$S^2 = \frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N} \qquad 3.5)$$

$$S = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N}} \tag{3.6}$$

Where:

S^2 = Sample Variance
S = Sample standard deviation
N = Number of observations in population
x_i = ith observation in the population
$\bar{x}$ = sample mean

3.6.3 Canonical Correlation Analysis

Canonical Correlation Analysis (CCA) is a multivariate statistical technique designed to explore the linear interrelationships between two distinct sets of variables. It functions by quantifying the correlation between the sets to allow researchers to assess the overall strength and nature of their association (Mihalik et al., 2022). In its basic structure, CCA constructs linear combinations of the variables from each set and identifies the pair of composite scores known as canonical variates that exhibit the highest possible correlation. Typically, X_1, X_2, ..., X_n is designated as independent while Y_1, Y_2, ..., Y_n is treated as dependent. However, CCA does not require a strict distinction between predictors and outcomes (Hubona et al., 2021). The basic form of the Canonical Correlation Analysis (CCA) model is illustrated in (3.7.

$$U_1 = a_{11}X_1 + a_{12}X_2 + \cdots + A_{1p}X_p \tag{3.7}$$

$$V_1 = b_{11}Y_1 + b_{12}Y_2 + \cdots + b_{1q}Y_q$$

Where:
U_1= first pair of canonical variates
V_1= second pair of canonical variates
a_{1j} and b_{1k} = canonical coefficients

$X_1, \ldots, X_p$= first set of variables

$Y_1, \ldots, Y_q$= second set of variables

In this study, the first set (X) comprised variables related to the frequency of damage, whereas the second set (Y) comprised variables related to the severity of damage. In CCA, new variables known as canonical variates are created by combining two or more variables from each dataset into a single composite score. These combinations are formed using a set of weights, where the first canonical variate is based on variables from one set and the second from the other set. The goal is to find the best possible weights that produce the highest correlation between these two new composite variables. This correlation is known as the canonical correlation coefficient. CCA generates multiple canonical functions, with the number of functions depending on the smaller number of variables in either dataset. Each function is independent from the others, indicating they show different patterns of relationships between the two sets of variables. The first canonical function usually represents the strongest and most meaningful relationship. In each function, the contribution of individual variables is measured through canonical loadings, which show how strongly each original variable is related to its corresponding canonical variate.

To conduct CCA, it is standard practice to begin by evaluating canonical functions that demonstrate statistically significant correlation coefficients, typically at a significance level of 0.05 or lower. To determine the significance of the canonical correlations, the Wilk's Lambda statistic was employed. This test is used to assess whether the relationships observed between the two sets of variables are unlikely to have occurred by chance. The Wilk's Lambda value (λ) was computed using the formulas presented in (3.8.

$$\lambda = \prod_{i=1}^{j}(1 - c_i^2) \qquad (3.8)$$

Where:

j = number of canonical functions

c = canonical correlation for the ith function

CCA is a flexible statistical technique that can be applied to both continuous and categorical data, irrespective of whether the variables are designated as dependent or independent (Mihalik et al., 2022). To evaluate the relative contribution of each original variable to the canonical functions, numerous studies have recommended the use of canonical loadings and cross-loadings for more stable and interpretable results (Sherry & Henson, 2005).

In line with previous recommendations, canonical loadings and cross-loadings with absolute values of ≥ 0.30 were considered to represent meaningful contributions to the canonical function. Variables with loadings below this threshold were interpreted as having limited influence on the underlying canonical relationship and were not emphasised in the substantive discussion (Nouri et al., 2022). The structural loading matrix, also known as the loading matrix, represents the correlations between the canonical variates and the original observed variables in each dataset. This matrix is derived by multiplying the correlation matrix of the original variables with the matrix of canonical coefficients, thus providing a clearer understanding of the underlying variable relationships within the canonical model.

3.7 Interview Data Analysis

This section describes how the interview data were analysed to gain a clearer understanding of post-flood damage assessment. The analysis focused on the views and experiences shared by experts during the interview sessions. Two methods were used which are thematic analysis and code trend analysis. Thematic analysis were used to identify key patterns and themes that emerged from the interview responses. In contrast, code trend analysis was used to examine which attributes were mentioned most often by the interviewees. By combining these two approaches, the study was able to highlight both the content and the emphasis placed on different aspects of flood damage assessment, contributing to the overall development of the research framework.

3.7.1 Agencies Portfolio

To achieve the objectives of this study, suitable informants were selected to respond to the interview questions. The data collected from these informants will be analysed and discussed in detail. Representatives from NADMA, MKN, JPS and JKR were interviewed to provide insights into post-flood damage assessment in Malaysia. The information of each of the agency's portfolio will be detailed in next subtopics.

3.7.1.1 Agency 1: National Disaster Management Agency (NADMA)

The National Disaster Management Agency (NADMA) was established in 2015 under the Prime Minister's Department that responsible for managing natural disasters, a role that were previously held by the National Security Council (MKN). This restructuring was a response to the severe floods in December 2014 that affected Kelantan, Terengganu, Pahang, and Johor, resulting in 25 fatalities, the evacuation of 541,896 individuals, and estimated damages of RM2.85 billion (Hashim, 2015).

On July 29, 2015, the Malaysian Cabinet decided to transfer MKN's crisis and disaster management division to the Prime Minister's Department. Later on August 26, 2015, the Cabinet approved the formation of NADMA to undertake the duties formerly performed by MKN's disaster management division. NADMA officially commenced operations on October 1, 2015. Its primary responsibility involves coordinating all activities and cooperation before, during, and after disasters including disaster risk mitigation and prevention, preparedness and response, as well as recovery and redevelopment efforts (NADMA, 2024b).

3.7.1.2 Agency 2: Malaysian Public Works Department (JKR)

The Malaysian Public Works Department or Jabatan Kerja Raya Malaysia (JKR) was established in 1872 under the direction of Major J.F.A. McNair. As a federal government department under the Ministry of Works Malaysia, JKR is responsible for the construction and maintenance of public infrastructure including federal and state roads, public hospitals, schools, and government buildings. In managing disaster, JKR is responsible to coordinate responses for infrastructure-related emergencies. The department has established the Bilik Gerakan Bencana (BiGBen) or Disaster Operations Room that functions as a centralized hub for managing information on incidents such as floods, landslides, road collapses, and bridge damages affecting roads under JKR's jurisdiction (JKR, 2025) .

3.7.1.3 Agency 3: Department of Irrigation and Drainage Malaysia (JPS)

Department of Irrigation and Drainage Malaysia or Jabatan Pengairan dan Saliran Malaysia (JPS) was established on January 1, 1932, originally named the Drainage and Irrigation Department (DID). Prior to its formation, all drainage and irrigation works were managed by JKR. The creation of JPS was driven by the need to develop new agricultural lands and provide adequate irrigation and drainage facilities, especially for paddy cultivation to enhance food security in the country.

In 1972, the Malaysian government established the Natural Disaster Relief Committee to coordinate flood relief operations at national, state, and district levels, aiming to prevent loss of lives and reduce flood damage. JPS is a key member of this committee with its flood relief and operations organized based on the Operation Procedure No. 29 published by the National Security Council.

3.7.1.4 Agency 4: National Security Council (MKN)

The Majlis Keselamatan Negara (MKN), or National Security Council of Malaysia was officially established on July 7, 1971, under the Prime Minister's Department. Its formation was a direct response to the dissolution of the Majlis Gerakan Negara (MAGERAN), or National Operations Council, which had been set up to restore order following the racial riots of May 13, 1969.

The primary role of MKN is to coordinate policies related to national security and issue directives involving security measures and public order. Over the years, MKN has been instrumental in addressing various security challenges such as illegal immigrants, smuggling activities, terrorism control, public order maintenance, and crisis and disaster management.

3.7.2 Interview Guide

An interview guide serves as a structured framework for the interviewer for the key questions and research areas related to post-flood damage assessment. However, it is not a rigid script but a flexible reference that allows for adjustments based on the flow of the conversation. As noted by Adeoye-Olatunde and Olenik (2021), the guide is not intended to be followed verbatim or in a fixed sequence for every interview.

Instead, it serves to provide structure and direction while allowing the conversation to flow naturally based on each interview's unique context. A semi-structured interview guide typically includes key open-ended questions, accompanied by follow-up probe questions that the interviewer can refer to as needed. This approach contrasts with closed-ended questions such as yes/no responses, Likert scale items, or multiple-choice questions that were commonly used in survey instruments for quantitative analysis.

Following this approach, additional questions may be introduced when new but relevant information arises, such as unforeseen structural issues or unique challenges in the recovery process. Likewise, if certain aspects of building damage assessment are not sufficiently addressed by the respondent, follow-up questions can be used to obtain a more comprehensive understanding. Several studies emphasize that interviews should prioritize the firsthand experiences of respondents, particularly those involved in flood damage assessment and recovery efforts. It is advisable to begin with general questions, such as observations about the condition of buildings after the flood, before progressing to more technical topics, including structural stability, repair processes, and mitigation strategies (Flick, 2021). Furthermore, overly personal or sensitive questions should be avoided to ensure professionalism and maintain a comfortable environment for the respondent.

Timing is also an important consideration in the interview process. The duration of each interview may vary depending on the role and expertise of the respondent, such as government officials, engineers, or homeowners. While some participants may provide detailed technical insights, others may focus on their experiences and challenges during post-flood recovery. To ensure efficiency, priority should be given to key questions that provide the most valuable insights for developing a comprehensive framework for post-flood damage assessment.

3.7.3 Interview Transcription

According to Flick (2021), data transcription is a crucial step before data analysis. In this study, interviews were conducted using various communication methods based on the availability and accessibility of respondents. Face-to-face interviews were conducted with representatives from NADMA and MKN while JPS interviews were conducted via voice call. Due to scheduling constraints, JKR interviews were conducted through WhatsApp. To ensure accurate transcription, MAXQDA (VERBI Software, 2021) was used for processing and analysing the recorded interviews. All interviews were conducted with the informed consent of participants and audio recordings were made where possible. Each interview lasted between 43 to 52 minutes on average. To maintain confidentiality, details about participants and their respective agencies remain undisclosed as revealing such information could lead to privacy concerns. As outlined in the consent form in Appendix, all participants are assigned numbered pseudonyms (e.g., Expert 1, Expert 2) to maintain anonymity. However, the agency names (NADMA, MKN, JPS, and JKR) are mentioned for understanding their roles in post-flood damage assessment.

While no universal standards exist for interview transcription, it is essential that the process remains accurate and systematic. Transcription is more than a mechanical process of converting spoken language into text. It is an interpretative and selective task that requires careful consideration of accuracy, readability, and manageability (Point & Baruch, 2023). The transcription process is not neutral as researchers must make decisions that impact the final representation of data, including whether to transcribe verbatim or selectively based on theoretical perspectives (Davidson, 2009; Point & Baruch, 2023). Researchers must also be transparent about their transcription methods and strategies as the data remains clear, structured and reflective of its original meaning. Once transcription is completed using MAXQDA, the next phase involves data analysis where themes and patterns in the interviews will be systematically examined.

3.7.4 Code Trend Analysis

Code trend analysis serves as a supporting tool to examine the distribution and importance of specific codes across the interview transcripts. This analysis provides a visual and quantitative overview of how often certain codes appear and in which sections of the interviews they are most discussed. Using MAXQDA 2022, each relevant theme assigned a code during the coding process (VERBI Software, 2021). The analysis uses two key elements which are the y-axis, which indicates the percentage of coverage of how much of the transcript content contains a specific code and the x-axis which represents the progression of the interview document. A higher coverage percentage displays greater emphasis or more frequent discussion of a specific code by the interviewee. Code trend analysis allows the researcher to identify dominant patterns, track the rise or decline of certain themes across interview segments and compare the relative importance of multiple codes.

3.8 Analysis Limitation

Limitations exist in the data analysis approach and methodology used to gather data for the research. One notable constraint occurred during the interview sessions, where individuals from diverse backgrounds in the disaster field might offer varied perspectives on the discussed topics. Additionally, limitations associated with secondary data obtained from literature reviews, articles and books include the potential irrelevance of the data to the research objectives and the possibility of outdated information. However, such data may still be repurposed to address other research objectives.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents a thorough analysis of the findings derived from the questionnaire surveys and semi-structured interviews. The questionnaire survey was specifically designed to collect data on significant attributes including structural, fluid flow and hydraulics, environmental and non-structural factors that serve as a basis for the development of the framework. Malaysia was selected as the case study to provide a practical context for identifying significant attributes and supporting the framework development. Expert interview was conducted to complement the survey findings including the appropriate damage level assessment identified.

The collected data were analysed using both quantitative and qualitative methods. For quantitative data, descriptive statistics including percentage frequency distribution, mean, standard deviation and reliability tests were applied to identify trends and assess data consistency. Qualitative data utilises thematic analysis to interpret the findings from semi-structured interviews to identify recurring themes such as the adequacy of current damage assessment guidelines, critical areas for improvement and the importance of systematic protocols for post-flood evaluation. The case study, surveys and interviews contributed to identifying significant attributes and proposing the conceptual framework. The results are analysed and discussed in detail in the following sub-sections.

4.2 Data Analysis of Questionnaire Survey

The survey received a total of 94 responses out of 174 participants within two (2) months which indicated a response rate of 54.02%. This response rate suggests the effectiveness of the survey design and the relevance of the topic to the participants. Generally, studies often report response rates between 40% and 60% as acceptable for most research contexts (Sharma, 2022). According to Wu et al. (2022), the average response rate for online surveys in education-related fields is 44.1%, while earlier studies, such as Shih and Xitao (2008) and Cook et al. (2000) reported averages of

34% and 39.6% respectively. When contextualized, the response rate of this study reflects a good survey design and sufficient engagement from respondents. This rate surpasses averages reported in other studies and demonstrates strength in terms of participation.

4.2.1 Validity Analysis

The obtained correlation coefficients were compared with the critical values of r at the selected significance level, α, in order to test the significance of each relationship. The degree of freedom was calculated as df = N − 2, where N represents the number of valid paired responses for each variable. As some pilot respondents did not answer all items, the number of valid responses differed slightly across variables resulting in different values in the Degree of Freedom column. The correlation analysis results obtained from NADMA staff responses is presented in Appendix D.

Based on the analysis of the pilot study, all the calculated values for the variables were higher than the critical value, r in Appendix D. This finding confirms that the survey questions were well-designed and effective in collecting meaningful data. Therefore, the questionnaire was considered suitable for distribution to the target respondents to obtain reliable information.

4.2.2 Reliability Analysis

Table 4.1 displays the case processing summary including the number of valid and excluded cases used in this study. Out of 94 total respondents, only 48 cases (51.1%) were included in the reliability analysis, while 46 cases (48.9%) were excluded. This exclusion is due to the survey design where respondents were instructed to leave questions blank if they were unfamiliar with severity of specific attributes. This approach helped to avoid uncertain answers, but it also created a large amount of missing data. Missing data of less than 5% is usually considered small, while missing data above 10% may affect the results (Pham et al., 2024). Therefore, the exclusion rate in this study is considered high and should be recognised as a limitation. However, the reliability analysis as in Table 4.1 was kept only for respondents who were able to provide informed answers, so that the analysis would be based on more reliable judgments. However, the smaller number of valid cases may reduce the overall representativeness of the findings.

Table 4.1
Case Processing Summary of Reliability Analysis

Cases	**N**	**%**
Valid	48	51.1
Excluded[1]	46	48.6
Total	94	100.0

Table 4.2 presents the reliability statistics for Cronbach's Alpha conducted using the SPSS software. In this research, Cronbach's Alpha was applied to evaluate the reliability of the variables. With a sample size of 94, the analysis produced a Cronbach's Alpha value of 0.985, which is close to the threshold of 1, indicating excellent reliability. This result demonstrates outstanding internal consistency among the survey items, proving that the data collected in this research is both reliable and suitable for analysis. As highlighted by Douglas et al. (2023), data reliability is essential for ensuring that research findings are consistent, accurate and valid. Reliable data provides a strong foundation for producing strong and trustworthy research outcomes.

Table 4.2
Reliability Statistics

Cronbach's Alpha	**N of Items**
0.985	57

Based on Amirrudin et al. (2020) and Imasuen (2022), they caution against relying solely on high Cronbach's Alpha values, as these may not always reflect meaningful consistency. Instead, researchers should also evaluate inter-item correlations to ensure the reliability based on cohesive measurement rather than redundancy or multidimensionality within the test items. Thus, inter-item total statistic

[1] Listwise deletion based on all variables in the procedure.

was evaluated for the 57 variables in Section B until Section E. These sections covered the frequency and severity of building damage, as well as the criticality of structural, fluid, environmental and non-building attributes. This analysis ensured that the questionnaire items were consistent and aligned with the constructs being measured.

Table 4.3
Item Total-Statistics

Variable Code	**Corrected Item-Total Correlation**	**Cronbach's Alpha if Item Deleted**
V1	0.523	0.985
V2	0.731	0.985
V3	0.579	0.985
V4	0.585	0.985
V5	0.694	0.985
V6	0.644	0.985
V7	0.678	0.985
V8	0.558	0.985
V9	0.632	0.985
V10	0.587	0.985
V11	0.619	0.986
V12	0.658	0.985
V13	0.597	0.985
V14	0.674	0.985
V15	0.749	0.985
V16	0.772	0.985
V17	0.766	0.985
V18	0.765	0.985
V19	0.855	0.985
V20	0.852	0.985
V21	0.767	0.985
V22	0.785	0.985
V23	0.759	0.985
V24	0.814	0.985
V25	0.814	0.985
V26	0.778	0.985
V27	0.834	0.985
V28	0.813	0.985
V29	0.771	0.985
V30	0.919	0.985
V31	0.920	0.985
V32	0.880	0.985
V33	0.808	0.985

V34	0.800	0.985
V35	0.770	0.985
V36	0.886	0.985
V37	0.894	0.985
V38	0.860	0.985
V39	0.895	0.985
V40	0.813	0.985
V41	0.847	0.985
V42	0.809	0.985
V43	0.830	0.985
V44	0.854	0.985
V45	0.832	0.985
V46	0.911	0.985
V47	0.810	0.985
V48	0.825	0.985
V49	0.831	0.985
V50	0.858	0.985
V51	0.832	0.985
V52	0.845	0.985
V53	0.755	0.985
V54	0.902	0.985
V55	0.931	0.985
V56	0.894	0.985
V57	0.868	0.985

The results in Table 4.3 demonstrate that the questionnaire displays excellent internal consistency, as indicated by the high Cronbach's Alpha value of 0.985. The corrected item-total correlations for the variables range from 0.523 (V1) to 0.931 (V55). These values exceed the generally accepted level of 0.3, indicating a high level of correlation between each item and the overall construct (O'Connor et al., 2022; Prigerson et al., 2021). The column "Cronbach's Alpha if Item Deleted" indicates that removing any item from the scale would not significantly impact the overall Alpha value, which consistently remains at 0.985. This demonstrates that no single variable disproportionately affects the reliability of the scale. The consistency reflects a well-designed questionnaire that effectively aligned with the intended dimensions of the research focus.

4.2.3 Frequency Analysis of Respondent Background

Frequency analysis is a fundamental statistical method used to examine the distribution of values within a dataset. This analysis involves measuring how often certain events or values occur within a dataset (Field, 2013). Table 4.4 shows the overall frequency analysis of demographic data obtained from the survey for identification of post-flood damage significant attributes.

Table 4.4
Participant Demographic Profile

	Respondent Characteristics	**Frequency**	**(%)**
Gender	Female	52	55.3
	Male	42	44.7
Age	20-29 years old	46	48.9
	30-39 years old	28	29.8
	40-49 years old	18	19.1
	50 years old and above	2	2.1
Highest Qualification	Bachelor's Degree	35	37.2
	Diploma	45	47.9
	Master's Degree	12	12.8
	PhD	2	2.1
Department	Corporate Communication Unit	4	4.3
	Finance and ICT Section	8	9.6
	National Disaster Command Centre (NDCC)	9	7.4
	Operations and Implementation Division	18	19.1
	Planning and Preparedness Division	10	12.8
	Post-Disaster Management Division	25	25.5
	Search and Rescue Team (SMART)	18	19.1
	Training and Development Unit	2	2.1
Working Experience	Less than 5 years	47	51.1
	6 to 10 years	12	12.8
	11 to 15 years	17	17.0
	16 to 20 years	6	6.4
	More than 20 years	12	12.8
Experiences in dealing with flood	Less than 5 years	58	61.7
	6 to 10 years	6	6.4
	11 to15 years	9	8.5
	16 to 20 years	2	2.1
	More than 20 years	8	8.5
	None	11	12.8

Figure 4.1 until Figure 4.6 shows the details of analysis of respondent characteristics and their relevance to the study on post-flood damage assessment. In Figure 4.1, gender distribution of respondents was relatively balanced with females

representing a slight majority at 55.3% (52 individuals), while males accounted for 44.7% (42 individuals).

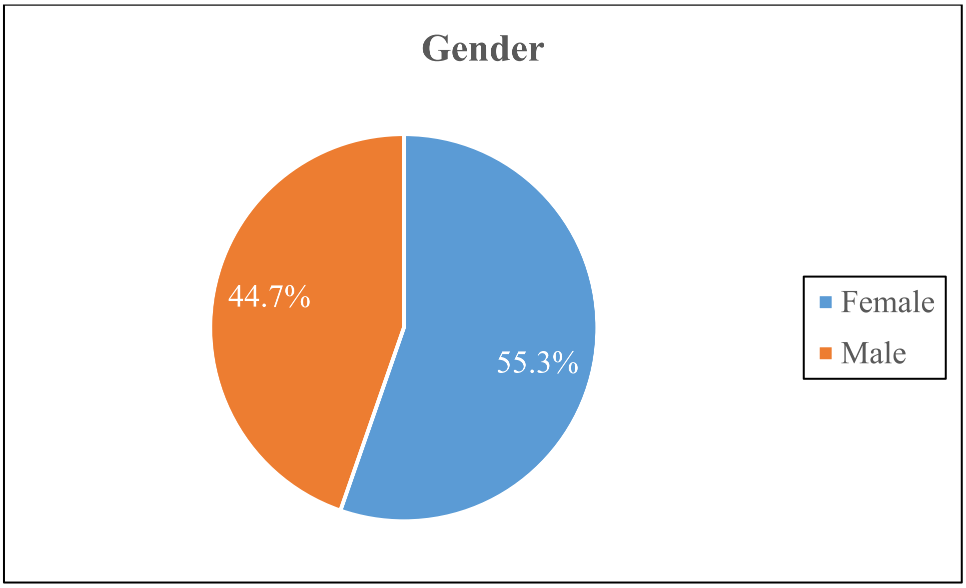

Figure 4.1 Respondent’s Gender

Figure 4.2 shows the analysis of respondent’s age. Most respondents were younger with 48.9% aged 20–29 years and 29.8% (28 individuals) aged 30–39 years. A smaller proportion were aged 40–49 years (19.1%, or 18 individuals) while only 2.1% (2 individuals) were 50 years or older. This age range suggests that most participants are early to mid-career professionals who are likely more actively involved in on-the-ground disaster management tasks such as flood assessment and recovery operations.

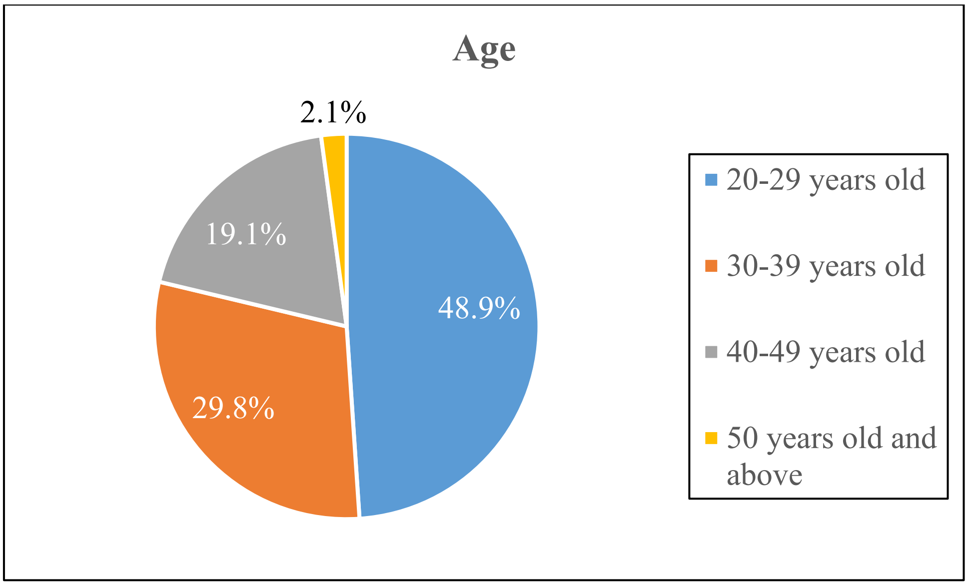

Figure 4.2 Respondent's Age

In Figure 4.3, the analysis indicates a strong representation of professionals with undergraduate qualifications. Respondents had varying levels of education with the majority holding diplomas (47.9%, or 45 individuals) or bachelor's degrees (37.2%, or 35 individuals). A smaller group had master's degrees (12.8%, or 12 individuals) and only 2.1% (2 individuals) held a PhD. This suggests that the survey primarily reflects a workforce oriented toward practical application rather than high-level theoretical development.

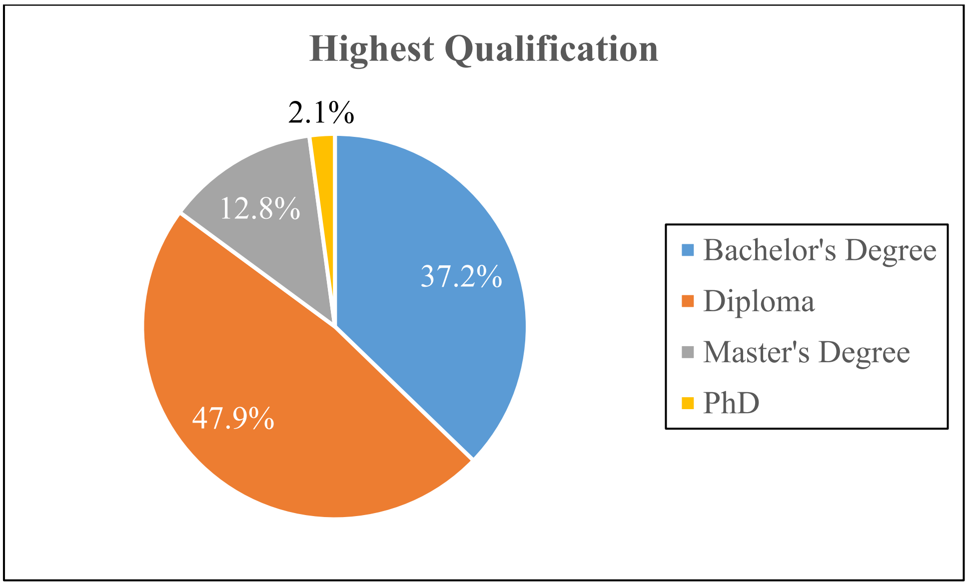

Figure 4.3 Respondent's Highest Education Level

Respondents correspond to a range of departments in Figure 4.4, with the highest number from the Post-Disaster Management Division (26.6%, or 25 individuals). Other major groups included the Operations and Implementation Division and the Search and Rescue Team (SMART), both at 19.1% (18 individuals each). Smaller contributions came from departments such as Planning and Preparedness (10.6%, or 10 individuals), Finance and ICT (8.5%, or 8 individuals) and the National Disaster Command Centre (9.6%, or 9 individuals). The high representation from Post-Disaster Management Division, Operations and Implementation Division and Search and Rescue Team (SMART) ensures that perspectives from individuals that directly involved in recovery planning and damage assessment are well captured as well as operational understandings from professionals that engaged in on-ground disaster responses.

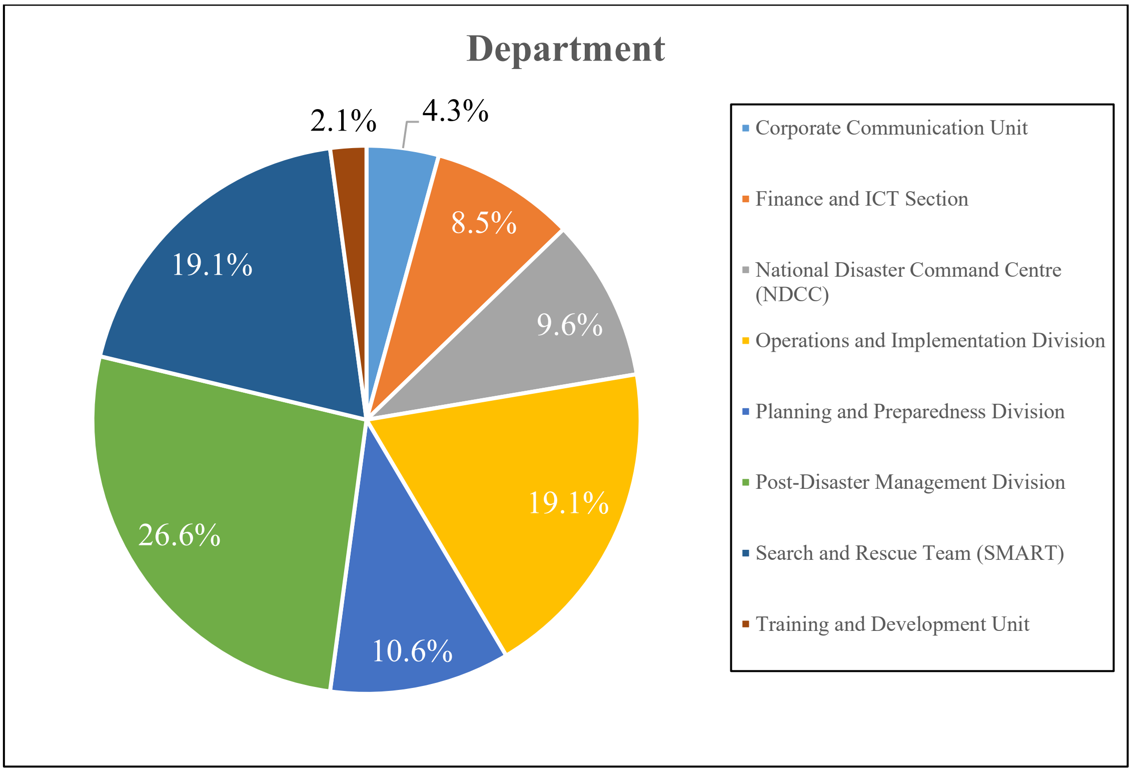

Figure 4.4 Respondent's Department in NADMA

In Figure 4.5, most respondents (50%, or 47 individuals) had less than five years of work experience, while 12.8% (12 individuals) had 6–10 years and 18.1% (17 individuals) had 11–15 years of experience. Smaller groups had 16–20 years (6.4%, or 6 individuals) or more than 20 years (12.8%, or 12 individuals).

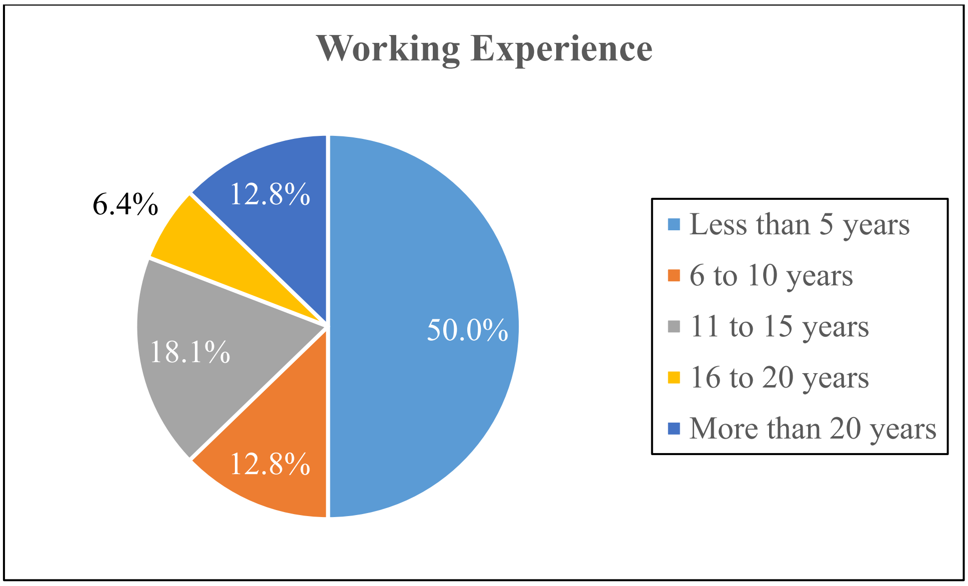

Figure 4.5 Respondents Year of Working Experience

In, Figure 4.6, most respondents (61.7%, or 58 individuals) had less than five years of experience in dealing with floods, while 6.4% (6 individuals) reported 6–10 years of experience. A smaller group (9.6%, or 9 individuals) had 11–15 years, with only 2.1% (2 individuals) having 16–20 years of experience. Another 6.4% (6 individuals) reported more than 20 years of flood-related experience and 11.7% (11 individuals) had no prior experience. This pattern likely reflects NADMA's establishment in 2015 as many respondents may joined the field after the agency was created. The smaller group with over 20 years of experience suggests some respondents brought expertise from other disaster related agency such as JKR or JPS.

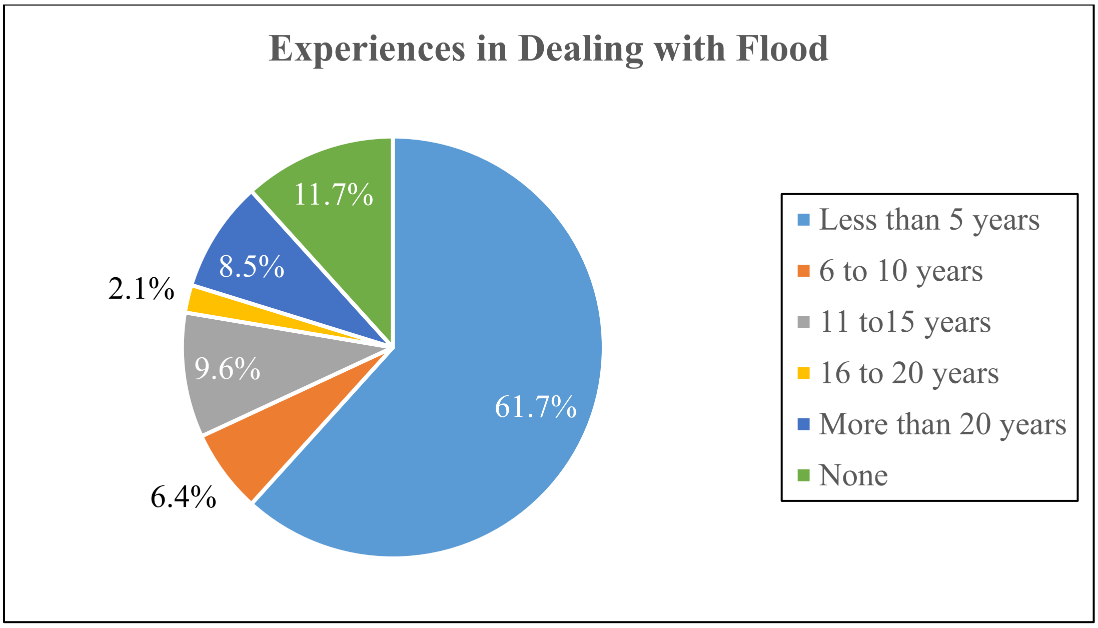

Figure 4.6 Respondents Year of Experience with Flood

4.2.4 Frequency Analysis of Variables

To make sure a comprehensive understanding of the surveyed data, a frequency analysis was conducted to examine the distribution of responses across the attributes. Table 4.5 until show the frequency of responses for each group of variables. The answers varied across the full scale, from 1 (strongly disagree) to 5 (strongly agree) indicating a range of opinions and levels of understanding among the participants. It is important to note that approximately 20% of the data for each item group related to attributes significance is missing. The items required more technical judgement on damage attributes compared with the more general damage component questions. Survey methodology studies have shown that item nonresponse tends to increase when questions are more difficult or when respondents are uncertain about how to answer them (Lipps & Monsch, 2022). The missing responses were therefore treated as a result of respondent uncertainty rather than simple omission. This approach was retained to reduce the risk of forced or unreliable answers, although it also resulted in a noticeable amount of missing data that should be acknowledged as a limitation when interpreting the results

Table 4.5
Summary of Frequency Analysis for the Frequency of Encountering Building Damage Types

Item Group	Damage Types	Code	Linkert Scale Indicator									
			Never (Linkert Scale 1)	%	1 to 2 times (Linkert Scale 2)	%	3 to 5 times (Linkert Scale 3)	%	6 to 10 times (Linkert Scale 4)	%	More than 10 times (Linkert Scale 5)	%
Frequency of encountering damage types in buildings	Foundation damage	V1	35	37.2	30	31.9	27	28.7	2	2.1	0	0.0
	Wall damage	V2	25	26.6	26	27.7	32	34.0	11	11.7	0	0.0
	Building structure shift or settling	V3	38	40.4	27	28.7	21	22.3	4	4.3	4	4.3
	Beam and column damage	V4	45	47.9	26	27.7	15	16.0	4	4.3	4	4.3
	Opening damage	V5	35	37.2	14	14.9	28	29.8	9	9.6	8	8.5
	Floor damage	V6	28	29.8	19	20.2	38	40.4	7	7.4	2	2.1
	Electrical system damage	V7	27	28.7	18	19.1	28	29.8	13	13.8	8	8.5
	Pipe burst	V8	30	31.9	33	35.1	17	18.1	8	8.5	6	6.4
	HVAC system	V9	35	37.2	20	21.3	25	26.6	8	8.5	6	6.4

malfunction										
Ceiling sagging or staining	V10	30	31.9	25	26.6	25	26.6	8	8.5	6	6.4
Material deformation and detachment	V11	30	31.9	21	22.3	21	22.3	8	8.5	14	14.9
Mold growth	V12	25	26.6	24	25.5	21	22.3	6	6.4	18	19.1
Roof leaks	V13	36	38.3	19	20.2	23	24.5	6	6.4	10	10.6
Sewage systems overflow	V14	25	26.6	24	25.5	25	26.6	6	6.4	14	14.9

In Table 4.5, each damage type is evaluated in terms of the frequency of damage encountered by the respondents. The items were ranged from "Never" (Scale 1) to "More than 10 times" (Scale 5). Based on the data, respondents reported that they don't frequently encounter foundation damage (V1) with 31.9% have seen it 1 to 2 times. Less frequent issues include beam and column damage where 47.9% reported never encountering it and building structure shifts which are also usually uncommon. According to Marvi (2020), fluvial and inland flooding can subject building structures to various forces such as hydrostatic pressure, hydrodynamic forces and soil erosion. However, it is important to note that, in certain Malaysian flood events such as those reported in Taman Sri Muda, floodwaters usually recede within approximately 48 hours (Tzu Chi, 2022) . This relatively short duration of flooding reduces the exposure of foundations and structural elements to prolonged hydrostatic pressure, which is a critical factor in causing severe damage. This condition may partly explain the lower frequency of severe damage observed in areas that are primarily subjected to short-duration fluvial flooding, compared with locations that experience longer or repeated periods of inundation.

However, the respondent stated that wall damage was frequently spotted with 34% reported encountering it 3 to 5 times. This can be attributed to the common use of brick walls in Malaysia as observed by Balasbaneh et al. (2020). Brick walls particularly in humid environments like Malaysia are prone to moisture absorption. Studies highlight that porous bricks absorb 9%-55% of their saturation capacity rapidly under water exposure (Kahangi Shahreza et al., 2021). This rapid absorption led to visible dampness patches, plaster damage and eventual cracking under repeated exposure to water which the possible contribution to the frequency.

Pipe bursts and HVAC malfunctions are also frequent with most occurrences between 3 to 5 times. Mold growth and sewage overflow shows more frequency than the other items with 19.1% and 14.9% respectively encountering them more than 10 times. Similarly, roof leaks show less common than other item but have 10.6% reporting frequent occurrences. This is possibly due to older neighbourhoods has an aging infrastructure that increases the likelihood of system failures such as pipe bursts and drainage issues due to material degradation over time.

Table 4.6
Summary of Frequency Analysis for the Severity of Different Damage Types

Item Group	Damage types	Code	Linkert Scale Indicator										Missing	%
			Least Severe (Linkert Scale 1)	**%**	**Less Severe (Linkert Scale 2)**	**%**	**Severe (Linkert Scale 3)**	**%**	**More Severe (Linkert Scale 4)**	**%**	**Most Severe (Linkert Scale 5)**	**%**		
Severity of damage types in buildings	Foundation damage	V15	20	21.3	8	8.5	18	19.1	11	11.7	16	17.0	21	22.3
	Wall damage	V16	14	14.9	8	8.5	27	28.7	10	10.6	12	12.8	23	24.5
	Building structure shift or settling	V17	17	18.1	13	13.8	20	21.3	9	9.6	14	14.9	21	22.3
	Beam and column damage	V18	18	19.1	10	10.6	23	24.5	10	10.6	12	12.8	21	22.3
	Opening damage	V19	14	14.9	8	8.5	18	19.1	21	22.3	12	12.8	21	22.3
	Floor damage	V20	14	14.9	6	6.4	28	29.8	19	20.2	8	8.5	19	20.2
	Electrical system damage	V21	14	14.9	8	8.5	14	14.9	19	20.2	16	17.0	23	24.5
	Pipe burst	V22	14	14.9	10	10.6	29	30.9	10	10.6	10	10.6	21	22.3

HVAC system malfunction	V23	16	17.0	10	10.6	21	22.3	14	14.9	10	10.6	23	24.5
Ceiling sagging or staining	V24	11	11.7	9	9.6	27	28.7	16	17.0	10	10.6	21	22.3
Material deformation and detachment	V25	14	14.9	12	12.8	22	23.4	9	9.6	18	19.1	19	20.2
Mold growth	V26	11	11.7	11	11.7	21	22.3	16	17.0	14	14.9	21	22.3
Roof leaks	V27	16	17.0	6	6.4	27	28.7	8	8.5	18	19.1	19	20.2
Sewage systems overflow	V28	14	14.9	6	6.4	25	26.6	12	12.8	16	17.0	21	22.3

Based on Table 4.6, a 5-point Likert scale were used to evaluate the severity of building damage types that categorizes responses into five levels from least severe (Scale 1) to most severe (Scale 5). The average of around 20% missing data across all items is due to the survey design which intentionally allowed respondents to leave items blank if they were unfamiliar with or lacked knowledge about specific types of damage.

Based on the analysis, structural damages such as foundation damage, wall damage and beam/column damage are averaging in moderate to severe category. Floor damage (V20) has some of the highest damage levels with 29.8% reporting severe damage and 20.2% most severe. Foundation damage (V15) shows a moderate range of severity with 21.3% categorized as less severe (Linkert scale 1), 18% as severe (Linkert scale 2) and 17% as most severe (Linkert scale 5). Wall damage (V16) has more pronounced severity based on 27% reporting severe damage and 12.8% reporting most severe. This finding diverges from research done by Jali (2023) that examined similar damage metrics in Taman Sri Muda, Shah Alam. Based on Jali, wall damage is rated in a scale of less to medium severity based on the interview done from experts from the authors institution. Non-structural components such as ceiling sagging or staining (V24) and sewage system overflow (V28) also demonstrated high severity, with 28.7% and 26.6%, respectively categorized as severe.

Table 4.7
Summary of Frequency Analysis for the Significance of Different Building Attributes

Item Group	Attr. Category	Attributes	Code	Linkert Scale Indicator										Missing	%
				Least Significant (Linkert Scale 1)	%	Less Significant (Linkert Scale 2)	%	Significant (Linkert Scale 3)	%	More Significant (Linkert Scale 4)	%	Most Significant (Linkert Scale 5)	%		
Significance of Damage Attributes	Building Attribute	Number of storeys	V29	20	21.3	4	4.3	21	22.3	10	10.6	14	14.9	25	26.6
		Framing system	V30	18	19.1	2	2.1	18	19.1	12	12.8	23	24.5	21	22.3
		Foundation type	V31	16	17.0	6	6.4	12	12.8	16	17.0	23	24.5	21	22.3
		Wall thickness	V32	18	19.1	4	4.3	25	26.6	12	12.8	14	14.9	21	22.3
		Building orientation	V33	18	19.1	4	4.3	21	22.3	14	14.9	10	10.6	27	28.7
		Building Opening	V34	18	19.1	2	2.1	23	24.5	16	17.0	8	8.5	27	28.7
		Building Dimension/size	V35	20	21.3	10	10.6	23	24.5	14	14.9	2	2.1	25	26.6

	Material type	V36	18	19.1	0	0.0	20	21.3	12	12.8	21	22.3	23	24.5
	Building age and condition	V37	18	19.1	4	4.3	18	19.1	12	12.8	21	22.3	21	22.3
	Roof type	V38	18	19.1	0	0.0	24	25.5	17	18.1	12	12.8	23	24.5

The significance of various building attributes in determining the resilience of buildings to flood damage is analysed in Table 4.7 . The items were asked based on scale ranges from 1 to 5, where 1 represents least significant and 5 represents most significant. The data shows that number of storeys (V29) is considered "significant" by 21% of respondents and "more significant" by 10%. Another notable attribute is wall thickness which was rated as "More Significant" by 12% and "Most Significant" by 14% of respondents. Foundation type (V31) is rated with high significance with 24% of respondents rating it as "Most Significant" and 17% as "More Significant." This confirms its importance for structural stability, especially in flood-prone areas.

Table 4.8
Summary of Frequency Analysis for Significance of Fluid Flow Attributes

Item Group	Attr. Category	Attributes	Code	Linkert Scale Indicator										Missing	%
				Least Critical (Linkert Scale 1)	%	Less Critical (Linkert Scale 2)	%	Critical (Linkert Scale 3)	%	More Critical (Linkert Scale 4)	%	Most Critical (Linkert Scale 5)	%		
Significance of Damage Attributes	Fluid flow	Flow velocity and depth	V39	18	19.1	0	0.0	18	19.1	18	19.1	19	20.2	21	22.3
		Distribution of hydraulic pressure	V40	18	19.1	0	0.0	16	17.0	17	18.1	18	19.1	25	26.6
		Turbulent flow	V41	18	19.1	4	4.3	18	19.1	15	16.0	16	17.0	23	24.5
		Sediment movement	V42	17	19.1	4	4.3	20	21.3	14	14.9	15	16.0	23	24.5
		Debris carried by flood water	V43	18	19.1	2	2.1	22	23.4	23	24.5	8	8.5	21	22.3
		Rainfall intensity	V44	20	21.3	0	0.0	14	14.9	17	18.1	22	23.4	21	22.3
		Water discharge	V45	18	19.1	2	2.1	14	14.9	20	21.3	20	21.3	20	21.3

	Length of time building exposed to floodwater	V46	18	19.1	0	0.0	18	19.1	16	17.0	21	22.3	21	22.3

In Table 4.8, the attributes were evaluated on a Likert scale ranging from 1 (Least Critical) to 5 (Most Critical), with the percentage of responses distributed across these categories. The results indicate that water discharge (V45) and the length of time buildings are exposed to floodwater (V46) were perceived as the most critical attributes, with 42.6% and 43.3% of respondents respectively, rated as "More Critical" or "Most Critical." Additionally, flow velocity and depth (V39), distribution of hydraulic pressure (V40) and turbulent flow (V41) were also considered important factors, receiving substantial responses in the higher criticality categories. In contrast, sediment movement (V42) and debris carried by floodwater (V43) were ranked lower in terms of criticality, as they received a higher percentage of responses in the "Less Critical" (Scale 2) and "Critical" (Scale 3) categories. The table also highlights a notable percentage of missing responses across several attributes, ranging from 22% to 26% that suggest some respondents may have found these factors less relevant or more difficult to assess in the context of flood damage.

Table 4.9
Summary of Frequency Analysis for Criticality of Environmental Factors

Item Group	Attr. Category	Attributes	Code	Linkert Scale Indicator										Missing	%
				Least Critical (Linkert Scale 1)	%	Less Critical (Linkert Scale 2)	%	Critical (Linkert Scale 3)	%	More Critical (Linkert Scale 4)	%	Most Critical (Linkert Scale 5)	%		
Significance of Damage Attributes	Environmental Factors	Proximity to water bodies	V47	16	17.0	2	2.1	20	21.3	19	20.2	10	10.6	27	28.7
		Building elevation	V48	16	17.0	2	2.1	20	21.3	19	20.2	10	10.6	27	28.7
		Surface Slope	V49	16	17.0	6	6.4	18	19.1	14	14.9	19	20.2	21	22.3
		Flood zone	V50	16	17.0	2	2.1	20	21.3	12	12.8	23	24.5	21	22.3
		Climate change	V51	16	17.0	2	2.1	18	19.1	12	12.8	25	26.6	21	22.3
		Soil type	V52	16	17.0	4	4.3	22	23.4	16	17.0	15	16.0	21	22.3
		Surface Permeability	V53	16	17.0	2	2.1	24	25.5	12	12.8	17	18.1	23	24.5
		Site-specific factor	V54	16	17.0	4	4.3	16	17.0	19	20.2	20	21.3	19	20.2

Based on Table 4.9, the attributes were evaluated using a Likert scale ranging from 1 (Least Critical) to 5 (Most Critical), with percentages representing the distribution of responses. In general, the results show that NADMA staff prioritize direct geographical and hydrological attributes in assessing flood risks, while other environmental factors like soil type and climate change are considered less immediate concerns in flood damage evaluation. The results indicate that building elevation (V48) and proximity to water bodies (V47) were considered the most critical environmental factors, with 21.3% of respondents rating them as "Critical" (Scale 3), 19% as "More Critical" (Scale 4) and 20.2% as "Most Critical" (Scale 5). Similarly, flood zone classification (V50) and surface permeability (V53) were also perceived as highly critical, reflecting the importance of land characteristics in determining flood impact. These findings suggest that flood exposure risk is strongly influenced by location-based attributes, particularly a building's elevation and its proximity to flood-prone areas.

In contrast, soil type (V52), site-specific factors (V54) and climate change (V51) received lower criticality ratings, with higher percentages in the "Less Critical" (Scale 2) and "Critical" (Scale 3) categories. While these attributes contribute to flood damage vulnerability, they may be viewed as secondary concerns compared to immediate physical factors such as elevation and flood zoning. Additionally, the table highlights a high percentage of missing responses, particularly for building elevation (28.7%) and proximity to water bodies (28.7%), suggesting that some respondents may have found these factors irrelevant or difficult to assess in their specific context.

Table 4.10
Summary of Frequency Analysis for Criticality of Non-Structural Component

Item Group	Attribute Category	Attributes	Code	Linkert Scale Indicator										Missing	%
				Least Critical (Linkert Scale 1)	%	Less Critical (Linkert Scale 2)	%	Critical (Linkert Scale 3)	%	More Critical (Linkert Scale 4)	%	Most Critical (Linkert Scale 5)	%		
Significance of Damage Attributes	Non-structural	Building content	V55	16	17.0	4	4.3	10	10.6	23	24.5	20	21.3	21	22.3
		Electrical system	V56	16	17.0	4	4.3	22	23.4	16	17.0	15	16.0	21	22.3
		Mechanical system	V57	16	17.0	4	4.3	18	19.1	18	19.1	15	16.0	23	24.5

In Table 4.10, the results show that building content (V55), electrical system (V56) and mechanical system (V57) were all perceived as highly critical, with a significant proportion of responses falling within the "More Critical" (Scale 4) and "Most Critical" (Scale 5) categories. Specifically, building content (V55) received the highest proportion of "Most Critical" ratings (20%), followed by electrical systems (V56) and mechanical systems (V57) at 15% each. These findings suggest that damage to essential systems and interior building components is regarded as a significant concern in post-flood damage assessment. Despite their high perceived importance, all three (3) attributes also exhibited a notable percentage of missing responses with mechanical systems (V57) having the highest at 24.5%, followed by electrical systems (V56) and building content (V55) at 22.3% each. While the electrical system (V56) received the highest proportion of "Critical" (Scale 3) responses (22%), suggesting a strong agreement on its importance, mechanical systems (V57) showed a more evenly distributed response pattern across the Likert scale categories.

4.2.5 Variables Ranking

In this study, all variables were analysed using mean and standard deviation to examine the relationship between the frequency and severity of post-flood damage. The mean represents the average response in the sample, while the standard deviation shows how spread out the responses are around that average. A larger standard deviation means the responses vary more widely, whereas a smaller standard deviation indicates they are clustered closer to the mean. This section ranks the variables based on their mean values from the analysis.

The descriptive analysis results indicate the mean scores for each variable related to the frequency and severity of damage as well as significant attribute such as building attributes, hydraulic factors, environmental factors and non-structural influencing building damage due to floods. Table 4.11 until present the rankings of variables from these sections. Most of the mean scores exceed 3.00, demonstrating that respondents provided substantial information on the occurrence, severity and contributing factors of flood-related building damage.

Table 4.11
Variable Ranking Based on Damage Frequency

Attributes	Code	Mean	Std. Deviation	Rank
Mold growth	V12	2.66	1.433	1
Sewage systems overflow	V14	2.57	1.348	2
Electrical system damage	V7	2.54	1.276	3
Material deformation and detachment	V11	2.52	1.405	4
Opening damage	V5	2.37	1.303	5
Floor damage	V6	2.32	1.049	6
Wall damage	V2	2.31	0.995	7
Roof leaks	V13	2.31	1.328	8
Ceiling sagging or staining	V10	2.31	1.192	9
HVAC system malfunction	V9	2.26	1.226	10
Pipe burst	V8	2.22	1.175	11
Building structure shift or settling	V3	2.03	1.092	12
Foundation damage	V1	1.96	0.867	13
Beam and column damage	V4	1.89	1.092	14

This observation aligns well with findings from report by Environmental Protection Agency (EPA) which notes that post-flood conditions often lead to mold growth within 24 to 48 hours and one of the most frequently occurring flood-related damage (EPA, 2018). However, research by Paulik et al. (2022) emphasize that internal finishes such as wall, floor and doors are the most frequently damaged components in residential buildings with a reported damage frequency ranging between 90% and 98%. The observed differences between this study and Paulik et al. (2022) can be attributed to regional climatic variations. Malaysia's tropical climate is characterized by high humidity levels ranging from 70% to 90% and warm temperatures which lead to rapid mold proliferation following flood events. This is supported by research indicating that mold growth is a significant concern in Malaysian buildings (Parham et al., 2018). In contrast, New Zealand's temperate climate with generally lower humidity levels reduces the frequency of mold growth. Instead, flood events in New Zealand more commonly result in damage to internal finishes.

Table 4.12
Variable Ranking Based on Damage Severity

Damage Type	Code	Mean	Std. Deviation	Rank
Electrical system damage	V21	3.21	1.433	1
Mold growth	V26	3.15	1.319	2
Sewage systems overflow	V28	3.14	1.378	3
Opening damage	V19	3.12	1.353	4
Roof leaks	V27	3.08	1.421	5
Ceiling sagging or staining	V24	3.07	1.228	6
Material deformation and detachment	V26	3.07	1.417	7
Floor damage	V20	3.01	1.236	8
Wall damage	V16	2.97	1.32	9
Foundation damage	V15	2.93	1.503	10
Pipe burst	V22	2.89	1.264	11
HVAC system malfunction	V23	2.89	1.347	12
Building structure shift or settling	V17	2.86	1.417	13
Beam and column damage	V18	2.84	1.385	14

Table 4.12 presents a ranking of flood damage severity based on mean scores. The ranking suggests that damages affecting essential systems and indoor components were perceived as the most severe while structural deformations and mechanical failures were ranked lower in terms of severity. The results show that electrical system damage (V21, Mean = 3.21), mold growth (V26, Mean = 3.15), sewage system overflow (V28, Mean = 3.14) and opening damage (V19, Mean = 3.12) were ranked as the most severe types of flood damage. These damages received the highest scores indicating that they are considered critical in post-flood damage assessment. This finding is consistent with Paulik et al. (2022) who highlighted that internal finishes and essential systems contribute significantly to overall building damage ratios, particularly because they are more exposed to water contact and indirect damage during repair. Additionally, electrical system damage is often severe because water exposure can cause short circuits, corrosion and complete system failures, leading to costly repairs or replacements (Paulik et al., 2024).

In the mid-range severity category, roof leaks (V27, Mean = 3.08), ceiling sagging or staining (V24, Mean = 3.07), material deformation and detachment (V25, Mean = 3.07), floor damage (V20, Mean = 3.01) and wall damage (V16, Mean = 2.97) were identified. These types of damage had relatively high mean scores but were ranked lower than those affecting essential systems and health conditions. The lowest-ranked damages include foundation damage (V15, Mean = 2.93), pipe bursts (V22, Mean = 2.89), HVAC system malfunction (V23, Mean = 2.89), building structure shift or settling (V17, Mean = 2.86) and beam and column damage (V18, Mean = 2.84). These damages received the lowest severity scores which indicates that they were perceived as less critical compared to other types of flood damage. Opel and Matthews (2025) argue that while structural damages may have lower frequency and perceived severity, they often lead to higher repair costs and long-term safety concerns, which are not always captured in short-term damage assessments. Other studies suggest that structural damage is sometimes underestimated immediately after a flood. This is due to issues like cracks and material weakening that may take time to appear (Aribisala et al., 2022).

Table 4.13
Variable Ranking Based on Building Attributes

Attribute	**Code**	**Mean**	**Std. Deviation**	**Rank**
Foundation type	V31	3.33	1.537	1
Framing system type	V30	3.27	1.548	2
Material type	V36	3.25	1.528	3
Building age and condition	V37	3.19	1.533	4
Roof type (flat vs. slope)	V38	3.07	1.397	5
Wall thickness	V32	3.00	1.414	6
Number of storeys	V29	2.91	1.483	7
Building Orientation	V33	2.91	1.401	8
Building Opening	V34	2.91	1.357	9
Building Dimension/Size	V35	2.54	1.195	10

Table 4.13 shows that foundation type (V31, Mean = 3.33), framing system type (V30, Mean = 3.27), material type (V36, Mean = 3.25) and building age and condition (V37, Mean = 3.19) were ranked as the most significant building attributes. These attributes received the highest scores suggesting that they play a important role in determining a building's resilience to flood damage. Study by Aribisala et al. (2022) and Paulik et al. (2024) supported the findings as they emphasize that foundation type is a key determinant of flood resistance such as elevated slab and pile foundations that can significantly reduce water intrusion risks.

Roof type (V38, Mean = 3.07), wall thickness (V32, Mean = 3.00), number of storeys (V29, Mean = 2.91) and building orientation (V33, Mean = 2.91) were identified in lower significance. These attributes were considered moderately important, meaning that they contribute to a building's structural performance but may not be as critical as foundation type and framing system type. This observation aligns with findings from Liu and Noonan (2022) who noted that building height can affect flood impact but is often secondary to foundation elevation and material durability. The lowest-ranked attributes include building opening (V34, Mean = 2.91) and building dimension/size (V35, Mean = 2.54). These attributes received the lowest scores, indicating that they are perceived as less critical in comparison to other structural factors.

Table 4.14
Variable Ranking Based on Fluid Flow Attributes

Attribute	**Code**	**Mean**	**Std. Deviation**	**Rank**
Water discharge	V45	3.30	1.515	1
Length of time buildings exposed to flood	V46	3.30	1.516	2
Rainfall intensity	V44	3.29	1.577	3
Flow velocity and depth	V39	3.27	1.493	4
Distribution of hydraulic pressure	V40	3.25	1.519	5
Turbulent flow (swirling water)	V41	3.10	1.485	6
Sediment movement	V42	3.06	1.463	7
Debris carried by flood water	V43	3.01	1.338	8

Based on Table 4.14, the ranking mainly reflects a prioritization of water volume, duration and movement dynamics as the most influential factors affecting flood damage severity.The results show that water discharge (V45, Mean = 3.30) and the length of time buildings are exposed to floodwater (V46, Mean = 3.30) were ranked as the most critical attributes, followed by rainfall intensity (V44, Mean = 3.29) and flow velocity and depth (V39, Mean = 3.27). This finding is strongly supported by Taramelli et al. (2022) in their study who found that water depth and duration accounted for up to 75% of observed flood damage in urban settings particularly in low-lying residential zones. Similarly, Nofal and van de Lindt (2020) reported that each additional hour of floodwater exposure increased the probability of severe structural damage by 62%, especially in buildings made of timber and porous materials.

In contrast, distribution of hydraulic pressure (V40, Mean = 3.25) and turbulent flow (V41, Mean = 3.10) were ranked moderately critical, signifying that while water pressure and flow turbulence contribute to flood damage, they are perceived as slightly less influential compared to discharge and exposure duration. The lowest-ranked attributes include sediment movement (V42, Mean = 3.06) and debris carried by floodwater (V43, Mean = 3.01), which suggests that they are not considered as primary drivers of flood impact. This perspective is not universally agreed upon. In Malaysia, Romali and Yusop (2021) found that flood duration was the leading predictor of structural damage in urban areas such as Kuala Lumpur. This aligned really well with the ranking. However, Rehan and Zakaria (2021) observed that in Kelantan's rural settlements, flow velocity and sediment transport had a more pronounced effect on structural failure than flood duration. According to some research, debris impact accounted for only 5–10% of total structural damage (Martínez-Gomariz et al., 2020). However, Balasbaneh et al. (2020) showed that debris-laden floods increased mold and microbial growth risks in Malaysian flood-prone homes by 25%. The issue can lead to higher maintenance and repair costs months after flood recession, which is a strong reason as to why debris should not be under evaluated.

Table 4.15
Variable Ranking Based on Environmental Factors

Attribute	**Code**	**Mean**	**Std. Deviation**	**Rank**
Climate change	V51	3.38	1.524	1
Proximity to water bodies (e.g., buildings located)	V47	3.34	1.539	2
Flood zone	V50	3.33	1.501	3
Site-specific factors (Land use, urban growth, etc.)	V54	3.31	1.47	4
Surface slope	V49	3.19	1.478	5
Surface permeability	V53	3.17	1.434	6
Soil type	V52	3.14	1.407	7
Building elevation	V48	3.07	1.374	8

Climate change (V51, Mean = 3.38) is ranked as the most important factor. While flood zones (V50, Mean = 3.33) and site-specific factors (V54, Mean = 3.31) are ranked highly, factors like surface permeability (V53, Mean = 3.17) and building elevation (V48, Mean = 3.07) are ranked lower. This view is supported by researchers who agree that climate change increases rainfall intensity and extreme weather events that contributes to more frequent and severe floods (Frame et al., 2020; Kundzewicz et al., 2019). However, some researchers may question the lower ranking of factors like building elevation and surface permeability. They argue that these elements play a crucial role in reducing site-level flood impacts. For example, Rosenzweig et al. (2018) emphasize that elevated structures and permeable pavements can significantly reduce flood exposure, especially in urban environments. Respondents may have placed less emphasis on site-specific characteristics such as building elevation and surface permeability due to the reality of flood experiences in predominantly rural or semi-urban monsoonal regions of Malaysia, particularly in east coast states such as Kelantan and Terengganu.

4.2.6 Canonical Correlation Analysis (CCA) between Damage Frequency and Severity

Canonical Correlation Analysis (CCA) is a statistical method used to examine the relationship between two groups of variables. Unlike Pearson correlation which focuses on the link between two individual variables, CCA analyses how two sets of variables relate to each other. This method provides data by analysing the connections within and between both groups. In this study, CCA was applied to explore the relationship between the frequency of building damage caused by floods (first set of variables) and the severity of that damage (second set of variables). CCA identifies pairs of linear combinations called canonical variates from each set that are most strongly related to one another. This allows to an understand of the overall relationship between the two groups rather than viewing at each variable separately.

Wilks' Lambda is a key statistic used in multivariate analysis to test whether there is a significant relationship between two sets of variables. In the analysis, the overall Wilks' Lambda value is indicated as significant ($p < 0.05$) showing that the first variables set have a significant effect on the second variables set. **Error! Reference source not found.** shows the results of the dimension reduction analysis in canonical correlation.

Table 4.16
Dimension Reduction Analysis in Canonical Correlation

Function	Correlation	Squared Correlation	Wilks Statistic	Sig.
1	0.897	0.8038	0.001	0.000
2	0.876	0.7678	0.004	0.000
3	0.828	0.6849	0.018	0.000

4	0.785	0.6162	0.056	0.000
5	0.682	0.4650	0.145	0.002
6	0.632	0.3997	0.271	0.092
7	0.531	0.2823	0.451	0.620
8	0.455	0.2097	0.629	0.935
9	0.309	0.0957	0.793	0.996
10	0.245	0.0370	0.877	0.997
11	0.181	0.0327	0.933	0.994
12	0.155	0.0242	0.964	0.974
13	0.108	0.0116	0.988	0.926
14	0.010	0.0001	1.000	0.931

Based on Table 4.16, the Wilks' Lambda values and significance levels indicate how many canonical functions contribute meaningfully to the relationship between the two sets of variables. The first five functions are statistically significant ($p < 0.05$) suggesting that they explain a significant portion of the shared variance. However, the Wilks Statistics on the fifth function indicates a weaker significance at $p = 0.145$, thus it is discarded for further interpretation.

From the sixth function onward, the p-values exceed 0.05, showing that these functions do not significantly contribute to the model. As a result, only the first four (4) functions will be retained for further analysis as they capture the most important relationships between the variable sets. The remaining functions have weaker correlations and are statistically non-significant, thus do not add meaningful statistical significance and will be excluded from interpretation. Table 4.17 shows the canonical loadings for damage frequency and severity of the damage types.

Table 4.17
Canonical Loadings for Damage Frequency and Severity

Variable	Function							
	1		2		3		4	
	Set 1[2]	**Set 2[3]**	**Set 1**	**Set 2**	**Set 1**	**Set 2**	**Set 1**	**Set 2**
Foundation damage	-0.263	-0.247	0.150	-0.015	-0.079	-0.386	0.582	0.257
Wall damage	0.273	-0.060	0.036	0.171	-0.274	-0.164	0.506	0.266
Building structure shift or settling	-0.191	-0.444	-0.059	0.112	-0.147	-0.196	0.512	0.181
Beam and column damage	-0.252	-0.312	-0.239	0.111	-0.146	-0.148	0.518	0.176
Opening damage	0.130	-0.012	-0.131	-0.212	0.148	0.092	0.378	0.047
Floor damage	0.135	-0.253	-0.180	-0.375	0.078	0.336	0.353	0.314
Electrical system damage	0.301	0.135	0.073	-0.146	0.181	0.125	0.520	0.307
Pipe burst	0.053	-0.114	-0.118	-0.067	0.449	0.288	0.439	0.028
HVAC system malfunction	0.121	-0.153	-0.015	-0.149	0.597	-0.101	0.394	0.290
Ceiling sagging or staining	0.250	-0.139	0.129	-0.024	0.297	0.270	0.297	0.103
Material deformation and detachment	0.198	0.041	-0.203	-0.249	0.102	0.055	0.578	0.033
Mold growth	0.452	0.018	-0.062	-0.328	0.006	0.223	0.431	-0.073
Roof leaks	0.175	-0.131	0.055	-0.067	0.192	0.177	0.211	0.083
Sewage systems overflow	0.170	-0.180	0.042	-0.153	0.029	0.342	0.362	0.316

[2] Set 1: Damage frequency

[3] Set 2: Damage severity

Based on Table 4.17, the canonical loadings for damage frequency and severity illustrate the correlation between different types of post-flood damage and the first four (4) canonical functions. These loadings identify which types of damage are most strongly associated with each function. Higher absolute values indicate stronger relationships while lower values suggest minimal relationship. The sign of the loadings (positive or negative) does not indicate the importance of the variable but a direction of the relationship. Even though there is no universally established threshold for determining variable importance, a commonly accepted guideline is loading value of 0.30 or higher indicates a meaningful contribution to the canonical function (Nouri et al., 2022).

Across all four canonical functions, the data shows a clear trend. Mold growth (Set 1: 0.452; Set 2: 0.431), wall damage (Set 1: 0.273; Set 2: 0.506) and ceiling sagging or staining (Set 1: 0.250; Set 2: 0.297) contribute strongly to the damage frequency dimension, while structural damages such as building structure shift or settling (Set 2: –0.444) and beam and column damage (Set 2: –0.312) are associated with greater severity despite the lower frequency loadings. This contrast is especially shown in Function 1, where damages like mold and wall deterioration is significant in frequency dimension, while severe but less frequent structural issues define the severity dimension.

Notably, mold growth is one of the few variables that is significant on both frequency and severity. Structural issues such as foundation damage (Set 2: 0.257 in Function 4) and floor damage (Set 2: 0.355 in Function 2) do not appear as frequently but are flagged as highly severe. Damages to internal systems including electrical system damage (Set 2: 0.320) and pipe bursts (Set 2: 0.298) also appear as severe contributors, particularly in Function 2, even though the frequency values remain relatively low.

4.2.7 Damage Priority Score

Damage priority score was developed using the results of CCA. This score combines the canonical loading values from Set 1 (frequency) and Set 2 (severity) which represent the strength of each variable's contribution to their respective canonical functions. Although canonical loadings do not represent cause-and-effect relationships, they show how strongly each variable is related to the overall pattern in its group. In this study, the highest absolute loading for each damage type was used to identify which damages are most strongly connected to the overall trends of flood damage frequency and severity.

To ensure both dimensions were treated fairly, the absolute values of the highest canonical loadings across all functions were extracted for each variable. These values were then normalized to a 0–1 scale using min-max normalization. By normalising these values and combining them, a practical and understandable score was created to show which types of damage are consistently important across both aspects. Equation (4.1 shows the formula used to calculate the normalized score.

$$Normalized\ score = \frac{X - X_{min}}{X_{max} - X_{min}} \tag{4.1}$$

Where:

X = Absolute value of the original canonical loading value

X_{min} = Smallest loading value in the dataset

X_{max} = Largest loading value in the dataset

The second formula, written in (4.2 represents the calculation of the priority score that combines the normalized values of each variable from the frequency and severity sets.

$$Priority\ Score = (w_1 * Normalized\ Score_1) + (w_2 * Normalized\ Score_2) \tag{4.2}$$

Where:

w_1= weights assigned to the normalized frequency score (w_1= 0.5)

w_2= weights assigned to the normalized severity score (w_2= 0.5)

The formula allows flexibility to assign greater importance to either frequency or severity based on the study's objectives. In this study, both weights were set to 0.5 to give equal importance to how often a damage occurs and how severe it is.

Table 4.18
Priority Score and Rank Based on Combined Normalized Value

Variable	Set 1	Set 2	Normalized Set 1	Normalized Set 2	Priority Score	Rank
Mold growth	0.452	0.431	1.000	0.837	0.918	1
Wall damage	0.273	0.506	0.549	1.000	0.775	2
Electrical system damage	0.301	0.320	0.620	0.595	0.607	3
Building structure shift or settling	0.191	0.444	0.343	0.865	0.604	4
Beam and column damage	0.252	0.312	0.496	0.577	0.537	5
Ceiling sagging or staining	0.250	0.297	0.491	0.545	0.518	6
Foundation damage	0.263	0.257	0.524	0.458	0.491	7
Sewage systems overflow	0.170	0.362	0.290	0.686	0.488	8
Floor damage	0.135	0.355	0.202	0.671	0.436	9
HVAC system malfunction	0.121	0.290	0.166	0.529	0.348	10
Roof leaks	0.175	0.211	0.302	0.357	0.330	11
Pipe burst	0.055	0.298	0.000	0.547	0.273	12
Material deformation and detachment	0.198	0.075	0.360	0.061	0.211	13
Opening damage	0.130	0.047	0.189	0.000	0.094	14

4.3 Thematic Analysis from Expert Interview

To complement the survey methodology, qualitative data was gathered through expert interviews. Qualitative data consists of non-numeric information, including interview transcripts, notes, videos, audio recordings, images, texts and documents. In this study, interview transcripts serve as the primary source for raw data collection. According to Kuckartz and Rädiker (2023), qualitative data analysis can be categorized into five approaches such as content analysis, narrative analysis, discourse analysis, framework analysis and grounded theory. The interviews were analysed using thematic analysis to map and interpret key themes relevant to the research context. The interview sessions were carefully structured into four (4) sections to ensure thorough coverage of relevant topics and alignment with the research objectives. This approach allowed for in-depth exploration of post-flood damage assessment, disaster response and mitigation strategies as perceived by disaster related agency. Virtual or in-person interviews were conducted with experts from NADMA, JKR and JPS chosen for their critical roles and extensive experience in managing flood-related challenges.

The interviews were conducted in semi-structured and organized into specific thematic sections to ensure clarity and focus. The script for the interviews is attached in Appendix for reference. Interviews were conducted with six (6) disaster management professionals, including two (2) from NADMA, two (2) from JKR, one (1) from MKN and one (1) from JPS. Each of the participants were chosen based on their expertise in disaster management for over ten (10) years of experience. These experts were selected from key agencies involved in disaster response to provide critical insights into the research context. The one-on-one interviews were conducted with participants chosen based on their credentials, expertise and active participation in flood management. Experts were asked about their background, roles in post-flood scenarios, damage assessment procedures, challenges encountered and recommendations for improvement. This approach provided flexibility to explore deeper into topics based on respondents' expertise and experiences while ensuring the key areas of interest were comprehensively covered.

4.3.1 Development of Codes

In this study, open coding is utilized. Table 4.19 below presents the compiled information, structured from data extracted through thematic analysis of the interview transcripts.

Table 4.19
Tabulated Thematic Information

Themes	Categories	Codes
Institutional Roles and responsibilities	Governmental & Operational Roles	federal disaster management, state disaster management, district disaster management
	Inter-Agency Collaboration	coordination meetings, observation and monitoring, inter-agency coordination
	Agency role	role of NADMA, role of JKR, role of JPS, role of BOMBA
Assessment Process	Assessment Methods	field survey, structural condition rating, community reported damage, green area, yellow area, red area, visual inspection, loss assessment, flood simulation, mapping
	Existing Guidelines	standardized damage indicators, post-flood impact reporting, effectiveness of existing guideline
	Timing of Assessment	emergency damage assessments, post-flood evaluations, seasonal reporting
	Procedures of Assessment	initial rapid survey, intermediate structural review, final rehabilitation assessment, structural condition rating, damage classification, two-stage damage assessment process, post-monsoon detailed damage assessment, data collection, accuracy of damage data, preliminary damage assessment, efficiency of damage assessment
Flood Damage Attributes	Structural	number of storeys, building age, foundation
	Environmental	soil, elevation, proximity to water bodies

	Non-structural	gas leakage, plumbing damage, electrical damage, content damage, mold growth, material type, wall damage
Challenges in Flood Management	Assessment Limitation	lack of standardized assessment procedure, lack of damage indicator, ongoing development of systematic damage assessment, low public perception, Accessibility Issues
	Operational	conflicting decision priorities, budget limitations, political considerations, challenges in rescue operation, experience-based decision making, overlapping agency responsibilities, limited communication in crisis

4.3.2 Demographic Profile of Expert Interview

Six (6) experts were conveniently chosen and engaged in one-on-one interviews to provide their valuable perspectives on proper damage level assessment method for the post-flood damage assessment. The demographic profiles of the expert interviewees are detailed in Table 4.20.

Table 4.20
Demographic Profile of Experts Interview

Experts	Organisation	Experts Designation	Year of Working Experience
Expert 1	NADMA	Principal Assistant Director	16 years
Expert 2	NADMA	Senior Officer in Disaster Policy	10 years
Expert 3	JKR	Disaster Unit	13 years
Expert 4	JKR	Disaster Unit	14 years
Expert 5	JPS	Head of Flood Mitigation and Drainage Division	12 years
Expert 6	MKN	Emergency Response Specialist	12 years

The details of the expert interview profiles are provided in Appendix. As presented in Table 4.20, these experts were from NADMA, JKR, JPS and MKN, holding positions such as Principal Assistant Director, Senior Officer in Disaster Policy, Disaster Unit personnel, Head of Flood Mitigation and Drainage Division and Emergency Response Specialist. Each expert had over ten (10) years of experience in disaster management, engineering and related fields. Their extensive knowledge and professional backgrounds establish their credibility in evaluating flood-related building damage.

4.3.3 Agency Roles and Responsibilities

Based on Table 4.21, findings reveal that disaster management in Malaysia involves multiple institutions working together to respond to and recover from floods.

The coordination between agencies is divided into three (3) level which are federal, state and district-level for the purpose of organized and efficient in coordination.

Table 4.21
Disaster Experts Perspectives on Institutional Role

Category	**Institutional Roles**	**Experts' Opinion**
Governmental & Operational Roles	Federal disaster management (NADMA)	NADMA serves as the central agency responsible for formulating national disaster management policies, coordinating emergency response efforts and conducting post-disaster evaluations. Its role is to ensure efficient resource allocation and national-level coordination for disaster preparedness and response.
	State disaster management committees	At the state level, disaster response is managed by the State Disaster Management Committees, which oversee the implementation of federal policies, allocate resources and make sure effective coordination between local agencies and national authorities.
	District disaster management committees	District committees handle direct disaster response including damage assessments, evacuation coordination and aid distribution. Their proximity to affected communities allows for rapid response and localized decision-making.
Inter-Agency Collaboration	Coordination meetings and strategy alignment	Regular inter-agency meetings help agencies align disaster response strategies, share updates and allocate responsibilities efficiently, reducing redundancy in relief operations.
	Observation, monitoring and resource-sharing	Continuous observation and monitoring of flood conditions, along with effective information sharing gives a proactive and well-coordinated response among different agencies.
Agency Role	Role of NADMA	NADMA administers national disaster policies, ensuring that federal, state and district levels are aligned in disaster preparedness and response.
	Role of JKR, JPS, DOSM	Technical agencies such as JKR, JPS and DOSM play an important role in evaluating damage, mitigating flood risks and assessing economic losses.
	Role of BOMBA, PDRM, ATM, APM	Executing agencies such as BOMBA, PDRM, ATM and APM focus on rescue operations, public safety, logistical support and evacuation assistance.

The roles of these institutions vary based on their jurisdiction with federal agencies concentrating on policies and coordination, state agencies managing localized responses and district agencies executing actions on the ground.

> *Expert 1:"NADMA acts as the coordinating agency in disaster management... we coordinate the operations of various technical agencies such as BOMBA, the military, JKR, JPS and local authorities."*

> *Expert 4:" In general, there are Central Disaster Management Committee chaired by the Deputy Prime Minister with NADMA under this level, the State Disaster Management Committee chaired by the Chief Minister and the District Disaster Management Committee chaired by the District Officer."*

Federal disaster management is led by the National Disaster Management Agency (NADMA) that focus on formulating policies, disaster response strategies and post-disaster evaluations. State disaster management manages response efforts at the state level to make sure resources are distributed effectively and coordinating with local authorities. District disaster management on the other hand handles on-the-ground implementation, conducting damage assessments, coordinating evacuations and ensuring affected communities receive necessary aid. Findings indicate that successful disaster management relies on strong collaboration between agencies.

> *Expert 2: "After a flood, NADMA's technical section collaborates with various technical agencies such as JPS, the Meteorological Department, JKR and PBT to plan follow-up actions and assess the extent of the damage.*

Based on the experts, coordination meetings are conducted to discuss response strategies and address challenges faced during post-flood recovery. The coordination is important to make sure all organizations involved in disaster management work together to prevent duplication of scope. Figure 4.7 illustrate an overall structure of how different agencies and committees operate within the disaster management system.

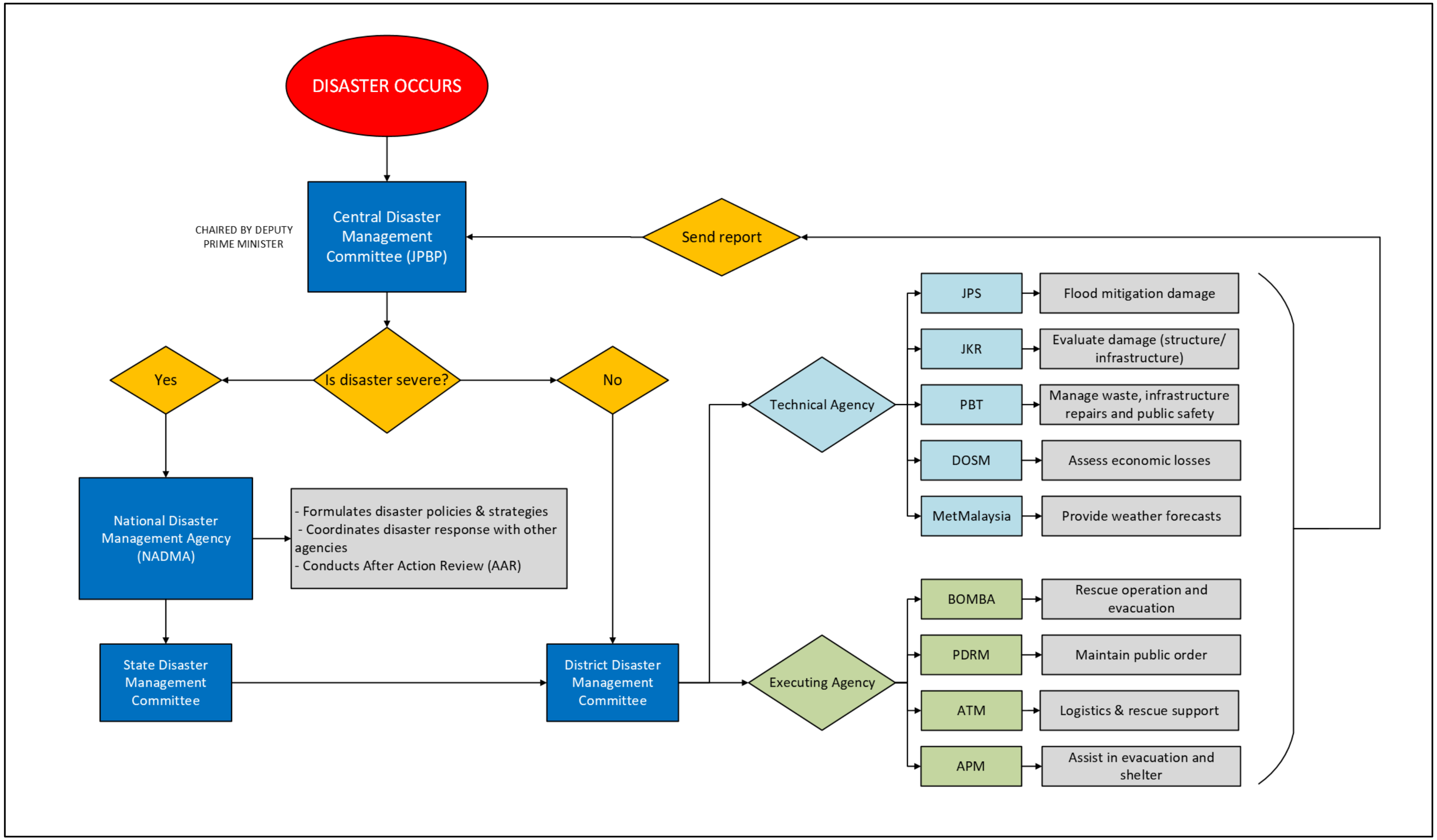

Figure 4.7 Disaster Management Structure

Figure 4.8 summarises the specific roles of these key agencies at each level of governance to highlight the distinction between national-level policy and coordination functions and local implementation responsibilities such as damage assessment, flood mitigation works, rescue operations and evacuation support.

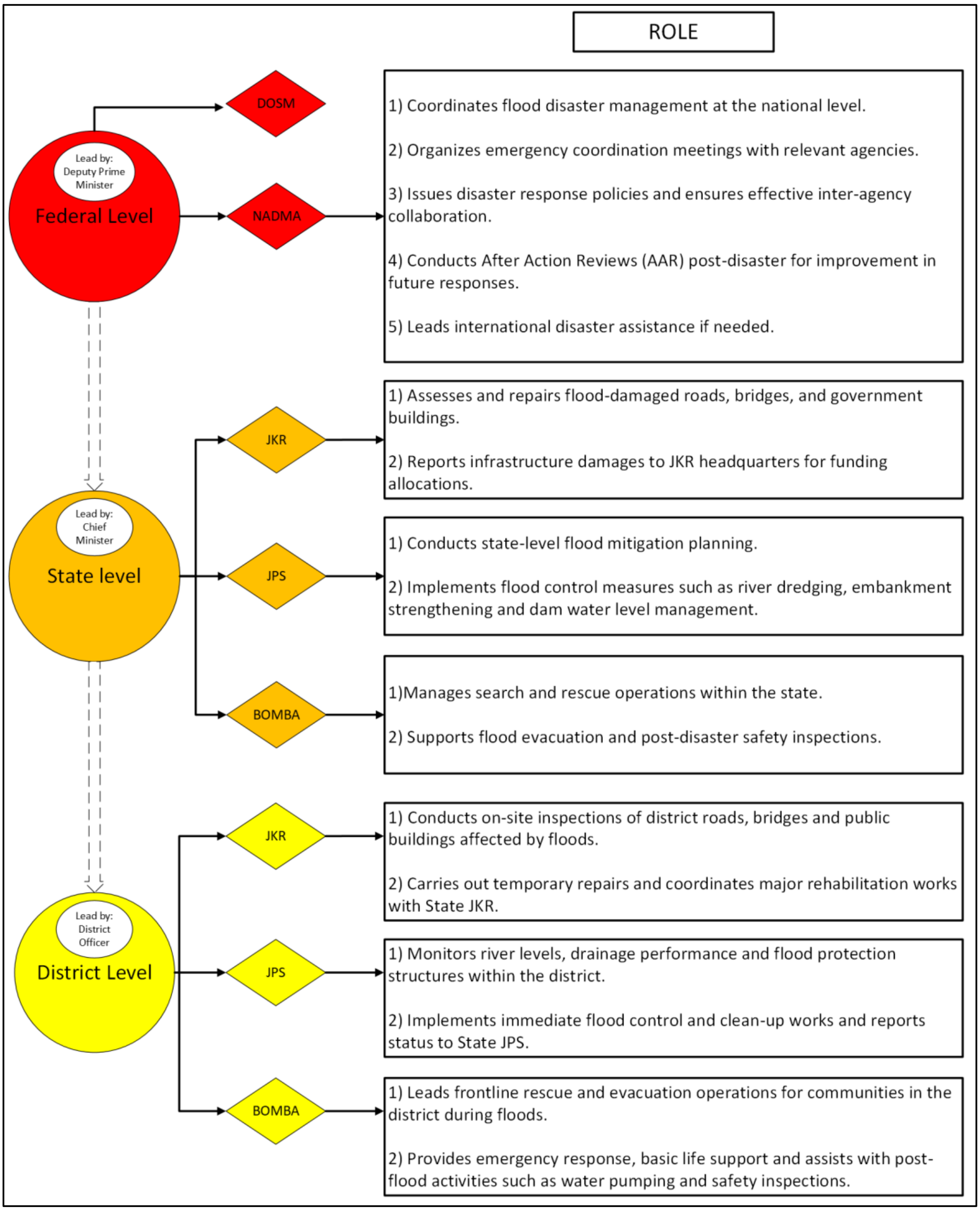

Figure 4.8 Specific Role of Key Agencies

Based on Figure 4.8, DOSM and NADMA, led by the Deputy Prime Minister are responsible for coordinating national flood management, organising inter-agency meetings, issuing disaster response policies, conducting After Action Reviews (AAR). At the state level, under the Chief Minister, JKR assesses and repairs damaged roads, bridges and public buildings, while JPS plans and implements flood mitigation measures such as river dredging, embankment strengthening and dam water management. BOMBA at state level manages search and rescue operations and supports evacuation and safety inspections. At the district level, under the District Officer, JKR conducts on-site inspections and carries out temporary repairs, JPS monitors river levels and local flood protection structures and undertakes immediate control and clean-up works, while BOMBA leads frontline rescue and evacuation and provides basic life support and post-flood assistance.

4.3.4 Damage Assessment Method

As a whole, all the significant data output from the expert interview sessions were analysed using thematic analysis and were consolidated accordingly in Table 4.22. Experts expressed differences in perspectives on the method of conducting damage assessment on buildings.

Table 4.22
Disaster Experts Perspectives on Assessment Method

Category	**Assessment Type**	**Description**
On-site Damage Assessment	Field Survey	Teams conduct on-ground surveys using visual inspections to assess flood impact, collect real-time data and document damage.
	Community Reported Damage	Local communities report damages and provide additional data for assessments.
Impact Assessment	Structural Condition Rating	Evaluation of building structures to determine safety and required repairs.
	Loss Assessment	Evaluation of economic and infrastructure losses due to the flood.
Risk Mapping	Area Classification	Areas are classified based on damage severity. Green (low-risk, minimal damage, basic recovery), Yellow (moderate-risk, requiring further assessment for structural issues) and Red (severe damage requiring major interventions).

	Flood Mapping	Use of GIS mapping to visualize flood-affected zones and damage distribution.
	Flood Simulation	Flood modeling and simulations to predict and assess future flood risks.

Based on Table 4.22, one of the key points that most agencies rely heavily on visual inspections to evaluate flood damage. Experts confirmed that their assessments are largely observational such as identifying visible signs of structural damage. As stated by expert 5 and 6:

> *Expert 6: "We only conduct visual observations to determine whether a building is safe or not. If there are visible cracks or structural weaknesses, we will recommend a further inspection by the relevant technical authorities."*

> *Expert 5: "Typically, the District Officer will lead the initial assessment and the district engineers will assist by conducting visual inspections."*

This aligns with findings from Rahman and Manan (2020) who noted that many flood damage assessments are conducted using rapid on-site evaluations, thus it often lacks precision in identifying underlying structural damage.

4.3.4.1 Assessment Procedures

Based on expert interviews, agencies in Malaysia follow a two-stage assessment process. The first stage of the damage assessment procedure is the initial assessment, conducted immediately after floodwaters recede. One expert described the Rapid Assessment Method (RAM) used for initial evaluations.

> *Expert 3:"We usually conducts a rapid assessment immediately after the floodwaters recede to record major damage. The frequency of these assessments depends on the risk level of the area. If it's a flood-prone hotspot, inspections may need to be carried out more frequently, such as annually or after every major flood event."*

> *Expert 1: "Initial assessment like visual inspections are likely the first step taken to identify any cracks in walls, sunken floors, or weak structures. Normally, PBT or JKR will conduct the assessment within one to two weeks after the flood recedes."*

Once initial assessments are conducted, a more detailed technical assessment is conducted after the flood situation has stabilized, typically within weeks to months depending on the severity of the disaster and available resources. During this phase, district level technical agencies such as JKR, JPS and PBT conduct in-depth damage evaluations and Department of Statistics Malaysia (DOSM) will compile economic loss data to guide recovery planning and financial aid distribution.

> *Expert 4: "Typically an initial assessment is conducted within two weeks, but for major structural evaluations, further inspections may take months depending on available engineering resources."*

This two-tiered approach is consistent with international post-disaster assessment practices such as the Post-Disaster Needs Assessment (PDNA) model recommended by the United Nations (European Union et al., 2013). Paulik et al. (2022) highlight that New Zealand also applies a staged approach where visual inspections are followed by technical assessments involving structural engineers and loss estimation experts. Experts also acknowledged that other agencies follow informal rating systems to classify affected buildings and infrastructure.

> *Expert 6: "Red zones are dangerous areas where only the emergency response team can go. Yellow zones are semi-dangerous areas where civilians are not allowed, but emergency support teams can stand by. Green zones are gathering areas, safe for everyone."*

Kreibich et al. (2017) also noted that similar color-coded hazard zones are used in European flood management systems particularly in Germany and the Netherlands to restrict access to highly vulnerable areas. These are also supported by McEntire (2022) which noted the colour coded classification for building habitability. Figure 4.9 shows the overall damage assessment process highlighted based on experts' perspectives.

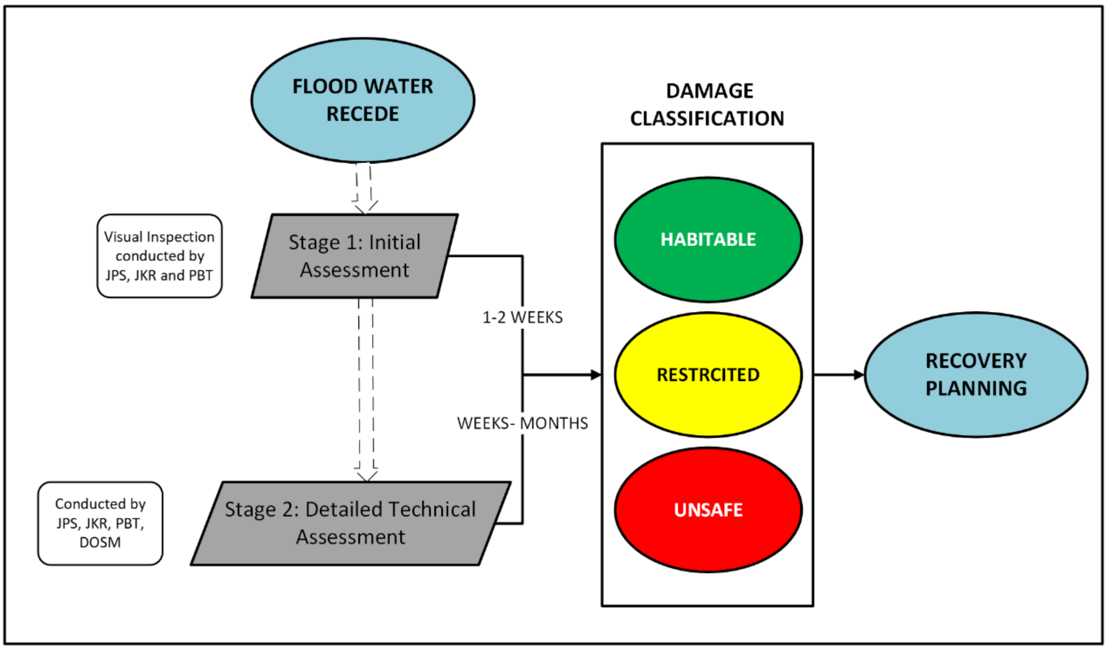

Figure 4.9 Proposed Damage Assessment Process

4.3.5 Experts Perspectives on Damage Attributes

According to experts, one of the most critical attributes in damage assessment is structural integrity that determines whether a building is safe for occupancy or requires further inspection. Experts emphasized that cracks in walls, foundation instability and partial collapses are among the most observed indicators of flood damage. Experts from JKR explained:

> *Expert 5: "In most cases, structural damage is our main concern. We assess whether the building has visible cracks, whether the walls are still stable, or if the foundation has shifted. If there are significant structural issues, we classify the building as unsafe and recommend evacuation."*

> *Expert 4: "Sometimes, buildings look fine from the outside, but structural shifts can weaken foundations. In cases of prolonged flooding, soil erosion can destabilize the entire structure."*

Wüthrich et al. (2020) supports the statements since they found that severe floods can cause significant structural failures, including partial or total collapse of buildings. Experts also noted that material degradation has a significant role in determining flood damage severity which aligns with Thieken et al. (2023) , who argue that post-flood inspections should not be limited to immediate damage but should also consider long-term material degradation.

> *Expert 4: "Not all damage is immediately visible. Some materials like wood and drywall deteriorate over time after prolonged water exposure. Even concrete absorbs water, which weaken the structure. That's why we need follow-up inspections months after a flood event.*

Some experts contend that building damage is simply limited mostly to superficial elements such as walls, windows and doors rather than the building's core integrity. These perspectives suggest that concrete buildings are largely resilient to floodwaters and that the primary concern is cleaning and restoring interiors rather than rebuilding entire structures. For instance, an expert stated:

> *Expert 6:"If the house is built with concrete, it is usually safe even after a flood. The most affected parts are the furniture and internal fixtures, not the structure itself."*

> *Expert 1: "Buildings may look damaged, but most of the time, the structure itself is still strong. Unless the water current was extremely strong, the main concern is cleaning up rather than rebuilding."*

This perspective suggests that structural failure is rare unless the flood is extreme. However, this directly contradicts other experts, particularly from JPS who argue that hidden damage is often underestimated.

To strengthen the reliability of the findings, the frequency with which experts emphasized particular damage attributes throughout the interviews was analysed using MAXQDA 24 (VERBI Software, 2021). A higher percentage indicates that a topic was mentioned more often and across larger portions of the text, therefore indicates a greater emphasis and attention from the experts. By using MAXQDA 24 code trends analysis, the total frequency of code was displayed in Figure 4.10 to evaluate which code were stated the most in the interview session.

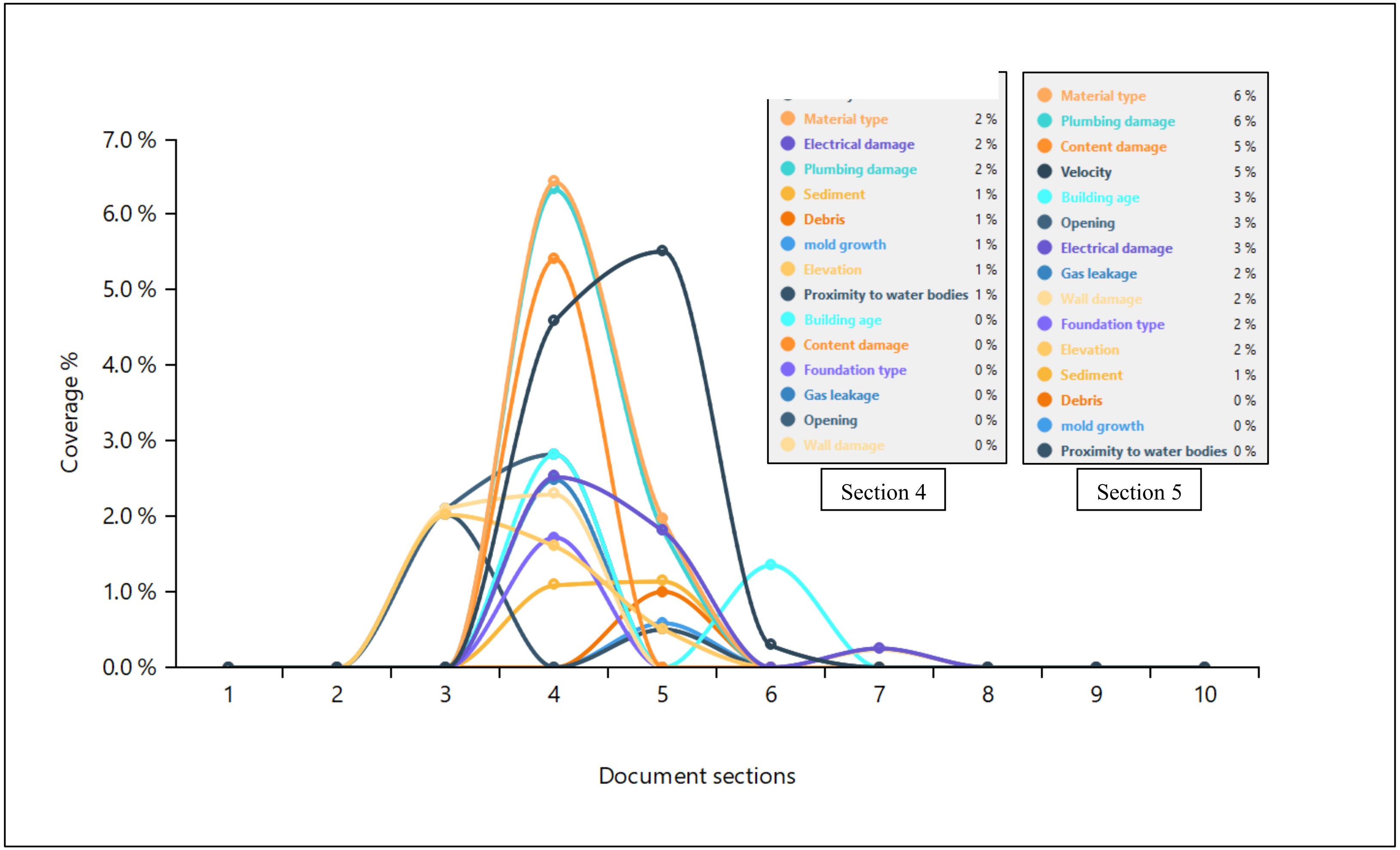

Figure 4.10 Code Trend Analysis on Experts Interview

Based on Figure 4.10, water velocity, material type and electrical damage were the three (3) most frequently mentioned, each peaking between 6% and 6.5% coverage in some section from the overall transcription. This indicates that these topics received the highest attention across the interviews. It shows that experts place strong emphasis on water-related forces, material resilience and internal system failures which should be prioritised in post-flood assessment frameworks.

In general, it can be said that the integration of thematic analysis and code frequency trends confirm that material and floodwater characteristics, particularly velocity are the most critical attributes considered during damage evaluation. These factors were repeatedly emphasized by experts as essential in determining whether a building is safe for reoccupation or requires further inspection and repair.

4.3.6 Damage Assessment Limitations

Based on the expert interviews, several limitations were identified in the current damage assessment in Malaysia. The limitations are tabulated in Table 4.23.

Table 4.23
Experts Perspectives on Current Damage Assessment Limitation

Limitation	**Description**
Lack of Standardized Assessment Framework	No standardized damage classification framework, inconsistencies in reporting and evaluation.
Variability in Assessment Timing and Resources	Assessments vary based on severity and available resources. Detailed evaluations may take months due to resource constraints.
Inconsistencies in Agency Responsibilities	Different agencies conduct assessments with overlapping responsibilities which directs to inconsistencies and delays.
Limited Use of Technology in Assessment	Traditional visual inspections is dominant with limited use of advanced tools.
Underestimation of Long-Term Damage	Focus is mainly on immediate damage. Long-term issues like mold growth, foundation weakening and material degradation are often overlooked.
Lack of Community Involvement in Damage Reporting	Community members are rarely included in assessments despite their local knowledge of recurring flood impacts and hidden damages.

As summarised in Table 4.23 one of the strongest consistent themes was the absence of a standardised national framework for post-flood damage assessment. All six experts agreed that assessments are largely guided by each agency's internal procedures rather than by a unified reference standard. As noted by Expert 1,

> *Expert 1:"Currently, there is no official standardized framework for assessing flood damage,"*

These views support the gap identified in the literature where many existing frameworks emphasise the integration of hazard, exposure and vulnerability components within a structured assessment system (Zhen et al., 2023; Zhou et al., 2017; Zhou et al., 2022). In contrast, as reflected in the interviews Malaysia has no common damage scale or classification consistent enough across different flood events and regions. Without clear categories or thresholds, the severity of damage may be interpreted differently by separate agencies or even by different officers within the same organisation. Expert 2 observed that;

> *Expert 2: "…we don't have a specific procedure or guideline to assess damage caused by floods… Malaysia lacks a standardized framework for evaluating damage post-flood,"*

These suggested that the same building could be rated as 'minor' by one team and 'moderate' by another. The inconsistency may complicate the process of comparing damage that may lead to patchy data and difficulties in deriving reliable loss estimates (Marvi, 2020). International experiences show that structured damage scales and tagging systems could improve transparency and facilitate communication with affected communities (Fulmer, 2024; Paulik et al., 2024), emphasizing the need for a more harmonised approach in the Malaysian setting.

Another prominent limitation highlighted by the experts is the variability in assessment timing and the strong dependence on available resources. According to the interviews, initial inspections are often carried out quickly after a flood, but detailed building-by-building assessments may take weeks or even months, especially when funding and manpower are limited. One expert explained,

> *Expert 4: "We conduct immediate inspections and start repairs as soon as possible. However, we depend on funding allocations, which can be delayed."*

This observation is consistent with previous findings that post-flood assessments are frequently constrained by logistical capacity and administrative processes, resulting in uneven coverage and delays in data collection (Birkmann et al., 2023). The interviews also pointed to overlapping and sometimes unclear agency responsibilities. Expert 5 noted that;

Expert 5: "each agency evaluates damage based on its own procedures,"

This multi-agency arrangement has strengths, as it brings together various technical competencies, but it also mirrors the governance challenges described in the literature where fragmented responsibilities and weak coordination mechanisms hinder integrated post-flood recovery (Randil et al., 2022). When different agencies operate with different criteria and reporting formats, it becomes difficult to consolidate information into a single, coherent picture of damage and the risk of duplication or conflicting assessments increases.

Most experts reported that damage assessments remain predominantly based on traditional visual inspection, manual note-taking and simple photographic records. Expert 6 summarised this by stating,

Expert 6: "Our assessment is still very conventional; we walk, we observe, we take pictures and we fill in forms."

This stands in contrast to the growing body of work demonstrating how remote sensing, UAV imagery, digital mapping and advanced modelling can support faster and more comprehensive assessments, particularly over large or inaccessible areas (Xing et al., 2023; Zheng et al., 2021). In the Malaysian context, earlier chapters have highlighted the importance of understanding spatial patterns of hazard, exposure and vulnerability (Capparelli et al., 2023; Santos et al., 2024). The experts' emphasis on the limited use of such tools suggests that there is considerable potential to enhance current practice through the strategic adoption of digital technologies and training.

Finally, the experts highlighted the lack of structured community involvement in reporting and validating damage. While residents are sometimes consulted informally, their local knowledge of flood history, recurrent problem spots and hidden vulnerabilities is not systematically captured within the formal assessment process. This is at odds with the increasing recognition in the literature that community-based approaches and participatory methods can strengthen disaster assessment and recovery by filling information gaps, capturing intangible losses and increasing the legitimacy of decisions (Birkmann et al., 2023; Randil et al., 2022). The findings from the interviews suggest that a more inclusive approach, where residents contribute to identifying and documenting damage could improve the completeness and relevance of assessment data particularly in densely populated or frequently affected neighbourhoods.

4.4 Development of Preliminary Conceptual Framework

A well-structured framework establishes a clear connection between evaluation methods, research variables and research objectives. It also helps refine the scope of relevant data by focusing on specific variables, defining the research perspective and confirming that concepts and variables are well understood (Torraco, 1997). In this research, key attributes relevant to flood damage assessment were identified, collected and analysed using both literature review and empirical validation through questionnaire surveys and expert interviews. The conceptual framework was developed by integrating findings from quantitative data and qualitative insights. The critical components of flood damage assessment such as structural integrity, floodwater intrusion, environmental impacts and non-structural components were carefully analysed and incorporated into the framework.

Once all data analysis was completed, the initial conceptual framework for post-flood damage assessment was structured based on the identified variables. To ensure its reliability and relevance, expert validation was conducted with a focus group of disaster management professionals from NADMA, JKR, JPS and MKN. This validation process helped refine the framework’s structure, optimize its design and ensure its practical applicability in real-world disaster management scenarios. Therefore, the proposed Post-Flood Damage Assessment (PFDA) framework is designed to be an essential tool for improving damage classification, assessment accuracy as well as recovery planning. Figure 4.11 illustrates the structure of the framework, which integrates preliminary findings, expert validation and practical assessment components.

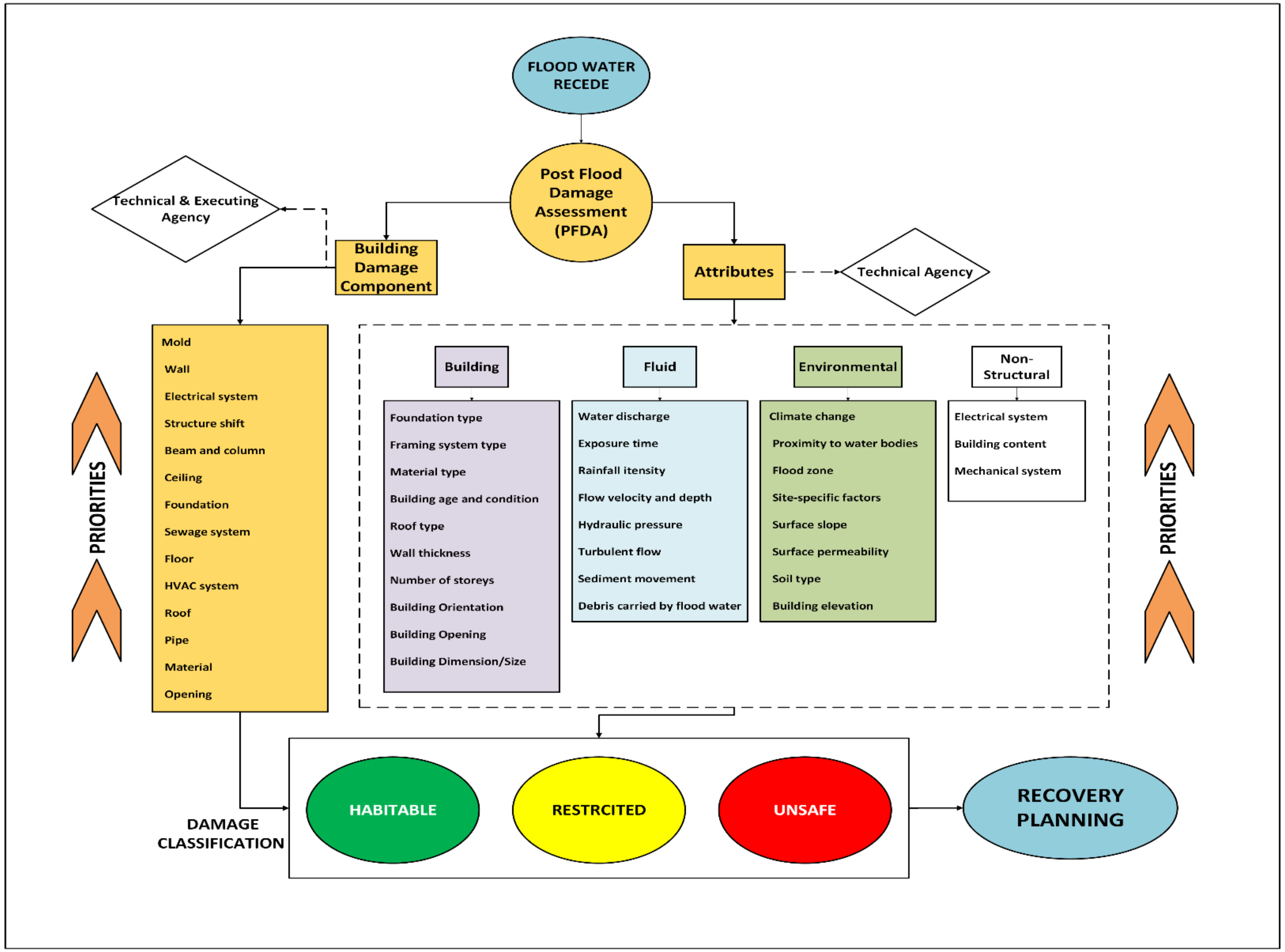

Figure 4.11 Post-Flood Damage Assessment (PFDA) Preliminary Framework

4.5 Framework Validation

A validation process is necessary to ensure the PFDA framework is accurate, practical and useful for real-world applications. This process helps confirm that the framework is based on reliable and relevant principles in flood damage assessment and disaster management. Since flood damage assessment gives an important role in disaster recovery and mitigation, it is crucial to gather expert feedback from professionals in disaster management, engineering and government agencies. Their input helps identify strengths, weaknesses and areas for improvement to make the framework more effective. The information collected from this validation process will be used to refine and improve the framework. This will validate that it meets the needs of government agencies (e.g., NADMA, JKR, JPS), engineering firms and disaster response teams. Hence, this step is important to make the framework more practical and applicable for assessing post-flood damage and supporting recovery efforts.

4.5.1 Interview Outline

The validation process for the PFDA framework was conducted through semi-structured interviews with technical experts in disaster management. This qualitative approach allowed for in-depth discussions and insights, thus align as a comprehensive evaluation of the framework. The semi-structured format provided a balance between predefined questions and the flexibility to explore additional relevant topics based on expert feedback. A purposive sampling method was used to select government officials with expertise in flood damage assessment and disaster response. The interviews were conducted via online platforms with most sessions lasting approximately 30-40 minutes. The recorded interviews were then transcribed using MAXQDA and analysed using content analysis method to identify recommendations.

The PFDA framework validation process was structured into five (5) sections to make sure a thorough assessment of its applicability and effectiveness. For the validation exercise, experts were first given a brief explanation of the preliminary PFDA framework and its intended purpose. The interview protocol was organised into five sections.

- Section A - information on the participants' professional background and areas of expertise related to flood disaster management.
- Section B - examined the accuracy and reliability of the framework for representing real post-flood damage scenarios and asked whether it was consistent with existing disaster management standards and agency procedures.
- Section C - structure and adaptability of the framework including whether it was sufficiently comprehensive yet flexible to be applied in different locations and types of flood events in Malaysia.
- Section D - practical application of the framework, particularly its ease of use for field teams and its potential integration into current workflows of agencies such as NADMA, JPS and JKR.
- Section E - any additional comments, including concrete suggestions for improving the preliminary framework.

The comments from these sections were then used to modify the preliminary illustration into the final PFDA framework

4.5.2 Validation Results

This section presents the findings from the expert validation of the PFDA framework. The experts consulted for validation formed a separate set of respondents from involved previous interview session. This was to ensure that the evaluation of the framework was independent to reduce the risk of confirmation bias and to obtain fresh perspectives on its structure, content and practicality. Two categories of respondents were selected for the interview: government agency experts and academicians. A total of four (4) respondents participated that were representing different organizations such as NADMA, JPS and JKR All respondents had extensive experience in flood damage assessment and disaster management, with over 10 years of professional expertise, which is aligned with the requirements of the validation process. The respondents' backgrounds are summarized in Table 4.24.

Table 4.24
Interviewee Demographic Profile

Experts	Experts Designation	Year of Working Experience
Expert 1	Principal Assistant Director	16 years
Expert 2	Disaster Unit	13 years
Expert 3	Specialist Head of Flood Mitigation and Drainage Division	12 years
Expert 4	Emergency Response	12 years

The first part of the interview focused on the respondents' backgrounds and expertise in flood damage assessment. This is to make sure that the validation of the PFDA framework was based on input from experts with both practical field experience and academic knowledge. The government agency respondents from NADMA, JPS and JKR provided insights into real-world disaster management, flood mitigation and post-flood recovery. The academician respondents specialized in disaster risk management, structural engineering and built environment studies. They contributed to assessing the framework's theoretical accuracy, adaptability and relevance to current research in post-flood damage assessment.

This part also measured the effectiveness and impact of the PFDA framework. Respondents were asked to rate the framework based on six (6) key aspects which are understanding, accuracy, suitability, practicality, comprehensiveness and alignment with existing guidelines. Ratings were given using a scale from 1 (least satisfied) to 5 (very satisfied), with the results summarized in Figure 4.12.

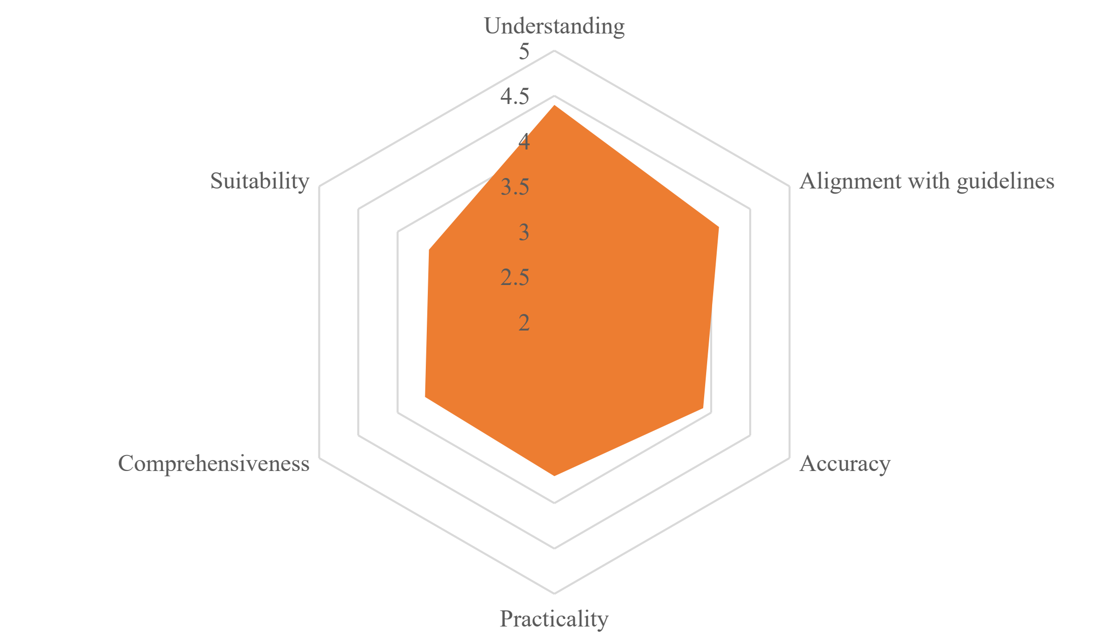

Figure 4.12 Experts Perceptions for the PFDA Framework

The first aspect evaluated was the level of understanding of the framework, which received the highest mean rating of 4.4. This indicates that respondents found the PFDA framework to be clear, well-structured and easy to comprehend. This was followed by alignment with existing guidelines, which had a mean rating of 4.1, suggesting that experts agreed the framework aligns well with current post-flood damage assessment protocols used by NADMA, JPS and JKR. The confidence in the framework's reliability and consistency was confirmed when assessing flood damage. Respondents found that the framework correctly identifies damage severity and types, though minor refinements were suggested.

The accuracy of the preliminary framework was rated at a mean of 3.9. Respondents affirmed that the building damage components and attributes were relevant but felt that their use in the assessment process was not clearly specified. They highlighted that in practice field teams first conduct a rapid visual check of key building components, while detailed attributes such as hydraulic conditions and environmental factors are usually evaluated later by technical specialists. They advised that the framework should clearly separate these two stages and indicate which information is used at each stage

The practicality of the preliminary framework received a mean score of 3.7. Experts expressed concern that using all components and attributes simultaneously might be unrealistic in the early phase of a disaster when time and resources are limited. They suggested that the framework should adopt a stepwise approach: use a smaller set of observable components for the initial screening and reserve the more detailed attributes for buildings that require further investigation.

For comprehensiveness and suitability, the mean rating was 3.65 and 3.6. Experts recognised that the framework already covered major physical and environmental aspects. However, some stated that it did not explicitly address institutional decision points such as when to involve technical agencies or the transition from assessment to recovery planning. They proposed that the framework combine these decision points to provide a more complete picture from flood recession to recovery.

Overall, the preliminary PFDA framework recorded an average mean score of approximately 3.9. Experts were generally satisfied with its structure and content but viewed it as requiring further refinement before it could be fully adopted in practice.

4.6 Presentation of Final Framework

This refinement process integrated findings from expert validation sessions, particularly in terms of the structuring of the attributes, damage level and assessment classification. These modifications were aligned with expert recommendations to ensure the framework is clearly defined and reflective of the real-world post-flood assessment process. Additionally, these enhancements aim to improve the clarity, usability and practicality of the framework for application in the disaster management context. This development is crucial for enhancing coordination among stakeholders such as NADMA, JKR, JPS and MKN to facilitate more effective post-disaster response and recovery planning. The framework as in Figure 4.13 represents a collaborative integration of practitioner insights to ensure a comprehensive, context-sensitive tool for strengthening Malaysia's flood resilience efforts.

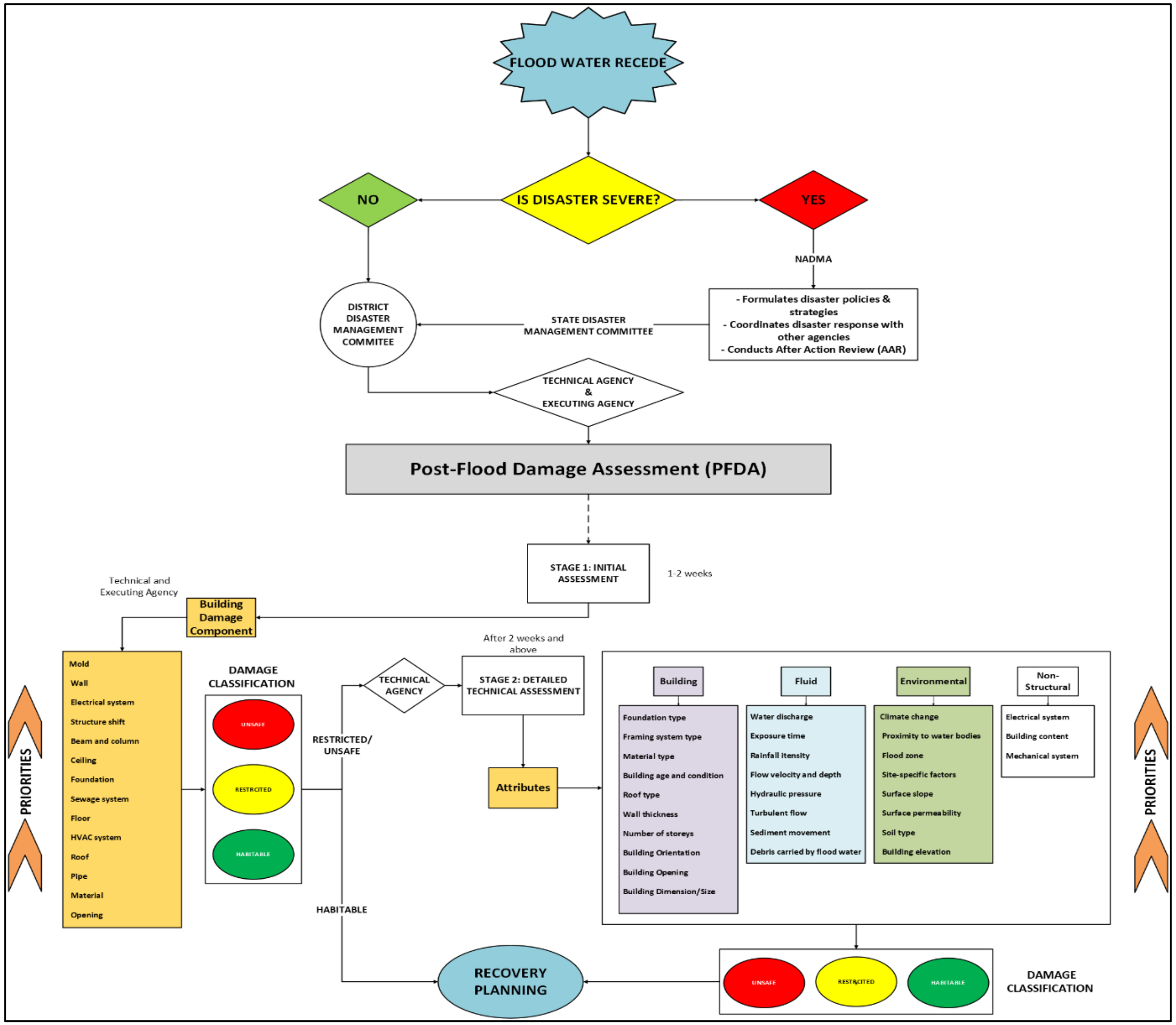

Figure 4.13 Post-Flood Damage Assessment (PFDA) Framework

Figure 4.13 presents the overall process of Post-Flood Damage Assessment (PFDA) from the moment flood water recedes until recovery planning is carried out. It integrates the institutional structure, the assessment stages and the technical attributes that determine the final building damage classification. The figure is developed based on the findings from, questionnaire survey, expert interviews and literature review of the thesis.

The process starts with the responsible authorities determine whether the disaster is considered severe. If it is classified as severe, overall coordination is led by the NADMA at the federal level that formulates response policies, coordinates actions with other agencies and conducts After Action Reviews (AAR) to improve future preparedness. The chain of command then cascades to the State Disaster Management Committee and subsequently to the District Disaster Management Committee. For less severe events, the process bypasses the federal escalation and proceeds directly to the District Disaster Management Committee. At district level, technical agencies such as JKR, JPS and DOSM provide engineering assessments, flood mitigation inputs and economic loss estimates while executing agencies such as BOMBA, PDRM, ATM and APM are responsible for rescue operations, maintaining public safety, providing logistical support and coordinating evacuation assistance.

Once institutional responsibilities are activated, the process moves into the Post-Flood Damage Assessment (PFDA) block which is divided into two stages. Stage 1: Initial Assessment takes place within the first one to two weeks after the flood. During this stage, rapid visual inspections are carried out by the technical and executing agencies to obtain an overall picture of building conditions in the affected area. The main objective is to quickly identify obvious damage and immediate hazards so that prompt safety decisions can be made. This stage directly addresses expert concerns that early decisions are required even when detailed technical data are not yet available.

In Stage 1, inspectors examine a set of building damage components that are organised according to assessment priority where items at the top of the list are inspected first and those at the bottom are of comparatively lower priority. These components include mould, walls, electrical systems, structural shifts, beams and columns, ceilings, foundations, sewage systems, floors, HVAC systems, roofs, pipes, materials and openings. They represent the most common forms of post-flood damage identified by the experts, covering structural, serviceability and habitability aspects.

Based on this rapid screening, each building is given a preliminary damage classification of habitable, restricted or unsafe. This classification supports decisions on which buildings require urgent intervention, evacuation or temporary closure and aligns with expert emphasis on avoiding duplication of effort and ensuring that limited resources are targeted towards the most critical cases.

Buildings classified as restricted or unsafe during Stage 1 are then channelled into Stage 2: Detailed Technical Assessment which takes place after two weeks and above once access, resources and technical teams are available. In this stage, technical agencies conduct more in-depth investigations using a broader set of attributes. These attributes are grouped into four domains such as building, fluid, environmental and non-structural. Within each domain, the attributes are arranged in order of priority, where items positioned at the top are assessed first and given significant emphasis while attributes at the bottom are comparatively less prioritised. These domains and their internal prioritisation reflected based on experts' views on the key attributes that influence post-flood damage.

Finally, the outcomes of Stage 2 feed into a refined damage classification, again using the categories habitable, restricted and unsafe. At this stage the classification is supported by both visual observations and technical evidence from the attribute assessment. The final classification then informs recovery planning which include decisions on repair, rehabilitation, temporary relocation, reconstruction or demolition. This framework provides a comprehensive and systematic representation of how post-flood damage assessment should be conducted in Malaysia that aligned with expert perspectives and addressing the gaps previously identified in the existing practice.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The goal of this chapter is to present the conclusion and recommendations derived from this research, specifically focusing on post-flood damage assessment and its implications for disaster management in Malaysia. The findings are critically analysed to draw conclusions for each research objective, reflecting on the previous chapters, methodologies and results. This process also identifies the limitations and challenges encountered during the study to provide a clear understanding of areas requiring further refinement. Additionally, this chapter highlights the unique contributions of the study, particularly its role in enhancing flood damage assessment frameworks for government agencies and disaster response teams. Based on these findings, recommendations are provided for disaster management practitioners to outline practical applications and future research opportunities to further strengthen flood resilience and post-disaster recovery strategies.

5.2 Main Findings

This study aims to enhance the current and future practices in disaster management by developing a comprehensive framework for post-flood damage assessment that integrates significant attributes, assessment classifications and expert-driven insights. Therefore, a conceptual framework for post-flood damage assessment was formulated to support systematic and consistent evaluation processes within the Malaysian disaster management landscape. The first phase of this research involved establishing the research foundation, including the identification of key motivations, problem statements, research objectives and literature review. The second phase focused on data collection through a mixed-methods approach, combining structured questionnaire surveys, semi-structured expert interviews and contextual analysis of major flood events in Malaysia. The final phase of this study entailed the development and validation of the proposed framework, integrating quantitative analyses with qualitative thematic findings. The research objectives were clearly outlined and the final conclusions are discussed in the subsequent sections.

5.2.1 Objective 1: To Determine the Most Significant Key Attributes That Significantly Influence the Classifications of Post-Flood Damage Assessment

The first objective of this study was presented to identify the most significant key attributes that influence post-flood damage assessment by conducting both quantitative and qualitative analyses. This objective was achieved through structured questionnaire surveys administered to disaster management professionals from NADMA, complemented by expert interviews with representatives from key agencies including NADMA, JKR, JPS and MKN. These methods enabled the triangulation of data to ensure comprehensive and reliable findings.

The survey results were analysed using frequency analysis, variable ranking and canonical correlation analysis (CCA), revealing four major attribute domains that consistently influence flood damage outcomes which are building attributes flow and hydraulics, environmental factors and non-structural components. Among these, damage component such as mold growth, sewage system overflow and electrical system were identified as the most dominant damage identified. The study also identified foundation type, water discharge, climate change and electrical system as the most significant attributes across structural, hydraulic, environmental and non-structural domains. Simultaneously, the qualitative thematic analysis reinforced these findings, where expert insights emphasized the critical role of both physical building properties and surrounding environmental conditions in determining the extent of flood damage.

The integration of both datasets provided a detailed overview of the primary factors influencing post-flood damage, thus offering a strong empirical foundation for the development of a standardized assessment framework. By consolidating the perspectives of practitioners, this chapter offers a comprehensive understanding of the significant attributes that should be prioritized in flood damage evaluations.

5.2.2 Objective 2: To Identify the Appropriate Damage Level Assessment for Assessing Attributes Identified

The second objective of this study was to identify appropriate damage level categories for the attributes established in the earlier phase of the research. This objective focused on translating the significant attributes into a set of practical damage levels that can be applied consistently in the field. To achieve this, qualitative methods were utilized primarily through expert interviews with representatives from NADMA, JKR, JPS and MKN. Through these consultations, a classification system was necessary to support rapid decision-making during and after flood events. Complex multi-tiered scales were seen as less practical for on-site assessments, especially when resources are limited and quick screening is required. As a result, the study formulated a three-level, colour-coded damage classification system comprising green (habitable), yellow (restricted) and red (unsafe). Each level was defined using clear descriptors that combine physical, functional and safety-related criteria.

The expert feedback confirmed that these three levels are aligned with how agencies already differentiate between “safe”, “conditional” and “unsafe” buildings in practice, but the PFDA damage levels provide more structured and transparent criteria. The damage levels were also mapped against the key attributes identified under Objective 1 to make sure that critical elements are explicitly linked to the final classification. This integration reduces subjective variation between assessors and encourages a more consistent interpretation of similar damage patterns across different locations and events.

5.2.3 Objective 3: To Establish a Conceptual Framework for Systematic Damage Assessment at a Post-Flood Event by Integrating Significant Key Attributes and Identified Damage Levels

The third objective of this study was to establish a conceptual framework for systematic post-flood damage assessment by integrating the significant key attributes and the damage levels identified in the earlier phases. This objective was achieved through a structured synthesis of the quantitative findings from the questionnaire survey and the qualitative insights derived from expert interviews and framework validation sessions. The development process started from attribute domains identified in Objective 1, the three-level damage classification system formulated in Objective 2 and the limitations of current practice highlighted by the participating agencies.

The proposed Post-Flood Damage Assessment (PFDA) framework organises the assessment process into a clear and practical sequence. It links four major attribute domains such as building attributes, flow and hydraulics, environmental factors and non-structural components with three colour-coded damage levels which are green (habitable), yellow (restricted) and red (unsafe). These elements guides assessors from initial information gathering and visual inspection, through structured consideration of key attributes towards a consistent classification of damage level. The framework emphasises visible indicators such as foundation condition, wall and floor integrity, water depth and duration, contamination, mould growth and disruption to critical services such as electricity and sewage systems.

The PFDA framework was refined through expert validation where representatives from NADMA, JKR, JPS and MKN assessed its clarity, practicality and alignment with existing procedures. Their feedback confirmed that the framework is compatible with current assessment practices while adding a more systematic structure and clearer criteria for classifying damage. Overall, Objective 3 was successfully achieved by producing a conceptual framework that responds directly to the identified gaps in Malaysia's post-flood damage assessment practice. The PFDA framework offers a structured, transparent and replicable approach that can be used as a reference by multiple agencies.

5.3 Recommendation

Based on the findings of this study and the development of the PFDA framework, several recommendations are proposed to enhance post-flood damage assessment practice and to guide future research. From a practical perspective, it is recommended that disaster management agencies particularly NADMA, JPS, JKR, MKN and local authorities consider adopting the PFDA framework as a reference tool in their post-flood assessment procedures. The framework can be included into existing standard operating procedures (SOPs), checklists and reporting templates to improve consistency in how damage is recorded and classified across different regions and events. Pilot implementation in selected flood-prone districts would allow agencies to test the framework in real operations.

Secondly, capacity-building initiatives should be developed to support the effective use of the framework. Training modules or short courses can be organised for district officers, engineers and local authority to familiarise them with the key attributes, damage levels and assessment flow proposed in the PFDA framework. Practical exercises using past flood cases or simulated scenarios would help assessors apply the framework consistently and improve their judgement when differentiating between green, yellow and red classifications.

In terms of future research, this study recommends further refinement and expansion of the framework through additional empirical applications. Future studies could apply the PFDA framework to multiple flood events in different regions of Malaysia including rural and coastal areas to test its strength across different physical and socio-economic settings. There is also scope to extend the framework to include intangible and long-term impacts such as livelihood disruption, health risks and social vulnerability. In addition, integrating the framework with geospatial tools, remote sensing data and IoT-based monitoring systems could enhance the timeliness and accuracy of assessments.

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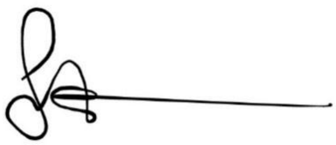
APPENDICES

APPENDIX A

A SYSTEMATIC EVALUATION OF POST-FLOOD BUILDING DAMAGE ASSESSMENT IN MALAYSIA: SURVEY FORM

INTRODUCTION
Assalamualaikum, My name is Muhammad Naziem and i am currently pursuing a master's degree in civil engineering at uitm shah alam. I am conducting a research study titled " A Systematic Evaluation of Post-Flood Building Damage Assessment In Malaysia” As a researcher, i greatly appreciate your participation in this survey. The insights you provide will be invaluable in developing effective strategies for assessing and managing flood damage to buildings. I want to assure you that all your responses will be treated with the utmost confidentiality and will be used exclusively for the purposes of this study. Your valuable input is highly appreciated and i thank you in advance for your time and contribution to this important research. Nama saya Muhammad Naziem, dan saya sedang melanjutkan pengajian di peringkat sarjana kejuruteraan awam di uitm shah alam. Saya kini sedang menjalankan kajian bertajuk “kerangka konseptual penilaian kerosakan bangunan pasca banjir dalam pengurusan bencana.”Sebagai seorang penyelidik, saya amat menghargai kesudian anda untuk menyertai tinjauan ini. Maklum balas yang anda berikan sangat penting bagi membantu saya memahami dan membangunkan cara yang lebih baik untuk menilai serta mengurus kerosakan bangunan akibat banjir. Segala maklumat dan jawapan anda akan dirahsiakan sepenuhnya dan hanya digunakan untuk tujuan kajian ini.
OBJECTIVE
The objective of this survey is: To determine the most significant key attributes that significantly influence the classifications building damage assessment focusing on the structural damage
QUESTION SECTION SUMMARY

Section	No. Of question	Durations
Section A: Demographic Information	7	5 minutes
Section B: Building Damage Types	2	5 minutes
Section C: Building Damage Attributes	1	3 minutes
Section D: Fluid Hydraulic Attributes	1	3 minutes
Section E: Environmental Attributes	1	3 minutes

Sincerely,	endorsed by,
	 DR. NAZIRAH MOHD APANDI Senior Lecturer School of Civil Engineering College of Engineering Universiti Teknologi MARA (UiTM) 40450 Shah Alam, Selangor Malaysia.
Muhammad Naziem Bin Mohd Salehen Email: muhammadnaziem123@gmail.com	Dr Nazirah Binti Mohd Apandi Email:nazirahapandi@uitm.edu.my

SECTION A: DEMOGRAPHIC INFORMATION

Email:____

Gender/jantina:

Male/lelaki	
Female/perempuan	

Age:

20-29 years old/tahun	
30-39 years old/tahun	
40-49 years old/tahun	
50 years old and	

above/tahun dan keatas	

Highest qualification/kualifikasi akademik tertinggi:

Diploma	
Bachelor's degree/ijazah sarjana muda	
Master's degree/ijazah sarjana	
Doctor of philosophy/ijazah kedoktoran	

Type of organisations/jenis organisasi:

Technical agency/agensi teknikal (e.g. : nadma, jkr, jmg, ps)	
Social welfare/kebajikan sosial (e.g. :jkm)	
Search and rescue/mencari dan menyelamat (e.g. :atm, apm)	
Engineering firm or consultancy related with disaster/firma kejuruteraan atau perundingan berkaitan bencana	
Non-governmental organization/pertubuhan bukan kerajaan (ngo)	

Working experience/pengalaman bekerja:

Less than 5 years / kurang 5 tahun	
6 to 10 years / 6 ke 10 tahun	
11 to 15 years / 11 ke 15 tahun	
16 to 20 years / 16 ke 20 tahun	
More than 20 years / lebih dari 20 tahun	

Experiences in dealing with flood/pengalaman pengurusan bencana:

Less than 5 years /	

kurang 5 tahun	
6 to 10 years / 6 ke 10 tahun	
11 to15 years / 11 ke 15 tahun	
16 to 20 years / 16 ke 20 tahun	
More than 20 years / lebih dari 20 tahun	
None / tiada	

SECTION B: BUILDING DAMAGE TYPES

How frequent do you encounter the following types of damage in buildings after flood event occurs?/seberapa kerap anda menemui jenis-jenis kerosakan berikut pada bangunan selepas berlakunya kejadian banjir?

	Never/tiada	1 to 2 times / 1 ke 2 kali	3 to 5 times / 3 ke 5 kali	6 to 10 times / 6 ke 10 kali	More than 10 times / lebih dari 10 kali
Foundation damage/kerosakan asas bangunan					
Wall damage/kerosakan dinding					
Building structure shift or					

	settling/peralihan atau pemendapan struktur bangunan					
	Beam and column damage/kerosakan rasuk dan tiang					
	Opening damage (eg: door, window)/kerosakan pada bukaan (contoh: pintu, tingkap)					
	Floor damage/kerosakan lantai					
	Electrical system damage/kerosakan sistem eletrik					
	Pipe burst/paip pecah					
	Hvac system malfunction/kerosakan atau kegagalan sistem hvac					
	Ceiling sagging or staining/kendur atau kesan kotor pada siling					
	Material deformation and detachment/kecacatan atau tertanggalnya bahan binaan					
	Mold growth/pertumbuhan					

kulapuk					
Roof leaks/atap bocor					
Sewage systems overflow/sistem kumbahan melimpah					

How severe do you find the following types of damage in post-flood buildings? (leave the checkbox blank if you never encounter the type of damage)/sejauh mana tahap keterukan kerosakan berikut yang anda temui pada bangunan selepas banjir? (biarkan kotak semakan kosong jika anda tidak pernah menemui jenis kerosakan tersebut.)

	5 (most severe/paling teruk)	4	3	2	1 (least severe/paling ringan)
Foundation damage/kerosakan asas bangunan					
Wall damage/kerosakan dinding					
Building structure shift or settling/peralihan atau pemendapan struktur bangunan					
Beam and column damage/kerosakan rasuk dan tiang					
Opening damage (eg: door, window)/kerosakan pada bukaan (contoh: pintu, tingkap)					
Floor damage/kerosakan lantai					
Electrical system damage/kerosakan sistem					

	eletrik				
	Pipe burst/paip pecah				
	Hvac system malfunction/kerosakan atau kegagalan sistem hvac				
	Ceiling sagging or staining/kendur atau kesan kotor pada siling				
	Material deformation and detachment/kecacatan atau tertanggalnya bahan binaan				
	Mold growth/pertumbuhan kulapuk				
	Roof leaks/atap bocor				
	Sewage systems overflow/sistem kumbahan melimpah				

SECTION C: BUILDING ATTRIBUTES

Which of the following structural variables do you consider critical in determining a building's resilience to flood damage? (if you are unfamiliar with the variable or have never encountered it, kindly leave the checkbox blank.)/antara pembolehubah struktur berikut, yang manakah anda anggap penting dalam menentukan ketahanan sesebuah bangunan terhadap kerosakan akibat banjir? (jika anda tidak biasa dengan pembolehubah tersebut atau tidak pernah menemuinya, sila biarkan kotak semakan kosong.)

	5 (most critical/paling kritikal)	4	3	2	1 (least critical/paling tidak kritikal)
Number of storey / bilangan tingkat					

	Framing system type (e.g., reinforced concrete, steel) / jenis sistem rangka (contoh: konkrit bertetulang, keluli)					
	Foundation type / jenis tapak bangunan					
	Wall thickness / ketebalan dinding					
	Building orientation (e.g., 45° towards flood direction) / orientasi bangunan (contoh: 45° ke arah aliran banjir)					
	Building opening / bukaan bangunan					
	Building dimension @ size / dimensi @ saiz bangunan					
	Material type / jenis bahan binaan					
	Building age and condition / umur dan keadaan bangunan					
	Roof type (flat vs. Sloped, concrete vs. Shingles) / jenis bumbung (contoh: rata atau bercerun, konkrit atau genting)					

SECTION D: FLUID HYDRAULIC ATRRIBUTES

How significant are the following fluid variables in exacerbating flood damage to buildings?(if you are unfamiliar with the variable or have never encountered it, kindly leave the checkbox blank.)/sejauh mana pembolehubah cecair berikut memberi kesan dalam memburukkan kerosakan bangunan akibat banjir?(jika anda tidak biasa dengan pembolehubah tersebut atau tidak pernah menemuinya, sila biarkan kotak semakan kosong.)

	5 (very high significance / kesan sangat besar)	4	3	2	1 (no significance / tiada kesan)
Strength and depth of floodwater / kekuatan dan kedalaman air banjir					
Water pressure on the building / tekanan air terhadap bangunan					
Swirling or uneven water flow / aliran air berpusing atau berputar					
Movement of mud or sand in floodwater / pergerakan lumpur atau pasir dalam air banjir					
Debris carried by floodwater / sisa atau serpihan dibawa oleh air banjir					
Heavy rainfall during flood / kelebatan hujan semasa banjir					
Amount of floodwater					

	in the area / jumlah air banjir yang mengalir di kawasan tersebut					
	Length of time the building is submerged / tempoh masa bangunan terendam air banjir					

SECTION E: ENVIRONMENTAL AND OTHER ATRRIBUTES

How do the following environmental factors influence the severity of flood damage to building?(if you are unfamiliar with the variable or have never encountered it, kindly leave the checkbox blank.)/bagaimanakah faktor-faktor persekitaran berikut mempengaruhi tahap keterukan kerosakan bangunan akibat banjir? (jika anda tidak biasa dengan pembolehubah tersebut atau tidak pernah menemuinya, sila biarkan kotak semakan kosong.)

	5 (most critical / paling kritikal)	4	3	2	1 (least critical / paling kurang kritikal)
Proximity to water bodies / kedudukan berhampiran badan air					
Building elevation / ketinggian bangunan daripada paras tanah					
Surface slope / kecerunan permukaan tanah					
Flood zone / zon banjir					
Climate change / perubahan iklim					
Soil type / jenis tanah					
Surface permeability / kebolehtelapan permukaan					

Site-specific factors (land use, urban growth and surrounding infrastructure characteristics) / faktor khusus tapak (contoh: guna tanah, pertumbuhan bandar, dan ciri-ciri infrastruktur di sekeliling)					

What is the criticality of the following attributes in determining the extent of flood damage to the building? (if you are unfamiliar with the variable or have never encountered it, kindly leave the checkbox blank.)/apakah tahap kepentingan atribut berikut dalam menentukan sejauh mana kerosakan bangunan akibat banjir? (jika anda tidak biasa dengan pembolehubah tersebut atau tidak pernah menemuinya, sila biarkan kotak semakan kosong.)

	5 (most critical / paling kritikal)	4	3	2	1 (least critical / paling kurang kritikal)
Building content (movable and removable items within a building. E.g., furniture and equipment) / kandungan bangunan (barangan boleh alih dan boleh tanggalkan di dalam bangunan, contoh: perabot dan peralatan)					
Electrical system / sistem elektrik					
Mechanical system (e.g., hvac units, plumbing system) / sistem mekanikal (contoh: unit hvac, sistem paip)					

APPENDIX B

A SYSTEMATIC EVALUATION OF POST-FLOOD BUILDING DAMAGE ASSESSMENT IN MALAYSIA: INTERVIEW CHEAT SHEET

BACKGROUND INFORMATION	
1. 2.	Full name/Nama penuh: Position/Jawatan
General Questions	
1. 2.	What is your agency's role after a flood event occurs? / Apakah peranan agensi anda selepas kejadian banjir berlaku? Does your agency need to follow any official guidelines or protocols when assessing post-flood damage? If yes, are they sufficient and effective? / Adakah pihak agensi anda perlu mengikuti sebarang garis panduan atau protokol rasmi dalam menilai kerosakan selepas banjir? Jika ada, adakah ia mencukupi dan berkesan?
BUILDING DAMAGE ASSESSMENT	
1. 2. 3. 4. 5.	When does your agency usually access the flooded area to carry out assessments of building damage? / Bilakah pihak agensi anda biasanya mengakses kawasan banjir untuk melakukan penilaian terhadap kerosakan bangunan? What types of damage are most common and most important to be considered in post-flood building assessments? / Apakah jenis kerosakan yang paling lazim dan paling penting untuk diberi perhatian dalam penilaian bangunan selepas banjir? How does your agency determine the level of building damage? Is there an indicator system, such as a Level 1 to Level 5 assessment? / Bagaimana pihak agensi anda menilai tahap kerosakan bangunan? Adakah terdapat system indikator, seperti penilaian tahap 1 hingga 5? Could you explain your agency's procedure for assessing building damage? / Boleh terangkan prosedur agensi anda dalam menilai kerosakan bangunan? Are there any specific tests used to evaluate structural damage to buildings, such as visual inspections? Which parts of the building are usually the

	main focus of the assessment? / Adakah terdapat ujian khusus yang digunakan untuk menilai kerosakan struktur bangunan, seperti pemeriksaan visual? Bahagian bangunan manakah yang biasanya menjadi focus penilaian?
6.	What is the recommended time frame or frequency for damage assessments, for example 5 days after the floodwaters recede or periodically, such as every month? / Apakah tempoh masa atau kekerapan yang disarankan untuk penilaian kerosakan, contohnya 5 hari selepas banjir surut atau secara berkala, seperti setiap bulan?
7.	How does your agency collaborate with other agencies, such as engineers or local authorities, in the process of assessing building damage? / Bagaimana agensi anda bekerjasama dengan agensi lain, seperti jurutera atau pihak berkuasa tempatan, dalam proses penilaian kerosakan bangunan?
ADDITIONAL QUESTIONS	
1.	What are your agency's recommendations for addressing flood issues in the future? / Apakah cadangan agensi anda untuk menangani isu banjir di masa hadapan?
2.	What solutions are currently being implemented by your agency to reduce the impact of floods? / Apakah penyelesaian yang sedang dilaksanakan oleh agensi anda bagi mengurangkan impak banjir?
3.	What safety measures does your agency recommend to the public after a flood event? / Apakah langkah keselamatan yang disarankan oleh agensi anda kepada orang awam selepas kejadian banjir?
4.	Does your agency maintain records or statistics related to building damage after floods? If yes, how is this data used to improve flood response in the future? / Adakah agensi anda menyimpan rekod atau statistik berkaitan kerosakan bangunan selepas banjir? Jika ya, bagaimana data ini digunakan untuk meningkatkan respons terhadap banjir di masa hadapan?

APPENDIX C

CRITICAL VALUES FOR PEARSON'S R (Aspelmeier, 2005)

df \ α	0.2	0.1	0.05	0.02	0.01	0.001
1	0.951057	0.987688	0.996917	0.999507	0.999877	0.999999
2	0.800000	0.900000	0.950000	0.980000	0.990000	0.999000
3	0.687049	0.805384	0.878339	0.934333	0.958735	0.991139
4	0.608400	0.729299	0.811401	0.882194	0.917200	0.974068
5	0.550863	0.669439	0.754492	0.832874	0.874526	0.950883
6	0.506727	0.621489	0.706734	0.788720	0.834342	0.924904
7	0.471589	0.582206	0.666384	0.749776	0.797681	0.898260
8	0.442796	0.549357	0.631897	0.715459	0.764592	0.872115
9	0.418662	0.521404	0.602069	0.685095	0.734786	0.847047
10	0.398062	0.497265	0.575983	0.658070	0.707888	0.823305
11	0.380216	0.476156	0.552943	0.633863	0.683528	0.800962
12	0.364562	0.457500	0.532413	0.612047	0.661376	0.779998
13	0.350688	0.440861	0.513977	0.5902270	0.6401145	0.760351
14	0.338282	0.425902	0.497309	0.574245	0.622591	0.741934
15	0.327101	0.412360	0.482146	0.557737	0.605506	0.724657
16	0.316958	0.400027	0.468277	0.542548	0.589714	0.708429
17	0.307702	0.388733	0.455531	0.528517	0.575067	0.693163
18	0.299210	0.378341	0.443763	0.515505	0.561435	0.678781
19	0.291384	0.368737	0.432858	0.503397	0.548711	0.665208
20	0.284140	0.359827	0.422714	0.492094	0.536800	0.652378
21	0.277411	0.351531	0.413247	0.481512	0.525620	0.6400230
22	0.271137	0.343783	0.404386	0.471579	0.515101	0.628710
23	0.265270	0.336524	0.396070	0.462231	0.505182	0.617768
24	0.259768	0.329705	0.388244	0.453413	0.495808	0.607360
25	0.254594	0.323283	0.380863	0.445078	0.486932	0.5907446

df \ α	0.2	0.1	0.05	0.02	0.01	0.001
35	0.215598	0.274611	0.324573	0.380976	0.418211	0.518898
40	0.201796	0.257278	0.304396	0.357787	0.393174	0.489570
45	0.190345	0.242859	0.287563	0.338367	0.372142	0.464673
50	0.180644	0.230620	0.273243	0.321796	0.354153	0.443201
60	0.164997	0.210832	0.250035	0.294846	0.324818	0.407865
70	0.152818	0.195394	0.231883	0.273695	0.301734	0.379799
80	0.142990	0.182916	0.217185	0.256525	0.282958	0.356816
90	0.134844	0.172558	0.204968	0.242227	0.267298	0.337549
100	0.127947	0.163782	0.194604	0.230079	0.253979	0.321095
125	0.114477	0.146617	0.174308	0.206245	0.227807	0.288602
150	0.104525	0.133919	0.159273	0.188552	0.208349	0.264316
175	0.096787	0.124036	0.147558	0.174749	0.193153	0.245280
200	0.090546	0.116060	0.138098	0.163592	0.180860	0.229840
250	0.081000	0.103852	0.123607	0.146483	0.161994	0.206079
300	0.073951	0.094831	0.112891	0.133819	0.148019	0.188431
350	0.068470	0.087814	0.104552	0.123957	0.137131	0.174657
400	0.064052	0.082155	0.097824	0.115997	0.128339	0.163520
450	0.060391	0.077466	0.092248	0.109397	0.121046	0.154273
500	0.057294	0.073497	0.087528	0.103808	0.114870	0.146436
600	0.052305	0.067103	0.079920	0.094798	0.104911	0.133787
700	0.048427	0.062132	0.074004	0.087789	0.097161	0.123935
800	0.045301	0.058123	0.069234	0.082135	0.090909	0.115981
900	0.042711	0.054802	0.065281	0.077450	0.085727	0.109385
1000	0.040520	0.051993	0.061935	0.073484	0.081340	0.103800
1500	0.033086	0.042458	0.050582	0.060022	0.066445	0.084822

26	0.249717	0.317223	0.373886	0.437184	0.478511	0.587988
27	0.245110	0.311490	0.367278	0.429693	0.470509	0.578956

2000	0.028654	0.036772	0.043811	0.051990	0.057557	0.073488
3000	0.023397	0.030027	0.035775	0.042457	0.047006	0.060027

APPENDIX D

CORRELATION ANALYSIS FROM PILOT STUDY

Correlations

Variables		Total	Degree of freedom at 2-tailed, (df) =N-2)	Table of Critical Value, (r)	Calculated Value> r
V1	Pearson Correlation	.582*	21	0.482	.582*>0.482, thus highly significant and valid question
	Sig.(2-tailed)	0.020			
	N	23			
V2	Pearson Correlation	.701**	21	0.640	.701**>0.640, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	23			
V3	Pearson Correlation	.587*	21	0.482	.587*>0.482, thus highly significant and valid question
	Sig.(2-tailed)	0.018			
	N	23			
V4	Pearson Correlation	.613*	21	0.526	.613*>0.526, thus highly significant and valid question
	Sig.(2-tailed)	0.012			
	N	23			
V5	Pearson Correlation	.664**	21	0.640	.664**>0.640, thus highly significant and valid question
	Sig.(2-tailed)	0.001			
	N	23			
V6	Pearson Correlation	.673**	21	0.640	.673**>0.640, thus highly significant and valid question
	Sig.(2-tailed)	0.001			
	N	23			
V7	Pearson Correlation	.707**	21	0.640	.707**>0.640, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	23			
V8	Pearson Correlation	.553**	21	0.526	.553**>0.526, thus highly significant and valid question
	Sig.(2-tailed)	0.006			
	N	23			
V9	Pearson Correlation	.642**	21	0.640	.642**>0.640, thus highly significant and valid question
	Sig.(2-tailed)	0.001			

	N	23			
V10	Pearson Correlation	.644**	21	0.640	.644**>0.640, thus highly significant and valid question
	Sig.(2-tailed)	0.001			
	N	23			
V11	Pearson Correlation	.689**	21	0.640	.689**>0.640, thus highly significant and valid question
	Sig.(2-tailed)	0.001			
	N	23			
V12	Pearson Correlation	.644**	21	0.640	.644**>0.640, thus highly significant and valid question
	Sig.(2-tailed)	0.001			
	N	23			
V13	Pearson Correlation	.708**	21	0.640	.708**>0.640, thus highly significant and valid question
	Sig.(2-tailed)	0.002			
	N	23			
V14	Pearson Correlation	.667**	21	0.640	.667**>0.640, thus highly significant and valid question
	Sig.(2-tailed)	0.001			
	N	23			
V15	Pearson Correlation	.623**	16	0.590	.623**>0.590, thus highly significant and valid question
	Sig.(2-tailed)	0.006			
	N	18			
V16	Pearson Correlation	.628*	16	0.543	.628*>0.543, thus highly significant and valid question
	Sig.(2-tailed)	0.024			
	N	18			
V17	Pearson Correlation	.684*	16	0.590	.684*>0.590, thus highly significant and valid question
	Sig.(2-tailed)	0.011			
	N	18			
V18	Pearson Correlation	.770*	16	0.590	.770*>0.590, thus highly significant and valid question
	Sig.(2-tailed)	0.014			
	N	18			
V19	Pearson Correlation	.793**	16	0.708	.793**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V20	Pearson Correlation	.824**	17	0.693	.824**>0.693, thus highly significant and valid question

	Sig.(2-tailed)	0.004			
	N	19			
V21	Pearson Correlation	.807**	16	0.708	.807**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V22	Pearson Correlation	.698**	16	0.590	.698**>0.590, thus highly significant and valid question
	Sig.(2-tailed)	0.001			
	N	18			
V23	Pearson Correlation	.618**	16	0.590	.618**>0.590, thus highly significant and valid question
	Sig.(2-tailed)	0.006			
	N	18			
V24	Pearson Correlation	.758**	16	0.708	.758**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V25	Pearson Correlation	.778**	17	0.693	.778**>0.693, thus highly significant and valid question
	Sig.(2-tailed)	0.001			
	N	19			
V26	Pearson Correlation	.794**	16	0.708	.794**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.001			
	N	18			
V27	Pearson Correlation	.754**	17	0.693	.754**>0.693, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	19			
V28	Pearson Correlation	.796**	16	0.708	.796**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V29	Pearson Correlation	.613**	15	0.606	.613**>0.606, thus highly significant and valid question
	Sig.(2-tailed)	0.009			
	N	17			
V30	Pearson Correlation	.792**	16	0.708	.792**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			

V31	Pearson Correlation	.798**	16	0.708	.798**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V32	Pearson Correlation	.792**	16	0.708	.792**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V33	Pearson Correlation	.874**	14	0.742	.874**>0.742, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	16			
V34	Pearson Correlation	.793**	14	0.742	.793**>0.742, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	16			
V35	Pearson Correlation	.814*	14	0.623	.814*>0.623, thus highly significant and valid question
	Sig.(2-tailed)	0.011			
	N	16			
V36	Pearson Correlation	.809**	15	0.725	.809**>0.725, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	17			
V37	Pearson Correlation	.764**	16	0.708	.764**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V38	Pearson Correlation	.788**	15	0.725	.788**>0.725, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	17			
V39	Pearson Correlation	.713**	16	0.708	.713**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.001			
	N	18			
V40	Pearson Correlation	.787**	16	0.708	.787**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V41	Pearson Correlation	.804**	16	0.708	.804**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			

	N	18			
V42	Pearson Correlation	.780**	17	0.693	.780**>0.693, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	19			
V43	Pearson Correlation	.749**	16	0.708	.749**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V44	Pearson Correlation	.766**	17	0.693	.766**>0.693, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	19			
V45	Pearson Correlation	.764**	17	0.693	.764**>0.693, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	19			
V46	Pearson Correlation	.787**	16	0.708	.787**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V47	Pearson Correlation	.787**	15	0.725	.787**>0.725, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	17			
V48	Pearson Correlation	.837**	15	0.725	.837**>0.725, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	17			
V49	Pearson Correlation	.780**	16	0.708	.780**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V50	Pearson Correlation	.763**	16	0.708	.763**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V51	Pearson Correlation	.770**	16	0.708	.770**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.002			
	N	18			
V52	Pearson Correlation	.806**	16	0.708	.806**>0.708, thus highly significant and valid question

	Sig.(2-tailed)	0.000			
	N	18			
V53	Pearson Correlation	.734**	16	0.708	.734**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.001			
	N	18			
V54	Pearson Correlation	.822**	16	0.708	.822**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V55	Pearson Correlation	.822**	16	0.708	.822**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V56	Pearson Correlation	.826**	16	0.708	.826**>0.708, thus highly significant and valid question
	Sig.(2-tailed)	0.000			
	N	18			
V57	Pearson Correlation	.870**	16	0.708	.870**>0.708, thus highly significant and valid question[4]
	Sig.(2-tailed)	0.000			
	N	18			

[4] **. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

AUTHOR'S PROFILE

Muhammad Naziem Bin Mohd Salehen is a dedicated scholar in the field of civil engineering, currently working as a Project Engineer in a flood mitigation project and a student enrolled in Master of Science in Civil Engineering at Universiti Teknologi MARA (UiTM), Malaysia. Building upon a strong academic foundation, he previously earned a bachelor's degree in civil engineering (Hons.) in 2023, demonstrating an early passion for structural integrity, disaster resilience and engineering solutions. With a keen interest in post-flood damage assessment, his research focuses on developing a structured framework for evaluating flood damage particularly within Malaysia's disaster management context. Through a combination of quantitative and qualitative method such as questionnaire surveys and semi structured interviews with government agencies, his research aims to develop a standardised and structured methodology as well as enhance the accuracy and practicality of post-disaster assessment methods.

LIST OF PUBLICATION

Mohd Salehen, M. N. ., Mohd Apandi, N., & Tengku Nasharuddin, T. N. A. . (2024). Optimization of Phase Change Materials as Backfill Materials for Underground Cable. *Scientific Research Journal*, *21*(2), 119–134. https://doi.org/10.24191/srj.v21i2.26990

M. Salehen, N. Mohd Apandi, M. Hisham, W. W. Zailani and C. Ibrahim Malaysian Journal of Civil Engineering (2025) Vol. 37 Pages 01-07 DOI:10.11113/mjce.v37.24726