Improving Flood Management Planning Decisions through Multi-Criteria Decision Analysis: A Case Study of Health and Safety Facility Management in Kelantan, Malaysia

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The candidate confirms that the work submitted is his/her own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

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Publications

Part of this thesis is based on these publications:

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Abstract

This thesis investigates interactions in optimising Multicriteria Decision Analysis (MCDA) applications in flood decisions through interconnected studies, enhancing understanding of complex relationships and their implications.

Based on Systematic Literature Review (SLR) of MCDA application trend in water-related disaster management, Analytical Hierarchical Process (AHP) is the common technique employed. According to Disaster Management Phase, mitigation is the primary focus, highlighting gaps in other phases. Future exploration of its potential in other phases and feasibility of alternative techniques is suggested for beneficial practical application.

Chapter 3 focuses on criteria selection for FMP through experts' interview and SLR. The Political, Economic, Social, Technological, Environmental, and Legal (PESTEL) analysis framework clusters the criteria, identifying 40 final criteria as potential and trade-off factors. Integrated domains are less represented, suggesting a framework coupling MCDA and PESTEL for criteria selection in the future.

Building on 40 criteria identified, Chapter 4 analyses the criteria using AHP and Quadrant Matrix Analysis with experts. Results revealed the importance of complementing criteria importance and certainty for better decisions. The Weather Reflection model introduced enhances the proposed framework for criteria analysis, significantly benefiting decision-makers.

Chapter 5 explores integrating spatial and MCDA techniques as a Decision Support System (DSS). A conceptual framework with five phases facilitates DSS development is proposed, which is adaptable to various domains.

A DSS prototype developed in Chapter 6 based on previous chapter, which employed four MCDA techniques. Its functionality is assessed through case studies, determining feasible locations for future hospital buildings. The prototype's acceptability is validated based on Content Validity Index (CVI) thresholds, thus aiding flood decision planning.

Collectively, these studies advance practical MCDA applications, offering actionable insights for decision-makers navigating MCDA challenges. By proposing frameworks for criteria selection, analysis, and DSS, and presenting a validated prototype, this thesis contributes to interdisciplinary knowledge, optimising MCDA in flood planning.

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List of Abbreviations

MCDA	Multi-criteria Decision Analysis
PESTEL	Political, Economic, Social, Technological, Environment and Legal
GIS	Geospatial Information System
AHP	Analytical Hierarchical Process
DMP	Disaster Management Plan
NAHRIM	National Water Research Institute of Malaysia
NRECC	Ministry of Natural Resources, Environment and Climate Change of Malaysia
FMP	Flood Management Planning
SDSS	Spatial Decision Support System
QMA	Quadrant Matrix Analysis
RRS	Rainfall Risk Score
RV	Rainfall Volume
LRS	Land Use Risk Score
ULSA	Urban Land Use Size Area
AFRS	Access to Health and Safety (H&S) Facility Risk Score
DF	Distance from Current Facility
RVI	Rainfall Vulnerability Index
WSM	Weight Sum Model
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
CVI	Content Validity Index
DID Malaysia	Department of Irrigation and Drainage of Malaysia
IPCC	Intergovernmental Panel on Climate Change

Chapter 1
Introduction

1.1 Introduction

Floods are natural disasters that can put people's lives in danger. From 2000 to 2020, there were 3,453 flood events recorded worldwide by the Emergency Events Database (EM-DAT) (CRED, 2020) with the year 2006 having the highest number of events. Over the same period, the total economic loss was estimated at more than $802 billion, which impacted more than 1.6 billion people. The impact of flood events not only affects the public but also the governments, which requires them to be well prepared by preparing a comprehensive strategy for flood management planning to lessen the impacts of flood damages.

Generally, flood management planning (FMP) could be defined as a comprehensive and systematic approach to reduce and minimise flood risks and their adverse impacts on communities, infrastructure, and the environment (Samuels et al., 2010; Sayers et al., 2015). A series of coordinated action measures, policies, and strategies are involved aimed to effectively managing various aspects of flooding. A well-executed FMP can reduce the effects of floods on communities, businesses, and the environment by 1) prioritising public safety, 2) ensuring the efficient allocation of resources, and 3) strengthening the resiliency of impacted areas (McClymont et al., 2020; Slavíková et al., 2020; Raikes et al., 2023). Furthermore, FMP can facilitate effective emergency response and improve operations, reducing the long-term effects of floods.

Identifying flood-prone areas, developing mitigation strategies, and outlining actions to be taken before, during, and after flood events are examples of flood management planning (FMP). The development of these approaches requires a strategy that integrates data-driven decision-making, expert knowledge, and appropriate tools such as simulation, modelling, spatial analysis, multi-criteria decision analysis (MCDA), and others. By considering all these aspects, it would facilitate decision-makers in improving the effectiveness of FMP decisions.

In recent years, data-driven decision-making has gained prominence as a crucial element in decision support. Studies on different aspects of flooding, like flood susceptibility (Chen et al., 2020) and flood volume (Li, 2020), have indicated the importance of data-driven approaches in improving

FMP, where data is the fundamental component used for analysis and supporting the actions to be taken. This approach enhances risk assessment, enables the development of early warning systems, optimises resource allocation, supports infrastructure planning, evaluates mitigation measures, addresses climate change challenges, fosters informed decision-making, and facilitates post-event analysis.

Meanwhile, with the new area of big data, data becomes easily available and accessible, thereby enabling decision-makers to use relevant information to enhance flood management strategies. This data can be used to make decisions, such as identifying flood-prone areas and implementing preventive measures. By analysing historical floods, monitoring real-time flood data, and assessing the potential impact of future floods, decision-makers prioritise public safety and reduce the impact of flooding. The significance of the big data era in supporting data-driven decision-making is exemplified in studies such as urban flood disaster relief supply preparation by Lin et al. (2020) and flood risk management by Towe et al. (2020).

As data is understandable as an essential component in decision-making, it is not the only component to be considered in decision-making. For decisions to be relevant and effective, they must be based on theories and concepts with practical experience gained from real-life situations, which are also crucial as decision-making inputs. Experts can provide valuable insight on the practicality and effectiveness of various flood management measures to assist decision-makers in making informed decisions. By incorporating expert insights, one can make well-informed and tailored decisions.

Multi-Criteria Decision Analysis (MCDA) is a valuable and useful technique that may be applied in FMP and that enables decision-makers to evaluate different options using a variety of flood criteria. MCDA can assist in determining the optimal course of action based on the priorities of the stakeholders involved. Using MCDA, decision-makers can analyse the advantages and disadvantages of various strategies, considering a variety of aspects such as environmental impact, economic impact, and social impact. The application of MCDA can facilitate FMP based on solid evidence, objective analysis, and stakeholder engagement, enhancing its effectiveness.

The context of this study is applying MCDA to FMP with the goal of enhancing and streamlining the decision-making process in the following focal areas:

a) Criteria selection: This involves choosing flood criteria based on a broader domain, particularly macro-level criteria based on the PESTEL analysis framework.
b) Expert-based review: Suitability of criteria based on experts' reviews using the MCDA technique and analytical tools.
c) Combined spatial-MCDA application: Explores the potential of a combined spatial-MCDA decision support system in the FMP decision-making process.

To investigate these aspects, this study employed multidisciplinary approaches, utilising methods such as literature reviews, expert interviews, and spatial decision support system development. The key findings highlighted several important points:

a) The role of decision-makers: Decision-makers are pivotal in the decision-making process. Their insight and involvement in the process influenced the decisions; thus, structured frameworks would facilitate them in the decision-making process.
b) Effective combined spatial-MCDA tool: The combined spatial-MCDA tool proves highly effective, specifically in complex decision environments. This tool enhances decision-making and aids in intricate challenges.
c) Enhance decision-making and outcomes: This study provides valuable insight into how decision-makers may make more informed decisions, resulting in improved outcomes by optimising MCDA application in the FMP process.

This study contributes to the growing body of research on effective MCDA application for decision-making in complex systems, which emphasises the need for integrated and comprehensive approaches. These approaches aim to improve flood resilience against flood disaster events and optimise decision-making across multiple domains. To achieve these goals, the study employs a combination of methods, specifically expert knowledge with spatial analysis and MCDA techniques. By utilising this approach, the study can optimise MCDA's application in prioritising criteria and making informed decisions in FMP.

1.2 Background of the Study

MCDA enables decision-makers to evaluate several options based on multiple criteria and rank the most effective and feasible option. Traditionally, it was not possible to collect sufficient data on many criteria, so the use of MCDA had its limitations. However, in recent years, the availability of big data and analytics has influenced the trend in flood management planning to adopt more data-driven decision-making processes (Towe et al., 2020). This trend has made more data available to be used for various criteria, optimising MCDA applications for various purposes.

The emphasis on decision-maker interaction is one of the most promising features of the application of MCDA in FMP. Communicating with stakeholders, such as affected communities, local government officials, and experts, can offer decision-makers valuable information that can aid in decision-making. Apart from focusing on the micro domain, another trend is the use of interdisciplinary approaches that combine macro domains criteria such as economic, social, and technological to support the decision process.

Previous studies from Abdullah, L. et al. (2020), Birgani and Yazdandoost (2018), and Seo et al. (2015) have exhibited a broad scope of macro domain that encompass a variety of criteria that can influence and leverage flood management planning. These criteria may include legalisation, demographics, economic activity, flood technology, and others. The use of macro domain criteria in FMP is trending towards more comprehensive and integrated approaches that consider the larger context in which floods occur. PESTEL (Political, Economic, Social, Technological, Environmental, and Legal) framework analysis is among the tools used to identify the macro domain criteria.

Among the applications of macro domain criteria is the use of economic and social data to plan flood mitigation to reduce the risk and improve resilience to flood impacts (Dassanayake et al., 2015; Xenarios and Polatidis, 2015; Daksiya et al., 2017). In addition to that, the employment of multiple criteria from multiple macro domain such as political, social, environmental, economic, and technological, has also been applied in flood mitigation and preparedness to reduce the risk and improve resilience towards flood events (Karamouz, Mohammad. and Farzaneh, 2020; Sun et al., 2020). In general, the application of macro domain criteria is trending towards a more holistic and integrated approach to FMP decisions.

Recognising the importance of FMP, which requires data and information to support decisions, spatial data should be treated equally with non-spatial data. Spatial data and MCDA technique applications have been employed in various FMP studies, such as Morea and Samanta (2020) for identifying flood vulnerability zones and Sepehril et al. (2019) for flood hazard mapping. In the context of FMP from a macro domain perspective, this method is gaining more attention as part of the optimisation method to improve FMP decisions. This indicated the significance of combined spatial-MCDA applications in facilitating the FMP decision process.

The spatial-MCDA method combines spatial data and multiple criteria to evaluate options. It helps decision-makers include expert knowledge and stakeholder input. Additionally, this method also includes spatial analysis, data visualisation, and decision support systems to enhance its effectiveness. It allows decision-makers to analyse how different factors, like flood-prone areas, infrastructure, and population density, relate spatially and affect management plans. Considering all these factors can lead to more effective FMP decisions.

The combined spatial-MCDA application trend is towards more sophisticated tools and techniques that can handle large amounts of data and provide more effective decisions. For instance, advancements in geospatial information systems (GIS) have made it feasible to analyse and visualise vast quantities of geographic data in real time, enhancing decision-making processes and providing criteria to be factored into FMP decisions.

1.3 Problem Statement

Implementing a proactive and improved disaster management plan can lessen the impact of flood disasters. The use of spatial planning and MCDA in flood management planning has gained popularity, necessitating a comprehensive and collaborative study (Abdullah et al., 2021). There were gaps between the MCDA technique application and the criteria selection used in previous flood management planning studies. The MCDA technique, such as the Analytical Hierarchical Process (AHP), has become the most prominent technique applied compared to other techniques. Meanwhile, the criteria selection used centred on the environmental domain compared to other domains such as social, economic, and technological.

This thesis examines the MCDA application scenario based on the gaps identified and proposes decision tools that may be feasible to optimise the MCDA application in the FMP decision-making process. The goal is to facilitate decision-makers to improve their decision-making strategies as part of FMP, as discussed in sub-section 1.2, based on the studies explained.

To carry out this, decision-makers require relevant and important data and information that serve as decision criteria to support their decisions.

Several studies have been done on data for disaster risk management in FMP. For example, Nundloll et al. (2021) looked at how to combine different types of data, and Towe et al. (2020) looked at how to use data to help make decisions. Therefore, it becomes challenging to determine how to select criteria, which criteria should be employed, and which criteria are important. With the recent development of big data, it has resulted in a paradigm shift in diverse aspects of data. Leveraging big data in FMP introduces challenges related to the volume, variety, and quality of data, requiring advanced analytics and infrastructure. Additionally, concerns such as data privacy, interoperability issues, and the need for skilled personnel underscore the importance of a thoughtful and comprehensive approach to overcome these hurdles and harness the benefits of data-driven decision-making in FMP.

The selection of decision criteria in decision-making processes typically relies on the relevance and significance of available data and information. In the context of decision-making within the PESTEL macro domain, the challenge lies in systematically identifying and utilising pertinent data and information. Among the challenges faced is ensuring the right data is used at the right time, in the right place, and in the right way for the right person (Fischer, 2012). Additionally, decision-makers may be faced with an overwhelming situation in determining the ideal and optimal decision criteria (quality) options (Emmanouil and Nikolaos, 2015).

While numerous studies have underscored the significance of MCDA in improving FMP decisions, there is a critical need to address the complexity of MCDA applications. Recognising that MCDA has emerged as a vital tool in FMP decisions, the challenge lies in determining whether to employ a singular MCDA technique or a mixed-method approach, given that relying solely on one technique may have limitations. Finding ways to overcome these limitations and achieve greater accuracy and reliability in decision-making remains a pressing concern in FMP.

The current study primarily concentrates on tabular and spatial data in its analysis, but there's a noticeable gap when it comes to exploring the utilisation of projected data, which is increasingly important for FMP decisions. The importance of using projected data to inform decision-making cannot be overstated, as there is a compelling need to incorporate projected data in FMP decisions, ensuring the decisions are not solely based on historical data but are forward-looking and aligned with future climate scenarios.

In the era of the geospatial revolution and digitalization, the integration of spatial technology into the decision-making process has become increasingly prevalent. This entails harnessing spatial data to enhance decision-making by providing visual context and extracting comprehensive information for problem-solving. However, the existing MCDA application within spatial decision support systems is predominantly centred on specific criteria from a single domain, lacking the crucial aspect of multi-domain integration (Abdullah, Mohammad Fikry et al., 2022). This limitation needs to be bridged, and a more comprehensive MCDA framework needs to be developed that incorporates multiple domains to improve spatial decision-making processes effectively.

Based on the problems discussed, this has prompted the idea of a comprehensive study that employs the MCDA approach and optimises its application in FMP decisions. Structured frameworks would be an ideal guideline for decision-makers to optimise MCDA applications that encompass a broader perspective of criteria selection, criteria analysis, and a decision support system to solve the problems.

1.4 Flood Management Planning: Malaysia Context

Flood risk and disaster management are critical considerations in Malaysia, a country prone to monsoons and tropical storms. The geographical and climatic characteristics of the nation make it susceptible to seasonal flooding, particularly during the monsoon seasons. Rapid urbanisation and land development have exacerbated the impact of floods, as increased impermeable surfaces contribute to faster runoff and overwhelming drainage systems. This heightened risk is particularly evident in low-lying areas and regions with inadequate infrastructure.

The economic and social implications of floods in Malaysia are substantial. Flood events disrupt transportation networks, leading to road closures and damage to critical infrastructure. Agriculture, a vital sector for the country's economy, is often adversely affected, causing losses in crops and livestock. Additionally, flooding poses a significant threat to public safety, displacing communities and sometimes resulting in the loss of life. The government had allocated flood projects in Malaysia approximately more than USD 9 billion for the past 55 years (1966-2020) as shown in Figure 1-1 on various flood management strategies.

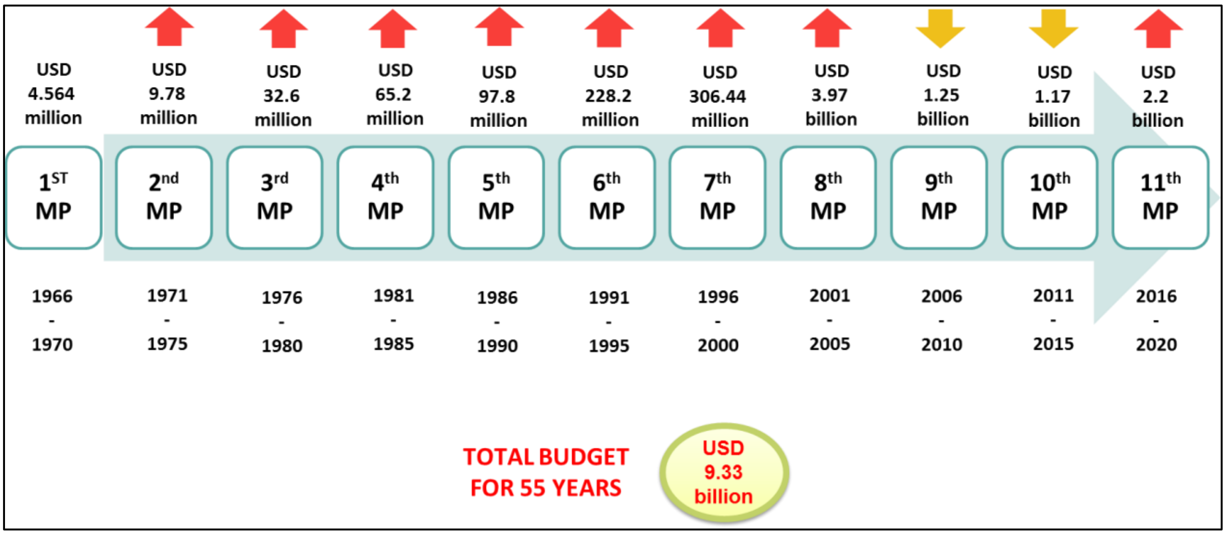


Figure 1-1: Budget for Flood Projects in Malaysia based on 5 years Malaysia Plan (MP)(Source: (Wing, 2004), (Islam et al., 2016), (DID, 2018)

In recent years, the impact of climate change has introduced new dimensions to flood risk in Malaysia. Changing rainfall patterns and more intense weather events are anticipated, further complicating flood management efforts. As the nation continues to address these challenges, there is a growing emphasis on adopting innovative technologies, engaging in interdisciplinary research, and fostering community resilience to enhance Malaysia's overall flood risk and disaster preparedness. Table 1-1 summarise the issues and challenges of flooding in Malaysia.

Table 1-1: Issues and Challenges of Flood in Malaysia

No	Issues and Challenges	Reference
1	Lack of disaster risk reduction incorporated in planning, redesign, construction and the operation of the built environment.	(Rani et al., 2017)
2	a. Imbalanced disaster management planning between top-down and bottom-up approaches, b. Lack of coordination in disaster management cycle, with greater focus only on the disaster emergency response stage and, c. Lack of planning of long-term recovery (post-disaster) process, which resulted in low level community and stakeholders' resilience to disasters.	(Omar Chong and Kamarudin, 2018)
3	a. Focusing more on structural measures b. Insufficient & incomplete flood legislation	(Chan, 2015)

No	Issues and Challenges	Reference
	c. Utilisation state of the art technology for telemetric station, forecasting models etc d. Flood hazard management in Malaysia has not kept up in the context of its rapid development. e. Politicization of Flood Disasters f. Mediatisation of Flood Disasters g. Lack of Awareness and Volunteerism h. Climate Change i. Short Memory Span j. Erosion of Social Capital	

Malaysia employs a multifaceted approach to flood management planning aimed at minimising the impacts of flooding on communities and critical infrastructure. The government has invested significantly in the enhancement of early warning systems to provide timely alerts to vulnerable areas. These systems utilise advanced meteorological data and technology to predict and monitor rainfall patterns, enabling authorities to issue timely warnings to residents and emergency responders. Additionally, the establishment and maintenance of a robust network of drainage systems, embankments, and reservoirs play a crucial role in flood mitigation, helping to control and divert water flow during heavy rainfall. Table 1-2 shows suggestions and improvements for flooding in Malaysia.

Table 1-2: Suggestion and Improvement for flood management planning in Malaysia

No	Suggestion and Improvement	Reference
1	a. Resource and expertise utilisation- Improve agencies roles and responsibilities in Disaster Risk Management Committee b. Strengthen the importance of local knowledge and community involvement (bottom-up approach) & decision & judgement from experts based on socio economic impacts assessment c. To explore cost-benefit approach	(Omar Chong and Kamarudin, 2018)
2	a. Focus to non-structure measures with state-of-the-art technology (e.g.: maps, satellite etc.) b. Top-down approach covering various stakeholders' participation	(Chan, 2015)

No	Suggestion and Improvement	Reference
	c. Capacity building for NGOs, local communities and disaster victims is also necessary (Resilient) d. Disaster insurance should be introduced, and disaster legislation strengthened. e. Improvement on policy i. Include education and preparedness in disaster management plan. ii. Constantly improve existing flood forecasting and warning systems with state-of-the-art technology. iii. Identify and gazette more emergency sites/shelters for evacuation centre. iv. Construct resilient shelters/houses and infrastructure to withstand future disasters. v. Healthcare centres, public utilities should be made flood-proof & resilient (materials & location) vi. Provide flood-prone areas/communities with complete emergency materials. vii. Compensation, subsidiary and financial aid for relocation of flood victims. viii. Post disaster programme for flood victims. ix. Government must consider gender differences when giving out aid and support, as disasters often affect men and women differently	

Furthermore, Malaysia focuses on sustainable land use planning and development practices to reduce flood risks. Policies and regulations are in place to guide urban and rural development, emphasising the importance of maintaining green spaces, preserving natural waterways, and implementing proper drainage solutions. Integrated floodplain management strategies are employed to strike a balance between development needs and environmental resilience. These initiatives showcase Malaysia's commitment to holistic flood management, combining technological advancements, infrastructure investments, and sustainable planning practices to build resilience against the impacts of flooding.

1.5 Government Participation

This study has been conducted in collaboration with the National Water Research Institute of Malaysia (NAHRIM), a government research institute under the Ministry of Natural Resources, Environment, and Climate Change (NRECC). As a research institute, NAHRIM's main role is to conduct basic and applied research in the context of water and the environment. NAHRIM also acts as a referral centre for research in water and the environment, including research on climate change.

This research focuses on the effects of climate change in the context of flood events and FMP. As a result, current and future FMP research would benefit from it in terms of understanding problems and devising solutions.

A consultation and interview session with NAHRIM's experts allows for the gathering of information and the discussion of how the research could benefit NAHRIM in terms of practical application. The input received has been used in Chapters 3 and 4. In addition, data collected and produced by NAHRIM has been used as secondary data in this study, specifically in Chapter 6.

From an academic perspective, this study would explore practical theory to be integrated with the current practices in NAHRIM. Thus, the integration of academia and practical implementation by NAHRIM is expected to directly benefit both in the sense that this study will offer the potential approach and process to improve current NAHRIM's practice, whereas NAHRIM will benefit by offering a more justified research result process. At the same time, NAHRIM and other organizations might use the study's findings as a guide in future work.

1.6 Thesis Outline

This thesis is divided into seven chapters. The introduction and executive summary of the entire research were provided in the first chapter. Chapter 2 discusses the literature review on some of the key topics, such as flood disasters, FMP, disaster management plans (DMP), MCDA application trends and patterns in FMP, flood criteria, and spatial decision support systems. For the entire research, four projects were carried out, with each project explained and discussed separately in Chapters 3, 4, 5, and 6. A summary of each project is explained in Table 1-3. Chapter 7 concludes the entire research by confirming that the research’s aim, contributions, and direction for the future were all achieved.

Table 1-3: Thesis Summary

Chapter	Chapter Title	Result & Findings	Significance
1	Introduction	a. Laying the groundwork for the overall thesis and the studies conducted within this thesis b. Provide insight into the existing literature that motivates the study.	a. Establish a foundation for understanding the complexities of implementing MCDA to improve FMP decisions.
2	Literature Review	a. Exploration of MCDA methods for FMP decisions. b. Discussion of contextual aspects, including flood disaster events as the case study, MCDA techniques and applications in FMP, flood criteria in current MCDA applications, and the role of spatial decision support systems.	a. Advancing the understanding of decision-making processes in flood management planning. It helps identify optimal methods for utilising MCDA, offering insights into its effectiveness, limitations, and potential improvements. b. Provides a comprehensive overview of the specific domain under consideration (flood management planning), making the research relevant and applicable. c. This contextual discussion bridges the gap between theoretical concepts and practical implementation, contributing both to academic knowledge and real-world problem-solving. d. Foundation building to shape understanding of the study's focus and context.
3	Criteria Identification and Selection from Macro-Domain Perspective in Multi-Criteria Decision Analysis Application based on PESTEL Analysis	a. Based on 131 articles, 56% of previous studies focused on single PESTEL domain, with 60% of studies focused on flood assessment as a flood measure aimed at reducing vulnerability and 40% employing spatial analysis.	a. Future research should incorporate more domains and emphasise combined assessment measures with spatial analysis. 40 identified criteria serve as trade-off criteria for PESTEL-based flood management planning. b. The proposed framework guides the criteria hierarchy for MCDA in flood management planning.

Chapter	Chapter Title	Result & Findings	Significance
	Framework for Flood Management Planning	b. Propose a framework for PESTEL analysis in flood management criteria identification and selection.	
4	Criteria Analysis for Flood Management Planning based on Analytical Hierarchical Process (AHP) and Quadrant Matrix Analysis (QMA) – An Expert Review	a. Political domain is prioritised, while 83% of environmental criteria rank low based on 40 identified criteria. b. 61% of the criteria were highly important and certain (Q1). 7.5% of the criteria were considered ideal based on AHP and QMA. c. Proposed PESTEL criteria framework for final criteria.	a. Give attention to quadrant-based criteria for competitive and collective flood management planning. b. Systematic criteria hierarchical structure based on comparative methods between AHP and QMA and c. The framework can be replicated for different domains of study.
5	Development of Conceptual Framework for Combined Spatial-MCDA Decision Support System based on Macro Domain Criteria for Flood Management Planning	Five stages are proposed: Data Collection, Pre-Processing, Processing, Analysis, and Visualisation, which involve criteria identification, data quality checking, spatial data preparation, computational analysis, and visual dashboards with multiple map layers.	The framework provides a structured approach to developing a combined spatial-MCDA decision support system. It enhances transparency in the decision-making process and improve stakeholder trust and confidence by clarifying the decision-making process and criteria considered.

Chapter	Chapter Title	Result & Findings	Significance
6	Exploratory Case Study for Health & Safety Facility Management in Kelantan, Malaysia: Identify New Location for Hospital Construction	a. Case study 1 (within 12-km of the current facility), based on total rank 1 (170), L1 was recommended, having the highest ranking (51%), compared to L2 (46%), and L3 (3%), with expert validation (S-CVI = 0.89) for L1. b. Case study 2 (more than 12-km of current facility), based on total rank 1 (179), L3 was recommended, having the highest ranking (66%) compared to L1 (34%) and L2 (0%), with expert validation (S-CVI = 0.84) for L3.	a. A similar case study on evacuation centres and clinics can be conducted in health and safety facility management using the prototype's criteria. b. The dynamic prototype allows adding criteria through spatial layers for better decision-making and is adaptable across domains like transportation, agriculture, and tourism.
7	General Discussion	a. The importance of each study conducted is highlighted to support the relevance of the thesis. b. The contributions to both academic literature and practical applications are emphasised. c. Recognition of potential future directions and opportunities for further research.	a. To justify and underscore the relevance of the entire thesis. It establishes the necessity of the research and its individual components for addressing specific gaps or challenges. b. To signify the broader impact of the thesis. It demonstrates how the research not only adds to theoretical knowledge in the academic realm but also offers tangible applications and solutions to real-world issues. c. Recognition of potential future directions and opportunities for further research indicates that the thesis is not just a standalone project but lays the groundwork for ongoing exploration. It identifies areas where future researchers can build upon or extend the current work, ensuring the sustainability and evolution of the research domain.

1.7 Chapter Conclusion

In conclusion, this study underscores the importance of exploring multiple approaches to optimise MCDA application in FMP decisions. The integration of multiple criteria domains holds significant potential for improving the quality of FMP decisions, and the adoption of an MCDA-PESTEL criteria selection framework can greatly assist decision-makers in prioritising criteria effectively.

In addition, the use of an integrated MCDA technique in conjunction with analytical tools offers a significant approach for identifying the optimal criteria to be employed in FMP decision-making. Moreover, the implementation of a combined spatial-MCDA decision support system introduced a simulation tool that empowers decision-makers to make more informed and effective choices within the realm of FMP decisions.

By leveraging these multiple approaches and frameworks, it is possible to optimise the MCDA application in FMP, ultimately leading to better-prepared and more resilient FMP strategies.

Chapter 2
Literature Review

This study explores the optimal method for optimal MCDA application in FMP decisions. This chapter discussed the relevant context related to this study, which supported the foundation that shaped the understanding of the study. The aspects related to this study context encompass:

a) Understanding flood disaster events as the domain or the case study;
b) MCDA technique and application as the focal subject, where its application in FMP is discussed in the context of MCDA in general, patterns and trends in FMP, its technique, and spatial-MCDA in FMP;
c) Understanding flood criteria employed in FMP in the current MCDA application; and
d) Spatial decision support system as a mechanism and tool to be applied in optimising MCDA applications.

2.1 Publication

A study was conducted in collaboration with NAHRIM to explore the potential of Big Data Analytics (BDA) to resolve the impact of climate change in Malaysia. The study examined publications related to BDA based on NAHRIM research data scenarios. The paper discussed the impact of BDA in climate change research and highlighted future research opportunities, particularly in the application of MCDA for Malaysian research institutes. The findings from this study were presented and published in a paper titled "Big Data Analytics as Game Changer in Dealing Impact of Climate Change in Malaysia: Present and Future Research" at the 5th International Conference on Internet of Things, Big Data, and Security (IoTBDS, 2020).

Additionally, to improve understanding of the MCDA application for water-related disaster management, a systematic literature review using the PRISMA method was conducted, covering a 20-year period from 2000 to 2020. The paper focused on analysing the trends and patterns of MCDA application in managing water-related disasters, specifically flood and drought events. The study specifically examines the techniques and application of MCDA within the context of DMP. The paper titled "An Overview of Multi-Criteria Decision Analysis (MCDA) Application in Managing Water-Related Disaster Events: Analysing 20 Years of Literature for Flood and Drought

Events" was published in May 2021. The initial findings from this study provided support for the literature review in this chapter.

2.2 Methodology

A Systematic Literature Review (SLR) study was conducted to cover aspects mentioned above. This study employed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, which is a structured and evidence-based approach. It strictly adheres to specific criteria (Moher et al., 2010; Doocy et al., 2013a; Ochi et al., 2014a; Mohammadinia et al., 2017a). The publications included in this study were obtained from many sources, such as published journals, conference presentations, and proceedings. Although extensive attempts were made, it is recognised that certain pertinent publications may have unintentionally been overlooked during the four phases (refer to Table 2-1) of the search process: identification, screening, eligibility, and inclusion, as seen in Figure 2-1.

Table 2-1: Four Phases in PRISMA

No	Phase	Explanation
1	Identification of the Key Research Question	a. Evaluate the current state and use of MCDA techniques in managing flood and drought events over a 20-year period, aiming to uncover new research opportunities. b. Identify trends in MCDA application within Disaster Management Planning (DMP) phases, specifically focusing on flood and drought management, to understand evolving practices. c. Explore innovative opportunities by examining the application of new MCDA techniques, their role in different DMP phases, and the processes of criteria identification and selection, contributing insights to MCDA and disaster management research.
2	Identification of Relevant Articles	a. Utilised 10 keyword combinations to query the Web of Science (WoS) database, as detailed in Table 2-2, for online searches related to MCDM, MCDA, natural disasters, floods, and droughts. b. Choose keywords strategically to encompass a wide-ranging exploration of MCDM and MCDA in the context of natural disasters, specifically floods and droughts.

No	Phase	Explanation
		c. Initial online search yielded 818 articles using specified keywords from Table 2-2. d. Utilised EndNote to identify and remove 356 duplicate articles, resulting in 462 remaining.
3	Selection of the Relevant Articles: Inclusion and Exclusion Criteria	a. The screening phase involved the manual assessment of 462 articles based on the title and abstract, with 309 deemed irrelevant. b. A detailed analysis was carried out for these 153 articles by carefully examining the whole text. This detailed analysis excluded four more articles that were not related to the use of MCDA techniques for flood and drought events. c. After a detailed analysis, 149 articles were considered relevant to the study's focus on MCDA techniques for flood and drought events.
4	Reporting and Summarising the Results	a. The metadata on the 149 relevant articles were extracted and compiled (authors' names, publication title, year of publication, MCDA techniques mentioned, the DMP phases, and the criteria employed). b. A detailed analysis of these metadata was conducted using both quantitative and qualitative approaches. The descriptive statistics were gathered to identify patterns and trends, while the qualitative and narrative approaches were used to present and discuss the results.

Table 2-2: Keywords and syntax used for online article query

No.	Keyword	Keyword Code
1	"MCDM" AND "flood"	KW1
2	"MCDA" AND "flood"	KW2
3	"MCDM" AND "drought"	KW3
4	"MCDA" AND "drought"	KW4
5	"Multi-criteria decision making" AND "drought"	KW5
6	"Multi-criteria decision analysis" AND "drought"	KW6
7	"MCDA" AND "natural disaster"	KW7
8	"MCDM" AND "natural disaster"	KW8
9	"Multi-criteria decision making" AND "flood"	KW9
10	"Multi-criteria decision analysis" AND "flood"	KW10

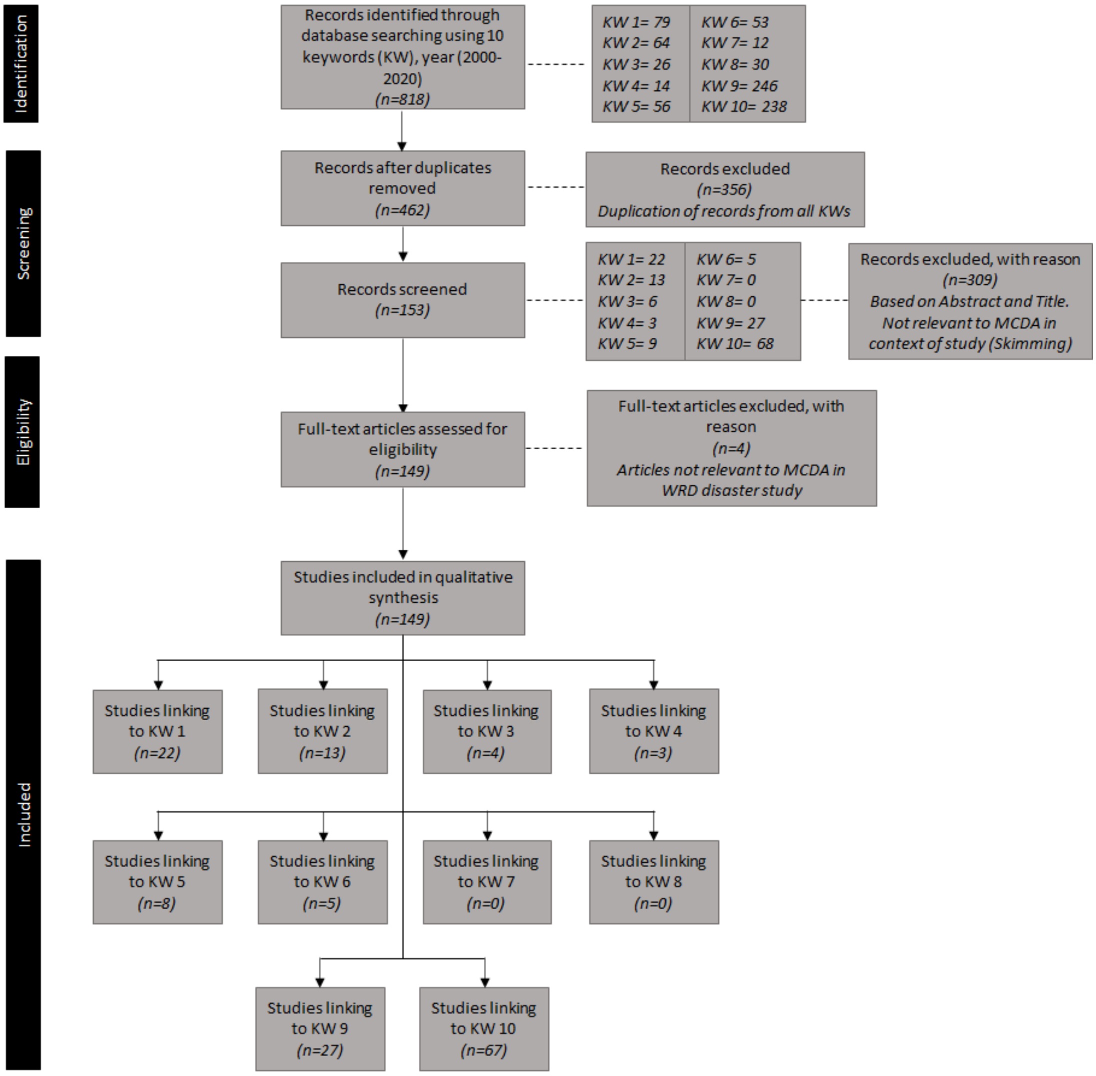


Figure 2-1: PRISMA flow diagram for the selection of eligible studies

2.3 Flood Disaster

Flood disasters occur when an excessive amount of water accumulates, caused by environmental control (climate variability), management control (inappropriate land use), and socio-economic pressure (development and construction in high-risk areas) (Kuwajima et al., 2019). Various studies find that factors will amplify the frequency and intensity of flood disasters in the future, as reported by ADB (2015) and Birkmann et al. (2012). The impact of flood disaster events would cause substantial damage to property, infrastructure, and the environment, resulting in economic losses and human deaths.

According to the Emergency Events Database (EM-DAT), 1,732 flood disaster events were recorded worldwide between 2010 and 2020 (CRED, 2020), highlighting the urgent need for strategic planning to reduce their effects. It is anticipated that by 2050, the number of people at risk from flood disasters will reach 1.6 billion. Therefore, an effective FMP is required to lessen the impact of flood events, which incorporates multiple strategies as part of Disaster Management Phase (DMP) measures. These include, but are not limited to, the development of the risk assessment framework (Giupponi et al., 2015), policy-making (ADB, 2015), vulnerability assessment (Vignesh et al., 2020), and the implementation of an early warning system by Rana et al. (2020) and Alfieri et al. (2012).

Given the escalating impact of flood disaster events, both in the present and their anticipated intensification in the future, the imperative for effective strategies to underpin the FMP decision-making process becomes undeniable. Considering the existing empirical evidence and study findings across diverse contexts concerning flood disasters, this study endeavours to serve as a vital conduit for decision-makers, equipping them with the insights and knowledge essential for navigating and overcoming the multifaceted challenges entailed in flood disaster management.

2.3.1 Flood Management Planning (FMP)

The realisation of an effective FMP requires a good governance model for collaboration between multiple stakeholders, including government agencies, communities, and the private sector (Ishiwatari, 2019). The plan for the FMP includes measures such as structural, non-structural, or both.

Flood structural measures may include building flood protection infrastructure such as dams (Sepehri et al., 2019) and concrete and mobile concrete walls (Kryžanowski et al., 2014). While non-structural measures may include flood risk maps (Nigusse and Adhanom, 2019), early warning systems (Noor et al., 2012), flood risk assessment (Hadipour et al., 2020a), and public awareness (Prashar et al., 2013).

Based on previous studies conducted, it can be concluded that FMP holds immense importance on multiple fronts:

a) Loss mitigation: FMP is crucial for minimising the loss of both human lives and property damage, for example by identifying flood-prone areas and implementing risk reduction measures, ultimately reducing fatalities and property losses.
b) Public safety: FMP enhances public safety, for instance, through early warning systems and emergency response plans, which

facilitate timely evacuations from flood-prone regions and enable swift and effective emergency services' responses.

c) Community resilience: FMP contributes significantly to community resilience by equipping communities with the skills and resources needed to cope with and recover from flood events.
d) Economic stability: FMP plays a pivotal role in supporting economic development by lessening the adverse impacts of floods on businesses, infrastructure, and long-term economic stability. Resilient plans prepare businesses to withstand flooding and minimise economic damage.
e) Environmental protection: FMP is vital for identifying and mitigating flood event impacts on natural habitats and ecosystems. Measures such as community-based flood management plans, disaster preparedness, and public education contribute to preserving ecosystems in the face of floods.

A study conducted by Sayers et al. (2015) listed ten (10) golden rules to develop a strategic FMP as follows:

a) Accept Residual Risk
b) Promote Controlled Flooding
c) Embrace Uncertainty
d) Anticipate Change
e) Diversify Responses
f) Efficient Resource Allocation
g) Clarify Responsibilities
h) Effective Risk Communication
i) Stakeholder Participation
j) Contextual Integration

The study emphasised the importance of adaptability, risk understanding, and stakeholder engagement. Thus, integrating MCDA into FMP would provide a structured, transparent, and data-driven framework for FMP decision-making. It enables decision-makers to assess trade-offs, consider uncertainties, and engage stakeholders effectively in the pursuit of effective FMP decisions. Table 2-3 explained the MCDA integration with the rules.

Table 2-3: MCDA Integration with FMP

No	Sayers et al. (2015) Rules	MCDA Role
1	Accept Residual Risk	MCDA helps prioritise flood management options while acknowledging that complete protection is impossible, guiding the selection of balanced, cost-effective measures.
2	Promote Controlled Flooding	MCDA assesses the benefits of controlled flooding within a portfolio of strategies, considering trade-offs between agriculture, ecology, and flood risk reduction.
3	Embrace Uncertainty	MCDA accommodates uncertainty by using sensitivity analysis to assess how data variations affect strategy choices, ensuring robust decision-making.
4	Anticipate Change	MCDA models changing conditions, like climate change, enabling the evaluation of strategies under various future scenarios.
5	Diversify Responses	MCDA evaluates a wide range of flood management options, including structural and non-structural measures, promoting diversification.
6	Efficient Resource Allocation	MCDA quantifies cost-effectiveness, considering risk reduction, fairness, and ecosystem enhancement for resource allocation.
7	Clarify Responsibilities	MCDA provides a transparent framework, clarifying stakeholder roles and encouraging collaboration in flood management.
8	Effective Risk Communication	MCDA results can be communicated effectively using visual aids, enhancing understanding of risks and benefits.
9	Stakeholder Participation	MCDA includes stakeholder preferences through surveys or workshops, ensuring their perspectives are considered.
10	Contextual Integration	MCDA customises criteria for flood-prone areas, accommodating adaptability while maintaining systematic analysis.

Therefore, FMP necessitates a multifaceted strategy where MCDA would offer benefits in the process. A structured and comprehensive FMP requires a key instrument known as a Disaster Management Plan (DMP). This instrument is specifically designed to address the impacts of disasters across different phases and purposes, ensuring effective management of the consequences of flooding.

2.3.2 Disaster Management Plan (DMP) in Flood Management Planning

Warfield (2008) described the Disaster Management Plan (DMP) as a comprehensive framework to serve as a means of mitigating potential losses from hazards, ensuring timely and appropriate responses to affected individuals, and facilitating effective recovery efforts before, during, and after a disaster. Meanwhile, the United Nations for Disaster Risk Reduction (UNDRR) defines DMP as a critical tool that encompasses organisation, planning, and the implementation of measures for preparing, responding to, and recovering from disasters (UNDRR, 2022).

The DMP comprises four phases: mitigation, preparedness, response, and recovery, as suggested by Klonner et al. (2016). It serves as a continuous process, as shown in Figure 2-2, by which governments, the private sector, and other sectors engage in proactive planning to mitigate the impacts of disasters. To minimise and reduce the effects of disasters, DMPs provide control measures such as decision-making processes, assessment, evaluation, policymaking, data management, and technology application.

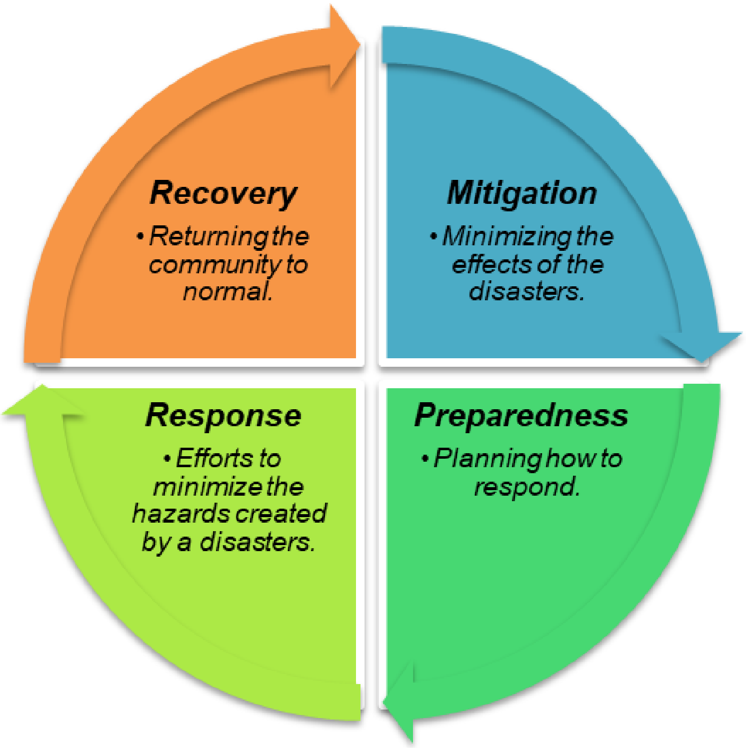


Figure 2-2: DMP Cycle (Source: Warfield (2008))

Each phase of the DMP has distinct objectives and actions to ensure a comprehensive disaster management strategy. As Yu et al. (2018) and Kumar (2010) explained, the objective of the mitigation phase is long-term planning, and the preparedness phase aims for short-term planning. Meanwhile, immediate action is required during the response phase and recovery, with an emphasis on the measures and actions taken for reconstruction and life preservation to support continuity post-disaster.

In the mitigation phase, the focus is to prevent or reduce disaster impacts and risks through long-term measures like policies, building codes, identifying disaster-prone areas, and assessing vulnerability and risk. The effectiveness of mitigation also depends on having access to data and information about hazards, emergency risks, and preventive actions.

The preparedness phase is essential to reducing the impacts. It includes advanced planning, such as prevention plans, training, and early warning systems. The measures taken during this phase can aid in ensuring a prompt response and lessening the impact of a disaster on the affected parties.

In the response phase, it is expected that, during the disaster, immediate action will be required. These include search and rescue operations, evacuation efforts, providing medical assistance, and ensuring the availability of essential resources such as food, water, and shelter. The goals are to save lives, meet basic needs, protect property, and minimise the overall impacts of disasters.

In the recovery phase, the final stage, the focus is on restoring normalcy and rebuilding affected communities. This includes fixing damaged infrastructure and essential services like water, electricity, and healthcare systems to ensure community recovery and resilience.

The DMP serves as a comprehensive strategy for mitigating the adverse effects of flood disasters. Its four phases create a structured framework for efficient and coordinated disaster planning. Its efficacy relies on consistent implementation, periodic review, and updates to maintain its relevance and effectiveness in tackling the challenges presented by disasters.

2.4 MCDA Application in Flood Management Planning

2.4.1 Multi-Criteria Decision Analysis (MCDA)

Multi-criteria decision analysis (MCDA) encompasses a collection of techniques to aid decision-makers in comparing, ranking, and selecting alternatives. It assists in situations where multiple criteria, both qualitative and quantitative, need to be considered to find a suitable course of action or choice (Doocy et al., 2013b; Mohammadinia et al., 2017b).

MCDA has proven to be useful in diverse domains like energy, water management, transportation, healthcare, and public policy. It enables the evaluation of real-world situations using quantitative or qualitative criteria, providing practitioners and researchers with effective tools to identify suitable choices and alternatives (Kumar, 2010; Velasquez and Hester, 2013; Zavadskas et al., 2014).

MCDA was designed to address four types of problems (Doocy et al., 2013b; Ochi et al., 2014b):

a. The choice problem involves selecting the best option from a set of alternatives.
b. The sorting problem involves assigning a set of alternatives to predetermined categories.
c. Ranking problems involve ordering the alternatives partially or completely, and
d. The description problem involves defining alternatives, constructing a set of criteria, and determining all or some alternatives' performance for the criteria, considering additional information.

In the Systematic Literature Review (SLR) paper published for this chapter (Abdullah, M.F. et al., 2021), a comprehensive discussion has been conducted on the widely used MCDA techniques in water-related disasters. The paper explores the strengths and weaknesses of these techniques, providing valuable insights into their application trends and patterns.

The aim of the paper is to enhance understanding and knowledge regarding the MCDA application in disaster management planning. The findings and analysis presented in the paper contributed to the existing literature on MCDA in water-related disasters, offering a deeper understanding of its potential benefits and future research opportunities.

2.4.2 MCDA Application Pattern and Trend in Flood Management Planning

MCDA is increasingly used in water-related disaster management, enabling flood actions like resilience and risk index estimation, flood hazards assessment, and policy development. It empowers decision-makers to evaluate options, considering both the risks and benefits of different options, to make informed decisions.

The application of MCDA in managing water-related disasters has witnessed substantial growth over the past two decades. Between 2000 and 2020, a total of 818 studies were conducted on MCDA's application for managing water-related disaster events. This significant increase in studies reflects the growing interest in and recognition of MCDA's effectiveness in this domain. The trend is depicted in Figure 2-3.

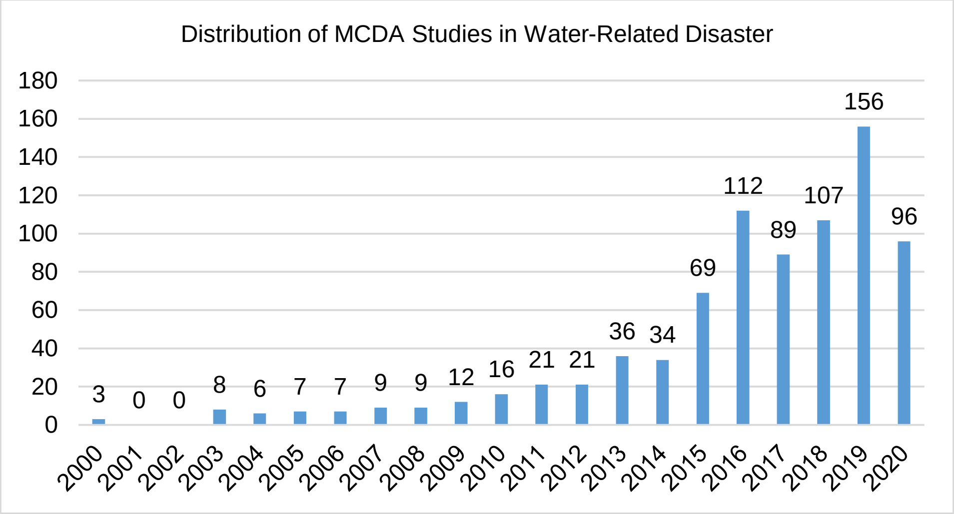


Figure 2-3: Distribution of MCDA Studies in Water-Related Disaster (Source: Abdullah, M.F. et al. (2021))

Within the same period of study, about 669 studies were focused on flood disaster events, as shown in Figure 2-4. The trend aligned with the number of flood events recorded, specifically in the last decade (2010–2020), as recorded by CRED (2020).

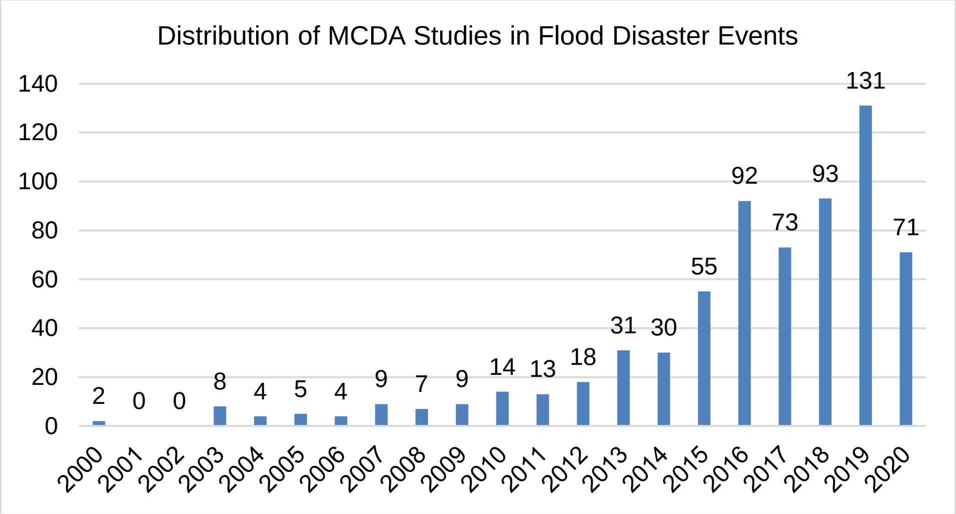


Figure 2-4: Distribution of MCDA Studies in Flood Disaster Events

Based on the SLR study, it identified 131 studies that specifically focused on flood disaster events. These studies were further reviewed to examine the MCDA application in various aspects, including MCDA techniques, its application according to DMP, flood criteria employed, decision goals, and flood measures and actions.

In the context of DMP for FMP, approximately 71% of MCDA applications have primarily concentrated on the mitigation phase, with less emphasis on the preparedness, response, and recovery phases, as illustrated in Figure 2-5. This inclination is attributed to the mitigation phase's role in assisting decision-makers in identifying the most effective long-term planning measures, as discussed in the previous sub-section.

For example, decision-makers can employ MCDA to evaluate the effectiveness of flood control measures. By comparing different alternatives and considering criteria like cost-effectiveness, social acceptability, and environmental impacts, MCDA facilitates the identification of the most suitable option.

Another example involves the prioritisation of flood-prone areas for necessary interventions. In this scenario, decision-makers can use MCDA to evaluate and rank these areas based on criteria such as flood hazards, exposure, vulnerability, and socioeconomic factors. This prioritisation process aids in the effective and efficient allocation of resources to reduce flood risk in the most vulnerable areas.

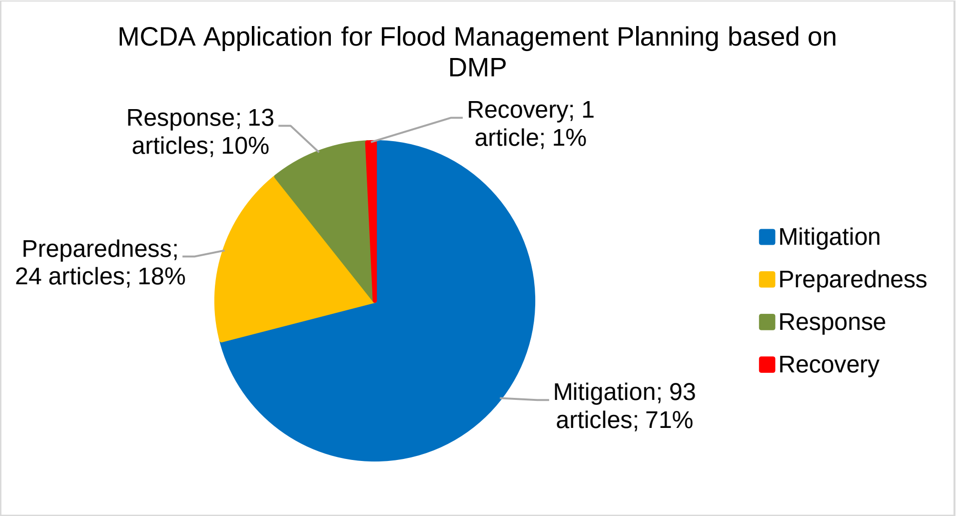


Figure 2-5: MCDA Application for Flood Management Planning based on DMP.

With a significant gap in the response and recovery phases of DMPs, future research should explore the inclusion of other phases of DMPs to enhance the overall effectiveness of FMP as a structured disaster management approach.

The ongoing trend of MCDA applications in FMP is expected to continue, given its growing acceptance for addressing intricate decision-making challenges. The use of MCDA techniques is anticipated to enhance the effectiveness of FMP, particularly in the preparedness, response, and recovery phases of DMP.

2.4.3 MCDA Technique in Flood Management Planning

An in-depth look at the results of the SLR study highlighted the extensive MCDA technique that had been applied in FMP. The top three techniques employed are AHP, mixed-method, and TOPSIS, as shown in Figure 2-6.

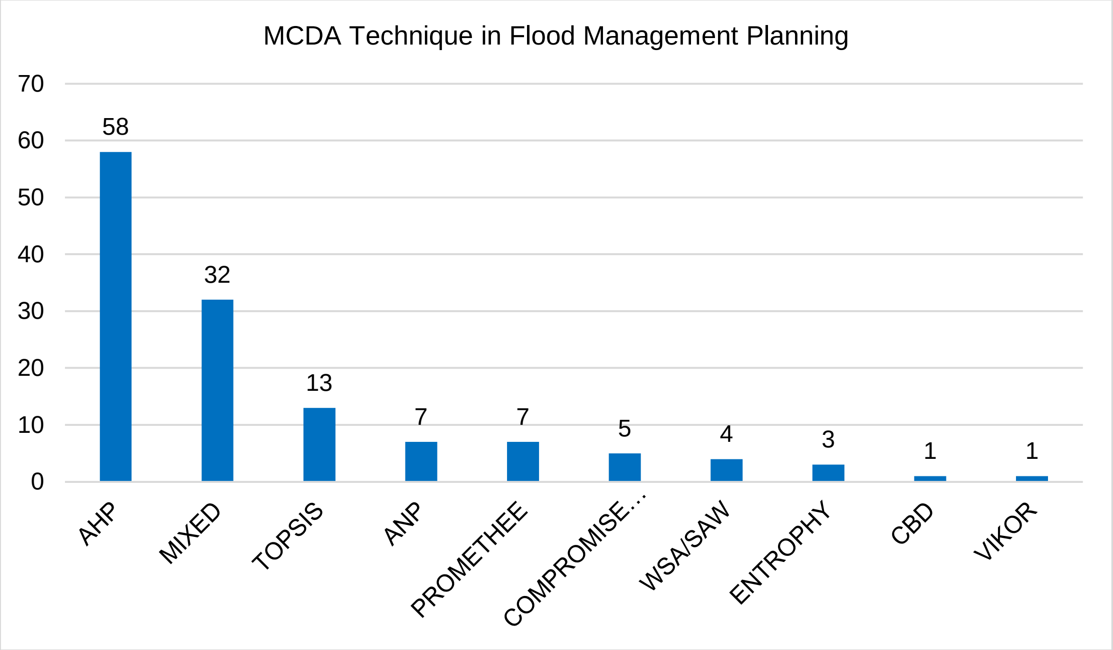


Figure 2-6: MCDA Technique in Flood Management Planning

The AHP is a structured decision-making technique that involves breaking down a complex decision into a hierarchical structure of criteria and alternatives, assigning numerical values to represent the relative importance of criteria and the performance of alternatives, and then using mathematical computations to derive a priority ranking. Mixed-methods is an approach that combines or integrates different MCDA techniques to address the complexity of decision problems. In mixed-method MCDA, researchers or decision-makers use a combination of two or more MCDA methods simultaneously or sequentially to enhance the decision-making process. TOPSIS, or Technique for Order of Preference by Similarity to Ideal Solution, is a decision-making approach for ranking alternatives based on their proximity to an ideal solution.

Figure 2-7 shows that most of these MCDA techniques primarily focus on the mitigation phase, with AHP being the most applied method in this phase. To compensate for the limitations of single MCDA methods, the use of mixed-method techniques is growing in popularity.

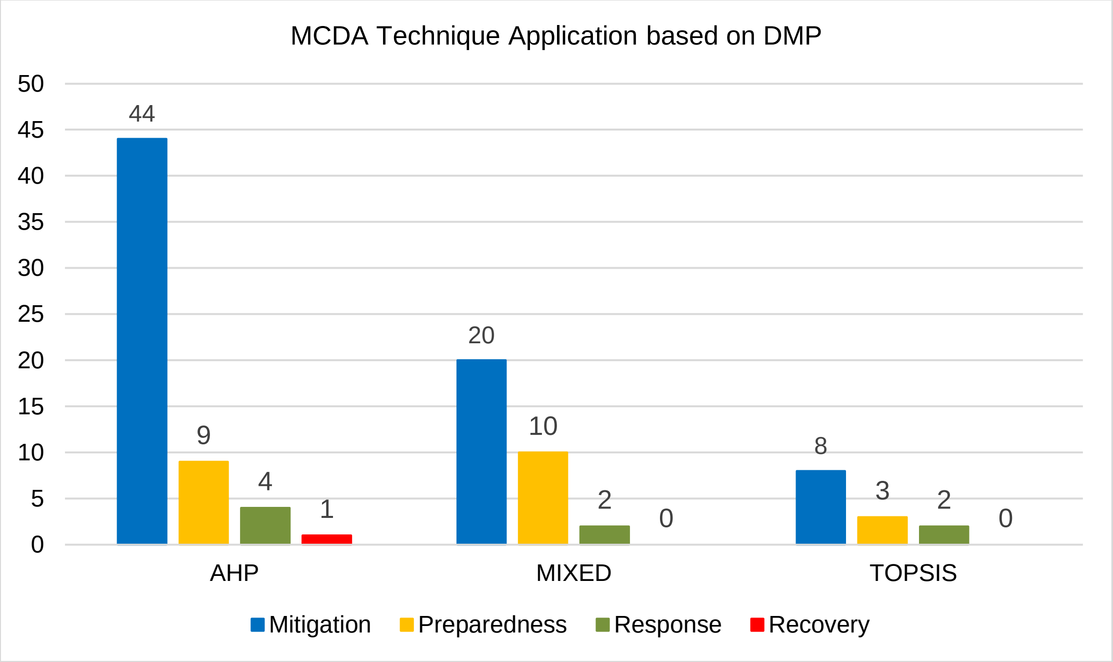


Figure 2-7: Top 3 MCDA Technique

Regarding the other phases of DMP, it's evident that AHP and mixed methods are the preferred techniques for the mitigation and preparedness phases. This choice may highlight the reliability of the AHP technique in disaster management.

While selecting the right MCDA technique for FMP, various factors need to be considered. These factors include the ease of computation, the ability to communicate results to non-technical individuals, the problem's size, and whether the technique suits multiple-criteria measurement. Each MCDA technique has its own pros and cons that should be considered before deciding which technique to use.

For example, AHP excels at handling complex hierarchical decision-making problems but may not be suitable for problems with numerous alternatives. In contrast, TOPSIS is better suited for problems with many alternatives but may struggle with complex hierarchical problems.

The discussion on the MCDA technique selection in managing water-related disasters had been discussed in the SLR study, along with the pros and cons matrix of different MCDA techniques, as presented in Table 2-4.

Table 2-4: Pros and cos of different MCDA techniques (source: (Abdullah, M.F. et al., 2021)

	AHP	ANP	DEA	WSM	WPM	GP	ELECTRE	Grey	MAUT	CBR	SMART	PROMETHEE	TOPSIS	SURE
Communicating to nontechnical people	✓	✕	✕	✓	.	✕	✕	.	✓	.	✓	✕	✓	✓
Allows inconsistencies in human judgements	✓	✓	.	.	.	.	.	✓	.	✓	.	.	.	✓
Robust against rank reversal	✕	.	.	✕	.	.	✓	.	.	.	✕	.	.	✕
Criteria can have different units of measurement	✓	✓	✓	✕	✓	✓	✓	✓	✓	✓	.	✓	.	✓
Takes uncertainty into account	.	.	.	.	.	.	.	✓	.	✓	.	.	.	✓
Supports indifference and vetoes	✕	✕	.	✕	✕	.	✓	.	✕	✕	✕	✓	.	✕
One criterion compensates for others	✓	✓	.	✓	✓	.	✕	.	✓		✓	✕	✓	✓
Robust against the trap of averages (To avoid overreliance on average values)	✕	✕	.	✕	✕	✓	✓	.	✕	✓	✕	✓	✓	✕
Easier to compute (ease of use)	✕	✕	.	✓	✓	.	✕	.	✓	.	✓	✕	✓	.
Can be applied to any size of problem (subject to complexity of problem)	✕	✕	✓	✓	✓	✓	✕	✓	✓	✕	✓	.	✓	✓
Can adapt to slight changes	✓	✓	.	.	.	.	.	✓	.	✓	.	.	.	.
Can be supported with visual aid	✓	.	✓	✓	✓	.	✕	.	.	✕	✓	✓	✓	✓

Legend: ✓ = Recommended, ✕ = Not Recommended, . = No Information

Overall, the application of MCDA techniques in FMP has shown promising results in supporting decision-making and selecting the optimal flood management strategies. It is essential to carefully weigh the pros and cons of each technique and the factors guiding the selection decision for an effective FMP. Nonetheless, it is imperative to continuously improve and refine MCDA techniques to address emerging challenges and issues in flood disaster management.

2.4.4 Combined Spatial-MCDA Application in Flood Management Planning

Combined spatial-MCDA application refers to the use of spatial data and analysis tools alongside MCDA techniques to support decision-making. As discussed previously in sub-section 2.4.2 on MCDA application in FMP, spatial analysis involves utilising spatial information to derive insights and enhance decision-making. Combining these two approaches allows decision-makers to evaluate the impact of location and spatial relationships on the decision.

In FMP, various criteria are considered, such as rainfall data, population density, and economic activity distribution. These criteria exhibit spatial variability, with certain areas being more susceptible to flooding while others are more vulnerable due to factors like population density, infrastructure, and land use, as studied by Abu El-Magd et al. (2020), Ziarh et al. (2021), and Nachappa et al. (2020). By combining spatial data with MCDA techniques, decision-makers can consider the spatial variability of these factors and evaluate the impact of location and spatial relationships on FMP.

Consider the example of selecting a location for a new waste disposal facility. MCDA techniques help identify the most suitable criteria, such as distance from residential areas, accessibility, and environmental impact. Simultaneously, spatial analysis tools come into play to map potential sites and assess their performance against these criteria.

Using a combined spatial-MCDA application plays an important role in achieving different flood decision goals across different phases of DMP. Various studies have demonstrated the utility of this approach in addressing diverse aspects of FMP that focus on different aspects of flood measures. For example, studies by Hong and Chang (2020) and Karamouz, M. et al. (2019) applied combined spatial-MCDA for assessing flood risk reduction and improving resilience. Other studies, such as those by Ghaleno et al. (2020) and Andrade et al. (2018), employed assessment measures to identify and reduce flood hazards. Meanwhile, Vojtek and Vojtekova (2019) and Papaioannou et al. (2015) utilised this technique to identify flood vulnerability areas in their studies.

Moreover, Abdelkarim et al. (2020) employed a combination of assessment and spatial techniques to identify flood-vulnerable areas and improve resilience. These examples highlighted the adaptability of combined spatial-MCDA in addressing various flood measures in different phases of DMP.

Incorporating more data sources, such as remote sensing, drones, and citizen science, can improve the accuracy of the combined spatial-MCDA. The cross-referencing of data from multiple sources improves the quality of the data. Furthermore, implementing advanced spatial analysis techniques, such as machine-learning algorithms, would further refine spatial analysis.

Conducting uncertainty analysis provides a realistic understanding of analysis limitations, while engaging stakeholders ensures their requirements are considered. Continuous evaluation and improvement mechanisms enable the ongoing monitoring of outcomes, facilitating necessary adjustments when required.

Utilising combined spatial-MCDA applications empowers decision-makers to make well-informed and prioritised decisions by considering a comprehensive array of criteria and factoring in the spatial context of the decision. This approach can result in more effective and efficient FMP decisions, ultimately leading to improved outcomes for the communities affected by these decisions.

2.5 Flood Criteria in MCDA Application

The criteria used in the FMP play a vital role in reducing the negative effects of floods. Hence, it's essential to gain a thorough understanding of how MCDA employs a well-defined set of criteria to evaluate the performance or suitability of each option and choose the best alternatives effectively. For instance, the study by Giannakidou et al. (2015) employed 15 criteria, such as distance, water and energy availability, and others, for mitigation purposes. While criteria such as slope, digital elevation model, flow accumulation, and others were among the criteria employed by Kanani-Sadat et al. (2019) in the study conducted for the preparedness phase. Therefore, a study on flood criteria would assist decision-makers in understanding and prioritising them based on their importance in achieving the FMP’s objective.

Criteria often conflict with each other, and each criteria may have competing goals or objectives. The conflict of criteria arises from misinterpretation and diverse perspectives among decision-makers regarding standard terms, leading to challenges in achieving consensus and clarity in decision-making processes. For example, a term such as a financial budget would be interpreted as a financial investment or financial allocation. This highlights the importance of identifying the most significant and ideal criteria for making trade-offs or compromises between them, which is essential for effective decision-making.

In the context of FMP, different flood plans necessitate different criteria. Previous studies have shown that these criteria can vary and encompass both quantitative aspects, such as project cost or damage cost, and qualitative aspects, such as the public's perception. For example, studies by Abdelkarim et al. (2020) and Ajjur and Mogheir (2020) focused on quantitative data such as groundwater depth, rainfall density, slope, and height to study flood vulnerability maps and flood-prone areas. Meanwhile, qualitative data such as ICT awareness, education and ICT capability were employed by Mondlane et al. (2013) for a study on flood risk management.

Conducting a well-designed study on flood criteria can enhance the transparency and objectivity of the MCDA process. This study ensures that the criteria are grounded in sound scientific principles and maintains consistency and impartiality in the evaluation process, boosting the decision-maker’s confidence.

With the advent of big data and data analytics, there is an opportunity to explore flood criteria identification and selection further to understand the impact of numerous criteria on the FMP. Previous studies by Bhangale et al. (2016), Arslan et al. (2017), and Martínez–Álvarez and Morales–Esteban (2019) have delved into this area. New data creations employed, such as projection data by Mohamed et al. (2018), social media data (Joseph et al., 2018), and structured and unstructured data formats by Towe et al. (2020), are examples of criteria that should be considered as potential criteria that can influence decisions in FMP.

Current MCDA studies on FMP are predominantly focused on environmental domains, overlooking other crucial aspects like socio-economic impacts, politics, and social factors, resulting in an incomplete FMP. To create a more comprehensive FMP, it is important to assess criteria from various domains, including social, political, economic, and technological, to name a few.

For instance, studies by Chitsaz and Banihabib (2015) considered social criteria such as awareness and education, health and safety, and population density to improve the effectiveness of FMP. Similarly, economic criteria such as flood budget, flood damage cost, Gross Domestic Product (GDP), and loss in economic productivity play a crucial role in addressing the economic impacts of floods, as highlighted by Kansal et al. (2019) and Daksiya et al. (2017).

To achieve a comprehensive FMP strategy, decision-makers should consider both macro- and micro domain criteria. The macro domain criteria would be understood as external criteria at a larger scale that influence the broader FMP strategy. Examples of macro criteria encompass political, economic, social, technological, environmental, and legal aspects. Meanwhile, the micro domain criteria focus on a specific measure or internal criteria within each macro domain. For example, in the technology domain, implementing an early warning system and flood modelling would be considered micro- criteria for the technology domain, and demographics could be treated as micro criteria from the social macro domain perspective.

To develop an effective FMP, decision-makers must ensure both macro- and micro-domain criteria complement each other. As different FMPs required different criteria to support the decision-making process, it highlights the need for a tailored approach to criteria identification and selection. A strategic analysis framework such as SWOT (Strength, Weakness, Opportunity, and Threats) (Sawangnate et al., 2022) or PESTEL (Political, Economic, Social, Technological, Environmental, and Legal) (Dockalikova and Klozikova, 2014) can provide structured approaches for identifying and analysing relevant criteria in FMP.

Selecting and identifying optimal flood criteria for FMP is important. Decision-makers need to consider the importance, certainty, and availability of the criteria from both macro- and micro domain perspective. In FMP, macro criteria encompass overarching factors such as economic, social, and technological factors, offering a comprehensive decision perspective. Conversely, micro criteria involve specific considerations like flood budget, education, and early warning systems, providing localised insights to enhance detailed flood management strategies. In addition, criteria quality also needs to be factored in to ensure its reliability before utilisation. Further studies could expand decision-makers' choices for selecting and identifying criteria in the MCDA for FMP.

2.6 Spatial Decision Support System (SDSS)

SDSS is a computer-based system that combines conventional data, spatially referenced data and information, and decision logic as a tool for assisting a human decision-maker (Crossland, 2008). It enables users to interactively analyse and visualise data, supporting complex decision-making tasks involving spatial factors. A typical SDSS includes a user interface, a spatial database, decision-making models, and visualisation instruments.

SDSS allows users to integrate various spatial data types, including maps, satellite images, and GPS data, with analytical techniques such as spatial statistics, spatial analysis, and MCDA. This integration supports the spatial decision-making process and improves decisions by combining value judgements and technical information in a structured decision-making framework (Levy et al., 2007).

In the context of DMP, Ghavami et al. (2019) conducted a study demonstrating how SDSS has been leveraged to improve disaster management plans by conducting a comprehensive analysis of spatially relevant information. Similarly, Zhang et al. (2019) applied SDSS to enable collaborative problem solving for flood emergency management, highlighting its potential as a tool for improving coordination and collaboration among decision-makers.

The integration of SDSS with MCDA offers the flexibility to work with various data types and formats. Hence, there is an opportunity to explore the use of NAHRIM’s gridded projection data and incorporate it into SDSS. This provides decision-makers with the capability to not only visualise but also comprehensively analyse the spatial distribution of diverse criteria.

This approach involves projecting data onto a grid, creating a detailed and localised dataset that can be effectively visualised using maps, graphs, and spatial analysis tools. Leveraging gridded data projection empowers decision-makers to make more informed and efficient choices by dissecting data at a finer level of detail.

2.7 Summary

Flood disasters pose significant challenges that require effective management strategies to mitigate their impacts on communities, economies, the environment, and infrastructure. The FMP was developed to outline procedures for flood response, recovery, and mitigation efforts. Within the framework of the DMP, comprehensive control measures are established to guide the course of the FMP.

MCDA is a valuable tool applied in FMP, offering decision-makers a systematic approach to prioritising flood management strategies and actions based on multiple criteria and objectives. Flood criteria are used in the MCDA to evaluate the effectiveness of various strategies in reducing flood impacts. Integrating these criteria into the decision-making process empowers decision-makers to make informed choices, aligning strategies and actions with the desired outcomes and priorities.

In FMP, decision-makers can further enhance their approach by employing a combined spatial-MCDA approach. This approach integrates spatial data with MCDA methods, facilitating a comprehensive evaluation of FMP strategies and action options. Additionally, the development of SDSS provides valuable spatial information that aids decision-makers. By harnessing the power of MCDA, flood criteria, combined spatial-MCDA approaches, and SDSSs, FMP can significantly improve their effectiveness in managing flood disasters and addressing various types of disasters.

Chapter 3
Criteria Identification and Selection from Macro-Domain Perspective in Multi-Criteria Decision Analysis Application based on PESTEL Analysis Framework for Flood Management Planning

3.1 Chapter Motivation

Based on a SLR on MCDA application in water-related disasters by Abdullah et al. (2021), it was found that 52% of the 131 research articles (specifically on flood events) focused solely on the environment domain. While only 2.3% focus on social, 1.5% focus on economic, and none of the studies focus on technological, legal, or political. Furthermore, out of the 1,332 criteria analysed, approximately 65.5% were linked to environmental perspectives such as rainfall data, slope, land use, and others. These initial findings drive the need to explore other criteria from a different domain perspective.

Identification of sub-criteria from the main macro domain criteria is important to facilitate decision-making. For example, under the political domain, sub-criteria such as fair distribution of resources such as manpower, finances, or technology need to be addressed politically by stakeholders to improve FMP. As for the social domain, sub-criteria such as personal loss, education, and awareness need to be considered in FMP decisions, as these criteria would also significantly affect and impact the effectiveness of FMP decisions.

To address this, this study will employ the PESTEL analysis framework, which encompasses Political, Economic, Social, Technological, Environmental, and Legal domains. The PESTEL analysis framework is a strategic tool for assessing the macro environment of a system and its impacts on decision operations (Team, 2013; Madsen and Grønseth, 2022). This framework would allow decision-makers to systematically evaluate external factors that can impact their decisions and understand the broader influences on them. It is widely employed in disaster management studies, as seen in the study by Sarwar et al. (2016) on risk management for natural disasters and studies by Zabihi et al. (2023) and Kopsidas and Giakoumatos (2021) specifically applying PESTEL for FMP.

The utilisation of big data in MCDA for FMP expands the range of criteria available due to the revolution in voluminous and diverse data creation. Decision-makers can gain valuable insight into flood risks, patterns, and trends, which inform the identification and selection of suitable criteria. When combined with strategic planning, big data enhances decision-making and disaster resilience across the four phases of DMP: mitigation, preparedness, response, and recovery (Rahman et al., 2017; Yang, C. et al., 2017).

Several studies have highlighted the significance of big data in various applications. For instance, Abdullah, M.F. et al. (2020), and Armbruster and MacDonell (2015) explored big data's role in studying climate change, while Akter and Wamba (2017), Arslan et al. (2017), and Afzalan et al. (2015) examined its feasibility in disaster management. These studies support the FMP by utilising the potential of big data to improve understanding, decision-making, and preparedness methods in response to climate-related issues and disasters.

Using the PESTEL analysis framework along with big data for FMP decision-making is vital for improving the efficiency and effectiveness of the process. This study aims to assist decision-makers in better selecting and identifying flood-related criteria within the broader context of MCDA applications.

3.2 Introduction

This study explores the significance of the PESTEL macro domain and its criteria by reviewing previous MCDA studies. The study focuses on the macro domain and its criteria for employment, as well as flood measures. Three methodologies were employed, which are: (1) a systematic literature review based on the study in Chapter 2; (2) a PESTEL analysis framework; and (3) expert semi-structured interviews.

The findings revealed that PESTEL macro-domain criteria contribute significantly to FMP decisions. The identified criteria are categorised into six PESTEL domains, serving as trade-offs or alternative criteria for FMP. Their selection is based on data availability and accessibility, allowing for quick decision-making.

In addition, this study delves into the challenges and opportunities that arise from these approaches, highlighting the importance of involving stakeholders, data-driven analysis, and expert input for successful outcomes. The findings underscore the significance of expert criteria selection within the macro domain to ensure effective decision-making.

To integrate different data formats and expert criteria, the study proposes a comprehensive MCDA framework to aid decision-makers in selecting the most suitable and optimal criteria for FMP decisions.

As a result, the inclusion of multiple criteria from various macro domains greatly influences decision outcomes. This approach can bridge existing gaps in using macro domain criteria in FMP, enabling decision-makers to enhance the process with MCDA. Thus, by considering a wide range of criteria, decision-makers are better equipped to make informed and effective FMP decisions.

3.3 Aim of the Chapter

This study aims to improve the FMP decision-making process by focusing on criteria identification and selection based on the PESTEL macro domain. Building upon previous MCDA studies, the study extends its scope to provide decision-makers with valuable insights and tools for effective criteria for employment.

3.3.1 Objectives of the Chapter

The following objectives are established to achieve this chapter’s aim:

a. To investigate macro domain criteria employed in FMP based on MCDA applications,
b. To identify potential key macro domain criteria, and
c. To construct a conceptual framework for macro domain criteria identification and selection for FMP.

3.4 Methodology

Based on work by Dodgson et al. (2009) on identifying the criteria and sub-criteria, this study employed two methodologies: (1) systematic literature review (SLR) and (2) semi-structured interviews with experts. The SLR extracted criteria from previous studies, mapping the criteria into PESTEL macro domains using the PESTEL analysis framework. The semi-structured interviews were conducted based on the findings from SLR.

The outline for this study consists of three process flow: (1) criteria identification, (2) criteria mapping, and (3) criteria analysis. Details on the methodology applied and the process involved are explained in Table 3-1.

Table 3-1: Explanation of the Study Outline

No	Process	Methodology	Explanation
1	Criteria Identification	SLR	a. Extract important data (refer to Table 3-2) from the previous study conducted.
2	Criteria Mapping	PESTEL Analysis Framework	a. The criteria identified were mapped to the PESTEL domain based on the steps explained in Figure 3-1 and guideline.
3	Criteria Analysis	PESTEL Analysis Framework	a. The final list of PESTEL domain criteria is identified.
		Expert Interview	a. Understand criteria roles and their significance in FMP's project b. Understand the impacts of PESTEL criteria analysis in FMP.

3.4.1 Data Collection

3.4.1.1 Systematic Literature Review (SLR)

An additional cycle of comprehensive SLR was carried out to extract relevant data based on the literature used in the study conducted by Abdullah, M.F. et al. (2021). The extracted data from 131 articles was categorised into five sections, which are: (1) MCDA technique; (2) macro domain criteria; (3) number of criteria; (4) decision goals; and (5) flood action and measurement. Table 3-2 provides a summary of the sections employed in this study, while Appendix A contains detailed information about these sections.

Table 3-2: Sections for Clustering Extracted Data

No	Section	Explanation
1	MCDA technique	Group the MCDA technique into two: Single or Mixed
2	Macro domain criteria	Identify and map criteria to six PESTEL macro domains
3	Number of criteria	Count criteria employed
4	Decision goals	Identify the MCDA decision goal
5	Flood Measure and Action	Determine flood action purpose and flood measure taken. a. Flood Measure

No	Section	Explanation
		i. Assessment ii. Spatial Application iii. Assessment & Spatial Application b. Flood Action i. Flood Risk ii. Flood Resilience iii. Flood Hazards iv. Flood Vulnerability

In Section 2 (Macro domain criteria), the study went through several steps to map the identified criteria to the PESTEL macro domain. The explanations by Sammut-Bonnici and Galea (2014), and Boyce (2021) were used interchangeably as guidelines for the mapping process. The aim was to accurately associate each criteria with the appropriate macro domain.

The studies by Sammut-Bonnici and Galea (2014) and Boyce (2021) provided detailed explanations of the six PESTEL domains, together with their examples, and how they could be applied and how they affected strategic decision. These studies guided the criteria mapping process for the identified criteria in this Chapter accordingly. It is crucial to map the criteria correctly to enhance the clarity, relevance, and applicability of the analysis. Navigating criteria falling into multiple domains posed a challenge, requiring the researcher's subjective judgement for mapping. Acknowledging inherent knowledge limitations across all domains, the researcher anticipates the need for improvement in future studies, emphasising a more nuanced and comprehensive approach to address these intricacies.

Once the identified criteria were mapped accordingly to respective domains, the duplicate criteria were then eliminated, and the remaining criteria were clustered based on common themes. Finally, the criteria were renamed and standardised to ensure consistent meaning. Figure 3-1 illustrates the steps involved in Section 2.

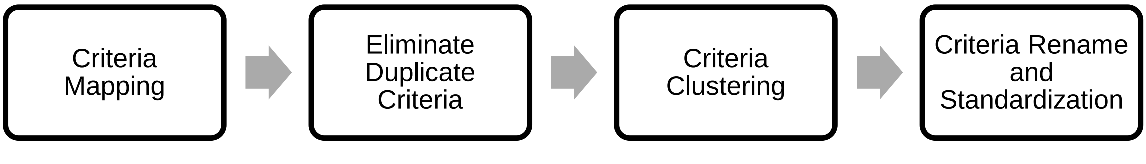


Figure 3-1: Section 2 (Macro domain criteria) Steps

3.4.1.2 Interview with Experts

Based on the findings from SLR in Section 3.4.1.1, a set of questions was formulated for a semi-structured interview with a diverse group of experts representing various macro domains. The objectives of the interview are:

a. to explore the influence and challenges of identified criteria in the decision process; and
b. to assess and validate the criteria's relevancy and importance in FMP.

This study involved ten experts who were selected based on their years of experience, areas of expertise, and domains of expertise. Experts for this study were recruited through a multifaceted approach, leveraging the researcher's professional network established through years of working experience. Additionally, experts will be drawn from project collaborations, tapping into individuals with firsthand experience in the field of water and environmental studies. In the event that a specific expert is unavailable, recommendations from other experts will be sought to ensure a robust and diversified panel of expertise.

Based on Dworkin (2012), the number of experts involved is considered suitable as the concern is to gain an in-depth understanding of the scenario or the what and why of particular issues. It is also based on pragmatic considerations (time and expert availability) and the exploratory nature of the study (Vasileiou et al., 2018). The criteria set for each expert are as follows:

a. Experience: at least ten years of experience in Malaysia government projects involving the environment, data analytics, or a related field.

b. Expertise in management, technology, and research and development (policymaking, project management, consultation, think-tankers, idealists, R&D, etc.)

c. Expertise in at least one of the PESTEL macro domains.

Expert judgement plays a crucial role as they bring valuable insights, experience, and knowledge to the table, contributing to the thorough examination and evaluation of identified criteria. Their expertise helps ensure the credibility, reliability, and validity of the analyses, especially in the criteria selected, and, importantly, expert judgement assists in identifying potential restrictions, gaps, or impacts that researcher might have overlooked, specifically in the discussion on the impacts of PESTEL in FMP (refer to 3.6.1).

The findings from the interview with experts help in gathering and structuring information to identify the impact of PESTEL analysis on FMP decisions and the development of a conceptual framework on issues of FMP. The critical eye of an expert can enhance the overall quality of this study and increase its acceptance within the academic or professional community. The collaborative effort between the researcher and expert reviewers is integral to the advancement of knowledge, fostering a culture of rigorous scrutiny and continuous improvement in scientific and scholarly endeavours.

Table 3-3 depicts the experts' profiles, giving insights into their backgrounds. Involving these experts enhances the discussion when it comes to identifying and selecting criteria for future FMPs. It's valuable to capture their insights, knowledge, and preferences about the criteria's relative importance, as these can vary based on their interests. This information can lead to fresh perspectives and opinions, and it also helps the interviewer understand the experts' experiences in this study's context.

The interview questions were formulated to achieve the goals and are divided into two sections (refer to Appendix B). In Section 1, experts answered an open-ended question about selecting and identifying criteria for project viability. In Section 2, they assigned scores to criteria (finalised based on a literature review) based on their importance and certainty within each macro domain, revealing how these criteria interact.

To ensure the interview questions were effective, we pilot-tested them with three unrelated individuals to ensure clarity and comprehension (refer to Appendix C for the interview plan).

Table 3-3: Experts Profile

Profile of the Interviewees	Gender	Years of Experience	Area of Expertise	Domain
Interviewee 1	Female	17	R, T, M	P, EN, L
Interviewee 2	Male	15	R, T, M	T, EN
Interviewee 3	Female	14	T, M	E, S, T, EN
Interviewee 4	Female	17	R, M	T, EN
Interviewee 5	Female	14	R, T, M	S, T, EN
Interviewee 6	Female	14	R, T	S, T, EN
Interviewee 7	Male	14	T, M	T, EN, L
Interviewee 8	Female	20	R, T, M	P, E, S, EN, L
Interviewee 9	Male	10	T, M	T, EN
Interviewee 10	Female	17	R, M	P, E, S, EN, L

*Area of Expertise: **R=** Research & Development**, M=** Management**, T=** Technical*

*Domain: **P=**Political, **E=**Economic, **S**=Social, T**=** Technological, **EN=**Environmental, **L=**Legal*

3.4.2 Data Analysis

The PESTEL analysis framework was originally created to evaluate the macro environment in which industries and businesses operate. This framework is valuable as an intermediary step for identifying and understanding critical political, environmental, economic, societal, technological, and legislative factors that might impact an industry (Kralj, 2009; Bell and Rochford, 2016).

The strength of PESTEL lies in explaining multidimensional aspects, but the analysis is confined to the identification and assessment of the relative importance of the issues to determine which should receive more in-depth analysis. Therefore, its usefulness lies in the assumption that the optimisation of management decisions cannot be realised without having all the relevant information relevant to a specific context (Buchanan and Gibb, 1998).

Therefore, the capability of the PESTEL framework to offer a comprehensive overview of the study context and conduct criteria analysis would facilitate decision-makers in obtaining refined criteria that are significant enough to be employed for FMP decisions.

3.5 Findings and Results

This subsection discusses the findings of the analysis conducted in the previous study. The findings will be discussed within the context of the PESTEL macro domain, and the criteria utilised for each macro domain.

3.5.1 PESTEL Domain Analysis

The analysis of the literature revealed that many studies tended to focus on a single macro domain instead of integrating multiple domains. Approximately 56% of previous studies employed criteria from the same domain, with over 50% focused on the Environmental domain. The Social and Economic domains also received significant attention. In contrast, integrated domain studies made up around 44% of the total, with the Social, Environmental, and Economic domains being the most prominent in FMP. Refer to Table 3-4 for the classification of studies as single or integrated.

Table 3-4: Study based on Single or Integrated Domain

No	Type of Study	Number
1	Single Domain	73
2	Integrated Domain	58

Table 3-5 provides the distribution of the study types, revealing some interesting patterns. The maximum number of domains integrated into a single study was five. This indicates that some studies This suggests that some studies combined several domains to conduct a more comprehensive analysis. However, it's worth noting that none of the studies included criteria from all six domains of the PESTEL framework.

Among the integrated domain studies, certain domains received more attention than others. The Economic, Social, Technological, Environmental, and Legal domains were frequently integrated into the analysis. These domains appear crucial to understanding the broader context and implications of FMP decisions.

Integrating multiple domains implies a holistic approach to FMP, recognising the interconnections between various criteria. By considering criteria from different domains, decision-makers can gain a more comprehensive understanding of the complex challenges in FMP. This approach enables them to make informed decisions that consider other domain aspects of the problem.

Table 3-5: Distribution of Domain

No	Macro Domain	No. of studies
1	EN	68
2	E + S + EN	19
3	S + EN	11
4	E + S + T +EN	6
5	E + S + T + EN + L	4
6	P + E + S + T + EN	3
7	S	3
8	S + T + EN	3
9	E	2
10	E + EN	2
11	E + S	2
12	E + S + EN + L	1
13	E + T + EN	1
14	E + T +L	1
15	P + E + S + EN	1
16	P + S + E	1
17	S + EN + L	1
18	S + T	1
19	T +EN	1

*Macro Domain: **P=**Political, **E=**Economic, **S**=Social, **T=** Technological, **EN=**Environmental, **L=**Legal*

Based on these findings, it suggests the need for more research in the integrated macro domain, particularly in domains like Political and Legal, which could benefit from further investigation within the context of FMP.

To effectively conduct integrated domain studies, it is crucial to address the potential challenges and constraints. These challenges include the availability of criteria and ensuring data reliability to support these criteria. Issues related to data accessibility also need resolution. By addressing these challenges, decision-makers can enhance the feasibility and effectiveness of conducting integrated domain studies. This, in turn, allows for consideration of a broader range of criteria, leading to more FMP decisions.

While FMP decisions are often designed for specific events, each decision is unique and depends on criteria such as flood severity, location, and impacts on social, economic, and environmental factors. It is advisable to incorporate a comprehensive set of criteria from various domains for well-rounded decision-making. This approach helps decision-makers formulate plans and objectives that address short-term, medium-term, and long-term goals. Additionally, it can streamline project implementation, resulting in cost savings and reduced execution time from a project management perspective.

3.5.2 PESTEL Criteria Analysis

Initially, a total of 1,332 criteria were extracted from 131 studies, and they were mapped according to the PESTEL macro domain. After analysis, the selection was narrowed down to the final 40 criteria. Figure 3-2 exhibits the criteria distribution across the PESTEL macro domain. The breakdown of the criteria distribution within the PESTEL domains is presented in Table 3-6, with 30% of the criteria focusing on the Environmental domain. The Social, Technological and Economic domains accounted for 20% and 17.5%, respectively, while Political and Legal criteria were the least utilised, each with 5% and 10%, respectively. Table 3-7, Table 3-8, Table 3-9, Table 3-10, Table 3-11, and Table 3-12 contain detailed sub-criteria information for each PESTEL domain.

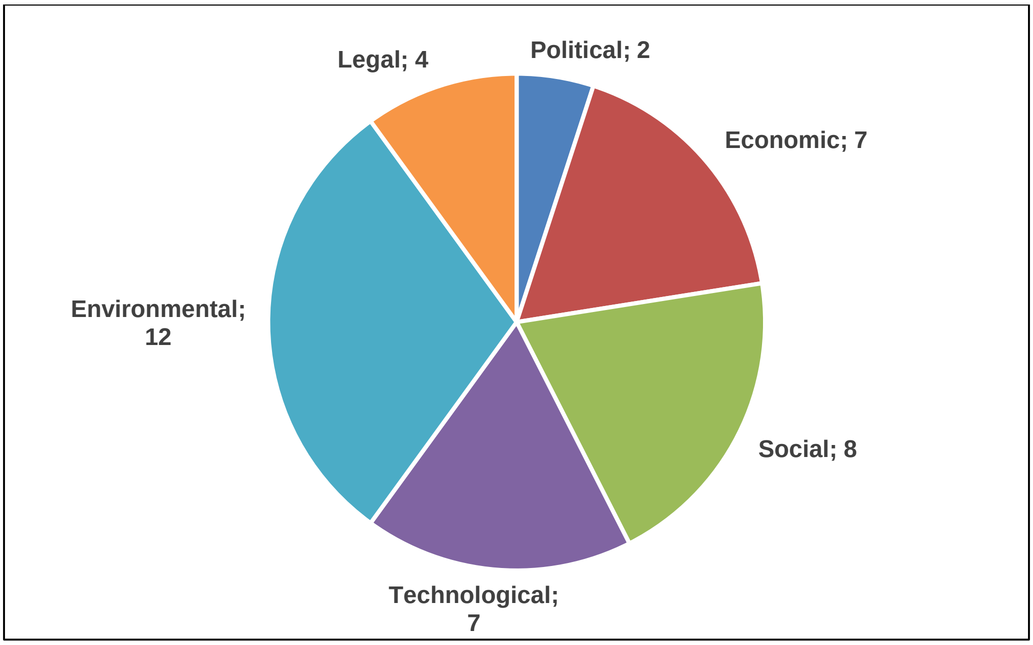


Figure 3-2: Distribution of Final 40 Criteria Distribution

Table 3-6: Number of Criteria based on PESTEL Macro Domain

No	Macro-domain	Number of Criteria	Percentage (%)
1	Political	2	5%
2	Economic	7	17.5%
3	Social	8	20%
4	Technological	7	17.5%
5	Environmental	12	30%
6	Legal	4	10%

Table 3-7: Sub-criteria for Political Domain

Domain	Sub-criteria Code	Sub-criteria
Political (P)	P1	Fair distribution of resources *(financial, manpower, technology etc.)*
	P2	Government capacity & capability *(financial, manpower, technology etc.)*

Table 3-8: Sub-criteria for Economic Domain

Domain	Sub-criteria Code	Sub-criteria
Economic (EC	EC1	Damage & Loss to Building *(commercial, residential, agricultural, industrial, religious, heritage and cultural)*
	EC2	Damage & Loss in Infrastructure *(transportation, telecommunication, energy, water, tourism, aesthetic & recreation)*
	EC3	Damage & Loss in Economic Activities *(related to fiscal, monetary, dollar & cents criteria)*
	EC4	Investment Cost *(cost related to implement the project such as cost for land intake, to build flood structures, to implement non-structures flood project etc.)*
	EC5	Financial Budget *(yearly budget for operation & maintenance cost for flood management plan)*
	EC6	Economic Density *(area related to economy activity)*
	EC7	Economic Loss *(type of economy activities impacted from flood events - tourism, agricultural, commerce etc.)*

Table 3-9: Sub-criteria for Social Domain

Domain	Sub-criteria Code	Sub-criteria
Social (S)	S1	Quality of Life & Human Needs *(Income, Residential, Food, Water etc.)*
	S2	Transportation Access *(land, sea and air transportation)*
	S3	Telecommunication Capacity
	S4	Religious, Cultural & Heritage *(preservation)*
	S5	Personal Loss *(tangible, intangible, physical, mental and emotional)*
	S6	Town planning *(existing and future planning)*
	S7	Health, Safety, Welfare & Lifestyle *(critical facilities, employment, landscape etc.)*

Domain	Sub-criteria Code	Sub-criteria
Social (S)	S8	Education & Awareness *(education level & awareness programme)*

Table 3-10: Sub-criteria for Technological Domain

Domain	Sub-criteria Code	Sub-criteria
Technological (T)	T1	Flood Early Warning System *(quantities, effectiveness etc.)*
	T2	Data collection and analyses *(mechanism, platform, equipment, tools, accuracy etc.)*
	T3	Flood System/Modelling *(accuracy, effectiveness, quality, satisfaction etc.)*
	T4	Education & Awareness *(technology updates, technology emergence etc.)*
	T5	Flood Structure & Control *(reliability, quantity etc.)*
	T6	Communication *(tower, equipment, etc.)*
	T7	Financial Budget *(coordination & planning - cost)*

Table 3-11: Sub-criteria for Environmental Domain

Domain	Sub-criteria Code	Sub-criteria
Environmental (EN)	EN1	Water Quality
	EN2	Land use & Planning
	EN3	Hydrology
	EN4	Topographic/Physical Data
	EN5	Protection of wildlife habit
	EN6	Protection & improvement of natural landscape
	EN7	Water Supply Quantity
	EN8	Flood risk management plan
	EN9	Water infrastructure for Flood Protection
	EN10	Damage in land use and land cover
	EN11	Flood Mitigation Plan
	EN12	Biodiversity

Table 3-12: Sub-criteria for Legal Domain

Domain	Sub-criteria Code	Sub-criteria
Legal	L1	Land ownership for flood protection *(land intake)*

Domain	Sub-criteria Code	Sub-criteria
(L)	L2	Government Law & Policy Regulation
	L3	Flood Disaster Institutional *(authorise institutional)*
	L4	International Constitutional & Standard, Guidelines *(compliance)*

These findings underscore the importance of further investigation, particularly in the identification and selection of criteria for the Political and Legal domains. Furthermore, the results from Section 3.5.1 reveal a concentration of previous studies on the Environmental domain, highlighting significant gaps in the coverage of the Political and Legal domains.

It is evident that there is a pressing need for a thorough exploration to identify and select more significant criteria for the Political and Legal domains. The limited attention given to these domains in previous studies has created gaps in understanding of their influence on FMP decisions. While the Environmental domain has been extensively studied, the Political and Legal domains have been relatively neglected. For example, addressing land ownership in FMP becomes complex when a significant portion of flood-prone land is privately owned, making the acquisition of land for flood protection infrastructure challenging. Legal disputes over federal land and property rights can further hinder flood management efforts, adding to the intricacy of dealing with this criterion. This highlights the importance of filling these knowledge gaps and gaining a comprehensive understanding of criteria relevant to these domains. This will enable a more holistic and well-rounded approach to addressing the various impacts of flood events.

During this process, decision-makers may encounter challenges related to criteria identification and selection. Involving experts can help address issues such as determining the importance and certainty of criteria. Considerations like data availability, type, format, confidentiality, ownership, and quality should also support the identification and selection of criteria. These elements guarantee that the data supporting the decision-making process in FMP is trustworthy and pertinent, fostering a favourable ecosystem for effective decisions.

To streamline the process of criteria identification and selection, it is recommended to employ standardised terms that represent thematic categories within each domain. For instance, within the Economic domain, terms like “fund”, “financial aid”, “budget”, and “expense planning” could be grouped under the theme of "Flood Budget". Similarly, terms like “economic loss”, “financial loss”, and “financial expenses” could be categorised under the theme of "Flood Financial". Using standardised terms with global or local recognition would greatly assist in organising and simplifying the criteria identification process.

Furthermore, it is advisable to involve more experts from various multidisciplinary domains, either directly or indirectly involved in the FMP decision, to broaden the understanding. This would facilitate the identification and selection of additional criteria by tapping into diverse perspectives and expertise. Additionally, establishing a centralised flood criteria repository to collect and archive flood criteria would greatly facilitate future FMP efforts and enable further studies. Such a repository would serve as a valuable resource for decision-makers, researchers, and stakeholders, enhancing the overall effectiveness of FMP.

3.5.2.1 Flood Measures (Flood Actions)

Previous studies provided valuable insight on the MCDA application in FMP. It was observed that MCDA has been employed to improve three distinct types of flood measures (actions), namely (1) assessment, (2) spatial, and (3) assessment and spatial (A&S) measures.

Assessment measures involve conducting evaluations and measuring specific factors like flood severity, risk, and mitigation effectiveness to assist FMP decision-making. Spatial measures consider geographical and spatial factors, such as flood-prone areas and optimal resource allocation, where spatial maps or applications will be prepared and developed to provide visual spatial information to assist FMP decisions. Meanwhile, A&S measures is a combination and integration of both assessment and spatial aspects, where evaluation of specific factors is conducted based on spatial maps or applications to assist FMP decision-making. This approach enables decision-makers to use assessment results alongside spatial context for more effective FMP decisions.

Figure 3-3 illustrates that the MCDA has predominantly been applied for assessment purposes, highlighting its significance in evaluating different FMP criteria. However, there is a growing recognition of the importance of integrating assessment and spatial considerations, indicating a shift towards more holistic approaches in FMP decision-making. This approach would enable decision-makers to gain a comprehensive understanding of the geographical context, allowing more informed FMP strategies. This integration allows a holistic approach that considers both quantitative assessments and spatial relationships, leading to optimised FMP decisions.

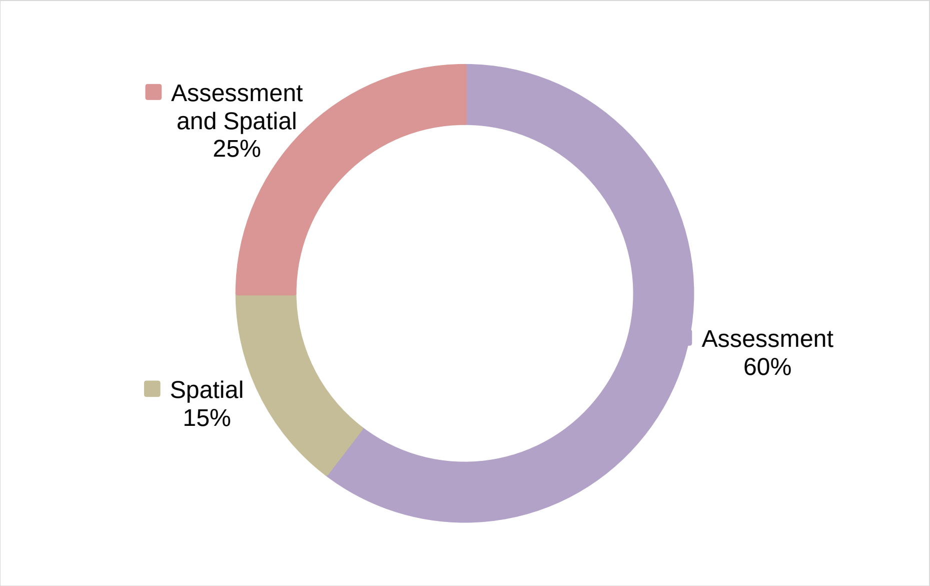


Figure 3-3: Trend Flood Measures based on MCDA Technique for Flood Management Planning

Based on the previous studies, the identified flood measures were applied to achieve four types of decision goals: (1) improve resilience, (2) reduce vulnerability, (3) reduce risk, and (4) reduce hazards. In this study, flood risk is considered a hazardous phenomenon that impacted various aspects of life, economy, and environment, which made these aspects vulnerable to damages. According to the UNISDR (2009), the following are the definitions of the goals:

a. Resilience

   "*The ability of a system, community, or society exposed to hazards to resist, absorb, accommodate to, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions*",

b. Vulnerability

   "*The characteristics and circumstances of a community, system, or asset that make it susceptible to the damaging effects of a hazard*".

c. Risk

   "*The combination of the probability of an event and its negative consequences*"

d. Hazards

> “*A dangerous phenomenon, substance, human activity, or condition that may cause loss of life, injury, or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage*”.

The analysis of the previous studies provided valuable insights into FMP planning priorities and preferences. Mapping flood measures to different types of decision goals revealed significant trends. Among these goals, enhancing resilience stood out as a key focus, with 29% of articles emphasising resilience in FMP decisions. Examples of flood measures to improve resilience are the development of detention basin (Ahmadisharaf et al., 2016) and flood control operations in reservoirs (Zhu et al., 2018).

Furthermore, vulnerability also emerged prominently as a crucial consideration in FMP decisions. A substantial 62% of spatial measures were dedicated as part of flood actions to addressing vulnerability, highlighting the importance of understanding and mitigating risks in vulnerable areas. Moreover, when analysing both A&S flood measures, reducing vulnerability remained the dominant decision goal, accounting for 61% of these measures. This underscores the critical importance of comprehensively addressing vulnerability and recognises A&S measures as an effective approach to achieving these goals.

Table 3-13 provides a comprehensive overview of these findings, showcasing the distribution of flood measures across various decision goals. These results emphasise the need for proactive measures to bridge gaps among the decision goals in future FMP decisions. By adopting a holistic approach that considers A&S, decision-makers can effectively address the complex challenges of FMP and make informed decisions.

Table 3-13: Details on Decision Goals based on Flood Measures

Flood Measures	Decision Goals	Number of Literature	Percentage
Assessment	Improve Resilience	38	44%
	Reduce Vulnerability	26	30%
	Reduce Risk	17	20%
	Reduce Hazards	4	5%
	Reduce Risk & Improve Resilience	2	2%
Spatial	Reduce Vulnerability	13	62%
	Reduce Hazards	5	24%
	Reduce Risk	2	10%

Flood Measures	Decision Goals	Number of Literature	Percentage
	Improve Resilience	1	5%
Assessment & Spatial	Reduce Vulnerability	14	61%
	Reduce Hazards	3	13%
	Reduce Risk	2	9%
	Improve Resilience	2	9%
	Reduce Vulnerability & Improve Resilience	1	4%
	Reduce Risk & Reduce Vulnerability	1	4%

Previous studies consistently prioritise addressing vulnerability as a key decision goal in flood management. For instance, Bouamrane et al. (2020), Ali et al. (2020), and Arabameri et al. (2019) have demonstrated the application of various flood spatial measures to achieve vulnerability-related goals, specifically in identifying flood-vulnerable areas. Similarly, Stavropoulos et al. (2020), de Brito et al. (2019), and Feloni et al. (2019) employed assessment measures focused on identifying flood vulnerability criteria. Additionally, Lee, G. et al. (2014) used assessment measures to rank the flood vulnerability quantification problem, reducing the inherent uncertainty in fuzzy multi-criteria decision-making processes.

However, the analysis also reveals an imbalance in the application of flood measures across different phases of DMP, as depicted in Figure 3-4. To ensure a more comprehensive approach to FMP decisions, it is essential to incorporate the discussed flood measures (assessment, spatial, and assessment and spatial) into all phases of the DMP. Neglecting certain phases while focusing on specific decision-making goals can significantly impact the overall effectiveness of the DMP.

By considering diverse flood measures for each phase of the DMP, decision-makers can establish a comprehensive approach to the FMP. This approach enables the identification and implementation of appropriate strategies at each stage, addressing the unique challenges and objectives associated with that phase. It helps minimise potential gaps, reduce vulnerabilities, and maximise the overall effectiveness of flood management strategies. For example, in the response phase, utilising assessment and spatial application measures to identify optimal locations for emergency shelters and coordinating rescue operations based on real-time spatial data for disseminating accurate and timely updates to the public. Therefore, it is essential to allocate attention to all phases and their respective decision goals to ensure successful DMP implementation.

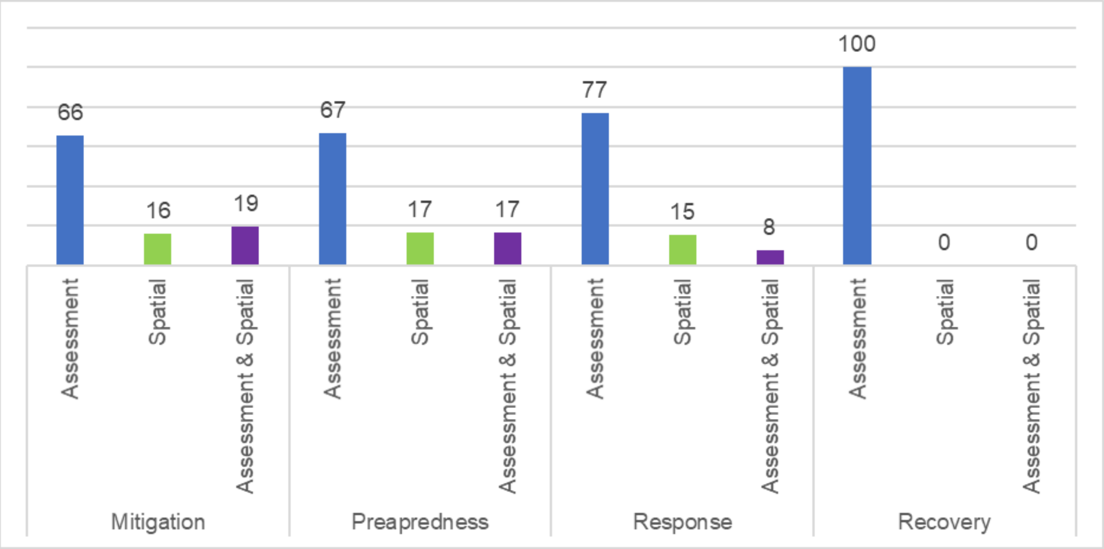


Figure 3-4: Flood Measures Distribution Percentage according to DMP Phase

The analysis highlights the Environmental domain as the most significant one for decision-making. However, it is evident that the integrated macro domain analysis lacks sufficient applications for each decision goal and flood measure. Therefore, future research should concentrate further in this area.

To understanding flood measures better for various decision goals within the macro domain, the results are presented in Table 3-14, Table 3-15 and Table 3-16. These tables offer insights into how the macro domain aligns with flood measures for specific goals, aiding future FMP decisions.

Table 3-14: Macro domain Analysis over Flood Measures (Assessment) and Decision Goals

Macro Domain	Assessment				
	Improve Resilience	Reduce Risk	Reduce Hazards	Reduce Vulnerability	Reduce Risk & Improve Resilience
EN	12	5	4	12	1
EC + S + EN	5	2	x	7	x
EC + EN	3	x	x	x	x
EC + S + T + EN	3	1	x	1	1
EC + S + T + EN + L	3	x	x	1	x

Macro Domain	Assessment				
	Improve Resilience	Reduce Risk	Reduce Hazards	Reduce Vulnerability	Reduce Risk & Improve Resilience
EC + S + EN + L	2	1	x	x	x
S + T + EN	2	x	x	x	x
EC + S	1	1	x	x	x
EC + T +EN	1	x	x	x	x
EC + T + L	1	x	x	x	x
P + EC + S +EN	x	1	x	x	x
P + EC + S + T + EN	1	2	x	x	x
P + S + EN	1	x	x	x	x
S	1	x	x	1	x
S + EN	x	4	x	3	x
S + EN + L	x	x	x	1	x
S + T	1	x	x	x	x
T + EN	1	x	x	x	X

***P**=Political, **E**=Economic, **S**=Social, T= Technological, **EN**=Environmental, **L**=Legal*

Table 3-15: Macro domain Analysis over Flood Measures (Spatial) and Decision Goals

Macro Domain	Spatial			
	Reduce Vulnerability	Improve Resilience	Reduce Risk	Reduce Hazards
EN	11	x	1	5
EC + S +EN	1	x	x	x
S	1	x	x	x
S + T + EN	x	x	1	x
EC + S	x	1	x	x

***P**=Political, **E**=Economic, **S**=Social, **T**= Technological, **EN**=Environmental, **L**=Legal*

Table 3-16: Macro domain Analysis over Flood Measures (Assessment & Spatial) and Decision Goals

Macro Domain	Assessment & Spatial					
	Reduce Vulnerability	**Reduce Risk**	**Reduce Hazards**	**Improve Resilience**	**Reduce Vulnerability & Improve Resilience**	**Reduce Risk & Reduce Vulnerability**
EN	11	1	3	2	1	x
EC + S + EN	1	x	x	x	x	x
EC + S + T + EN	x	1	x	x	x	x
S + EN	2	x	x	x	x	1

P=*Political,* ***E=****Economic,* ***S****=Social, T= Technological,* ***EN=****Environmental,* ***L=****Legal*

3.6 Discussion

For successful FMP decisions, it is crucial to consider various aspects that influenced the decisions. Experts have pinpointed seven key decision areas that play a pivotal role in this process. These areas are critical for informed decision-making and achieving desired FMP outcomes. The seven decision areas identified are as follows:

a. Flood Action Plan

Prior to implementation, the type of action plan, whether structural, non-structural, or hybrid, must be thoroughly determined and selected based on a detailed assessment. This assessment should consider factors such as location, data availability, technology requirements, expert input, stakeholder involvement, and financial considerations. Analysing the assessment results will enable the selection of a flood action plan based on priority, effectiveness, or other relevant factors crucial for successful plan implementation.

b. Flood Location

Flood risk areas, vulnerable locations, and previous flood occurrences greatly influence FMP implementation. Factors such as economics, social dynamics, politics, and the environment are key in determining the ideal implementation locations. The goal is to minimise future losses and mitigate flood impacts, drawing from the lessons of previous flood events.

c. Financial

The implementation of various FMPs relies on the allocation of flood budgets. The type of flood measure and its location are just two examples of the variables that affect each plan's cost. Additionally, long-term financial planning must account for maintenance costs. It is crucial to allocate different financial resources for different flood measures based on their respective locations.

d. Stakeholder

Identifying and engaging the stakeholders in FMP projects is vital for crafting an effective flood action plan. Stakeholders, including data owners, land authorities, and community representatives, all have unique roles. It's critical to establish and grasp the interests of the public and communities and gain their approval before proceeding with the project. Having a clear method for recognising the right stakeholders helps prevent delays, complications, and bureaucratic obstacles during plan execution.

e. Data

Selecting the right data is vital for effective flood decisions. Data quality and quantity are pivotal in improving decision-making. Historical and observed data shed light on the present situation, while projected data helps us grasp future trends and make predictions. Hence, the careful selection of relevant data for inclusion in the flood management plan significantly influences the effectiveness of FMP decisions.

f. Expert

Expert knowledge, expertise, and experience are invaluable resources for FMP. Experts contribute unique skills, specialised knowledge, and practical experience that can significantly enhance decision-making. Their input improves data analysis, ensures accurate interpretation, offers valuable guidance, and fosters stakeholder engagement. Selecting the right experts and harnessing their skills empowers decision-makers to enhance the quality of FMP decisions.

g. Technology

Technology plays a pivotal role in flood management, facilitating data collection, analysis, modelling, and communication. Effective technology enables streamlined data management, supports data-driven decision-making, and enhances stakeholder communication. Advanced monitoring systems, data analysis tools, and communication platforms are essential technological elements in FMP. The judicious choice and application of technology contribute significantly to the successful implementation of FMP.

Experts have identified various factors that impact and hinder effective decision-making in FMP. Based on a study by Lee (1966) on push and pull theory on migration, the same concept was applied with a reverse approach. In Lee’s theory, push factors are often characterised as factors that motivate out, while pull factors are factors that attract or motivate in. For this study, the push factors are considered as the factors that impact the decisions. These factors encompass stakeholders, technology, data, experts, legislation, public and community interests, political interests, environmental impacts, social impacts, economic impacts, and financial considerations.

Conversely, the "pull factors" are considered the factors that hinder the decision’s implementation, which involved data management, data analysis, technology, political constraints, legislative challenges, financial limitations, expert availability, project management constraints, public and community acceptance, and location-related issues. Recognising these factors helps grasp the complexities and challenges of translating decisions into practical FMP decisions.

Experts’ opinions have constructed a conceptual framework on FMP issues based on the “push” and “pull” factors identified, represented in Figure 3-5. The first component, known as the "push factor", consists of external or macro-level factors that exert influence on decision-making. These factors encompass various issues that drive the need for action. For example, the social impact of flood-prone areas necessitates the involvement of political authorities in creating flood budgets, action plans, and stakeholder engagement. Moreover, such decisions can indirectly mitigate environmental impacts and disruptions to economic activities.

Conversely, the second component, referred to as the “pull factor”, comprises internal challenges that hinder the decision’s execution. These challenges encompass aspects like data management, technological limitations, political and legislative constraints, financial constraints, expert availability, project management complexities, and public acceptance. Understanding these “push” and “pull” factors is crucial for devising effective FMP decisions.

Challenges can arise from conflicts related to factors that serve as both "push" and "pull" factors. Factors such as technology's emergence, recent data availability, and experts' knowledge can generate conflicts. These same factors also act as "pull" factors that hinder decision-making, leading to challenges such as high technology adoption costs, data confidentiality and accessibility issues, and a shortage of expert resources. Resolving these conflicts arising from "push" and "pull" factors is crucial for ensuring the smooth implementation of decisions without setbacks.

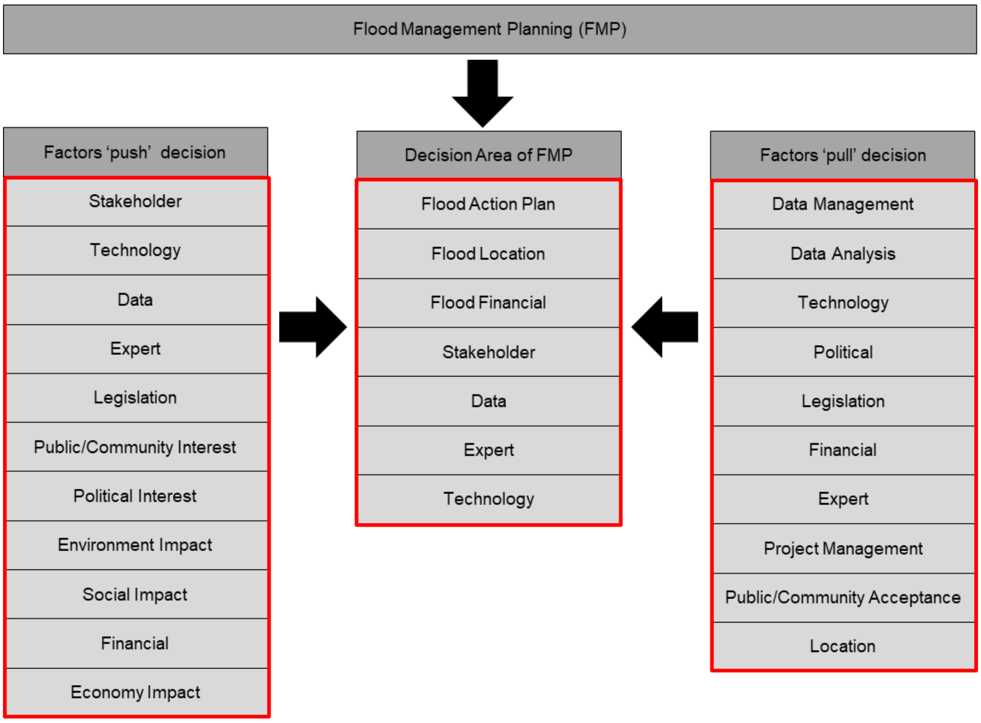


Figure 3-5: Conceptual Framework on Issues of Flood Management Planning

3.6.1 Impact of PESTEL Analysis on Decision for Flood Management Planning

The analysis, which includes expert opinions and a conceptual framework, supports the effectiveness of using the PESTEL analysis framework for identifying criteria in FMP. It shows that the PESTEL framework is a valuable tool for improving decision-making in FMP with the integration of MCDA.

Using the PESTEL framework enables the identification and selection of significant criteria in FMP. It segments the criteria and facilitates the criteria mapping based on the collected data and information. This segmentation also encourages the inclusion of previously overlooked ideas and knowledge. Additionally, the PESTEL framework helps identify domains lacking criteria that necessitate further investigation. It also highlights potential conflicts between criteria across different domains, like policy and governance in the Political and Legal domains, which require in-depth analysis and discussion.

a. Political

Mapping political criteria is vital for effective flood decision-making. Experts classify these criteria as either explicit or implicit. Explicit criteria, such as the number of established flood policies, are easily identified and structured. In contrast, implicit criteria, like political interest impacting flood budgets or location selection, are more subjective and unstructured. To handle implicit criteria, it's important to quantify and score them using an appropriate mechanism.

Various Political criteria are needed for selecting flood measures in different phases of the DMP. For example, during response and recovery after a flood, criteria like public engagement between citizens and politicians play a significant role in resource allocation and recovery efforts. Similarly, in the mitigation phase, addressing conflicts between federal, state, and public interests is crucial for implementing flood mitigation measures and ensuring acceptance.

b. Economic

In the economic domain, the most identified criteria relate to flood management project implementation. These include historical data on economic losses from past floods, the impacts of floods on economic activities, and investment losses. Additionally, it is essential to forecast the financial budget for future flood management projects.

The selection of economic criteria depends on the specific DMP plan chosen, leading to different economic considerations. For example, if the plan involves building a dam for flood mitigation and water catchment, criteria such as the financial budget, the economic activities affected by dam construction, and the development of alternative economic activities must be considered.

c. Social

In FMP, it is important to assess the social impact of floods before, during, and after they occur. Experts have identified various criteria that are crucial in flood decision-making. These criteria include demographics, infrastructure, health and welfare, transportation, communication, education, and awareness.

For instance, in terms of flood disaster preparedness, it is essential to establish accessible evacuation centres. Additionally, non-structural measures like promoting flood awareness and educating the public about the social impacts of floods can better prepare society for such disasters.

In the recovery phase after a flood disaster, specific criteria should be addressed to improve the community's quality of life. This might involve developing new residential areas as structural measures, implementing mental health programmes for flood trauma victims as non-structural measures, and addressing the impact of flooding on income and job opportunities through hybrid measures. Addressing these criteria can enhance the overall recovery and well-being of the affected community.

d. Technological

Technology plays a crucial role in supporting flood measures across all phases of the DMP. Experts agree that giving priority to computer technology and applications is crucial. This encompasses commercial software, spatial analysis tools, integrated systems, automated tools, business intelligence dashboards, and engineering technology, which includes materials, methods, and processes to aid and facilitate FMP.

Technology is applied in various aspects of FMP, such as construction, material selection, data collection, analysis, modelling, simulation, warning systems, and communication. By harnessing technology, flood control measures can be made more efficient, effective, and impactful while also reducing implementation time, costs, and the potential for human error.

Experts have identified specific criteria that must be considered when implementing technology in the DMP. These criteria include operational and maintenance costs, the need for training, the availability of technology experts, technology transfer capabilities, and the feasibility and suitability of the technology. A thorough assessment of these criteria is essential before incorporating technology into the DMP to ensure its successful integration and utilisation.

e. Environmental

Environmental criteria aid in comprehending how the environment affects health, social dynamics, and economic activities, as well as its own biodiversity, ecology, and ecosystems. This helps ensure the ecosystem's sustainability and promotes its improvement and preservation.

By including environmental criteria, a better understanding is achieved, leading to a more informed selection of flood measures within the DMP. For instance, utilising data on sea level rise or the water quality index, non-structural flood measures such as nature-based solutions can be identified as suitable mitigation and preparedness measures to mitigate the impacts of flood disasters.

f. Legal

Experts stress the importance of the Legal domain in FMP, underscoring the need to integrate relevant legislation into the planning process. This includes setting up appropriate institutional frameworks for implementation, management, response, and recovery. It involves making necessary reforms to regulate land development, resolve land acquisition conflicts, limit activities like logging and deforestation, and address political interference. Strengthening and improving flood project implementation is a major focus of the Legal domain.

Despite its significance, the Legal domain is frequently neglected in FMP. Criteria within this domain, such as adherence to government regulations and the extent of legislative enactments and acts, should be given due consideration.

During the analysis of the criteria, several similarities emerged across the PESTEL domains:

a. Data is available in both structured (organised and formatted data such as rainfall databases) and unstructured (free-form data such as emails, pictures, and audio files) formats, requiring different handling and analysis methods.
b. The number of criteria could vary, and additional criteria might emerge during evaluation.
c. Historical and projected data were considered, providing insights into past trends and future developments.
d. Criteria were assessed based on data availability and suitability for different purposes within each domain.

Recognising these similarities allows for a more comprehensive approach to criteria identification and selection across the PESTEL domains in FMP. To facilitate this, a conceptual framework is proposed in Section 3.6.2 to guide the process effectively.

3.6.2 Proposed Conceptual Framework in Criteria Identification and Selection for PESTEL Analysis in Flood Management Planning

Based on these findings, this study proposes a conceptual framework (see Figure 3-6) to simplify the process of identifying and selecting criteria within the macro domain using the PESTEL analysis framework. The conceptual framework comprises four distinct phases: (1) data management, (2) criteria analysis, (3) disaster management planning, and (4) flood measures.

In the Data Management phase, it is crucial to effectively handle the identified criteria, regardless of their format or type. The significance of both structured and unstructured data in supporting decision-making processes has been extensively studied in various contexts. For example, predictive modelling has been explored by Zhang, D. et al. (2020), and business intelligence by Abdullah, M.F. and Ahmad (2015). Methodologies for analysing this data have been discussed by Turet and Costa (2022) and Abdullah, Mohammad Fikry and Ahmad (2013). In the realm of flood risk management, studies by Nundloll et al. (2021) and Towe et al. (2020) have explored the roles of structured and unstructured data, while Wu et al. (2020) have focused on predicting urban floods.

Additionally, studies by Mbogga et al. (2009), Hamann et al. (2013), El-Jabi et al. (2016), Schlef et al. (2018), and Grillakis et al. (2022) have investigated the importance of historical and projected data in environmental, climate change, and flood event studies. Therefore, Phase 1 of the framework emphasised the need to consider data format and type during the data management phase before analysing and selecting the final criteria.

Phase 2 encompassed three key processes: (1) PESTEL criteria mapping, (2) MCDA analysis, and (3) criteria ranking. Initially, criteria were mapped to the relevant PESTEL macro domains, drawing insights from expert reviews and previous research. Subsequently, MCDA analysis was conducted to evaluate criteria based on their specific purpose, which could involve selection, sorting, ranking, or description, depending on the analysis's objectives. This framework integrated MCDA analysis within the PESTEL domains, drawing inspiration from previous studies by Yüksel (2012), Dockalikova and Klozikova (2014), and Yang, Y. et al. (2016).

The selection of the MCDA method can vary based on the specific approach's strengths and weaknesses. The anticipated outcome of Phase 2 is a comprehensive list of affirmative criteria, grouped by PESTEL macro domain and subjected to thorough analysis. This list can potentially be applied in FMP, aligning with the DMP established in Phase 3.

Considering the different phases of the DMP (mitigation, preparedness, response, and recovery), different flood measures can be planned and implemented. These measures may include structural, non-structural, or hybrid approaches that combine both structural and non-structural measures (Phase 4). The components of the proposed conceptual framework are summarised in Table 3-17.

Table 3-17: Explanation on Components for Conceptual Framework in Criteria Identification and Selection for PESTEL Analysis in Flood Management Planning

No	Phase	Explanation
1	Data Management	a. Data Format: i. Structured Data ii. Unstructured Data b. Data Type i. Historical Data ii. Projection Data
2	Criteria Analysis	a. Identify the criteria and map them according to the PESTEL macro domain. b. Conduct MCDA for each macro domain c. Rank each criteria for each PESTEL macro domain
3	Disaster Management Plan	The final criteria could be used to support planning by decision-makers on different DMP phases, which are: a. Mitigation b. Preparedness c. Response; and d. Recovery
4	Flood Measure	A different flood approach could be applied to manage floods based on: a. Structural b. Non-structural c. Hybrid (combination of structural and non-structural)

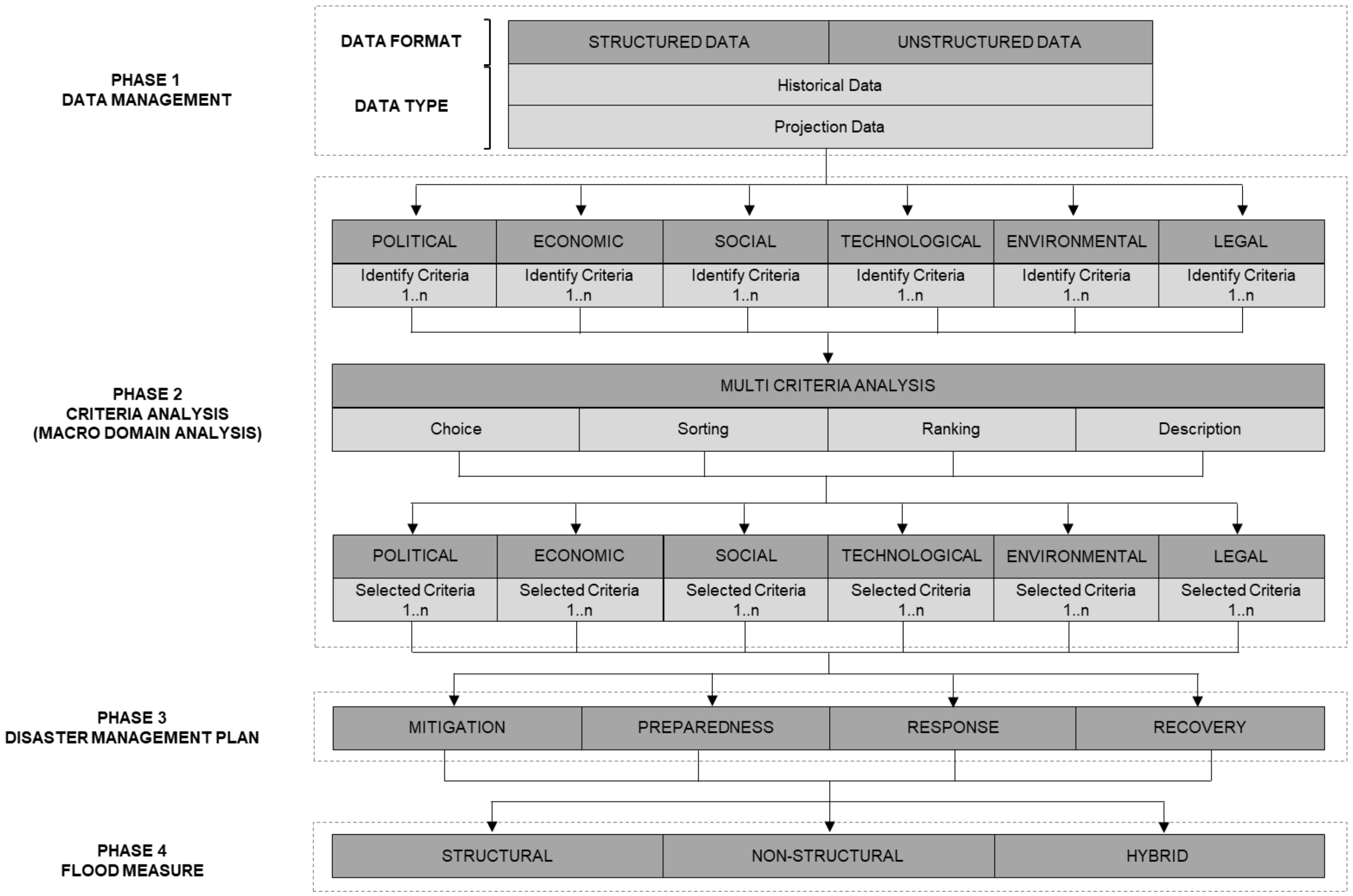


Figure 3-6: Conceptual Framework of Criteria Identification and Selection for MCDA Application in Flood Management Planning

3.7 Conclusion

The study proposes a conceptual framework for criteria identification and selection for FMP decisions. It addresses the limitations observed in previous studies and integrates influential macro domain criteria. The framework is built upon the established PESTEL analysis framework, offering a strong foundation for the identification and selection of criteria. It encourages future studies to consider multiple domains and their respective criteria, blending them into the FMP context. This proposed framework serves as a fundamental tool for criteria identification and selection in FMP, is tested with expert participation, and is discussed in detail in Chapter 4.

Prior studies have recognised the effectiveness of using spatial applications for assessment and analysis, a practice also adopted in Malaysia. Several FMPs in Malaysia, like PRABAN (DID, M., 2019), PublicInfoBanjir (Noor et al., 2012), and the N-HyDAA Malaysia Climate Change Knowledge Portal (Abdullah, Mohammad Fikry et al., 2018) have integrated spatial technology to enhance decision-making processes. Therefore, in this study, the combined spatial-MCDA technique was chosen as the basis for developing a flood decision support system. Details regarding the system development framework are further elaborated in Chapter 5, and the prototype system is discussed in Chapter 6.

3.7.1 Contribution

Findings from SLR indicate that a comprehensive criteria identification and selection process for macro domain analysis in FMP using the MCDA application has not been adequately conducted. Therefore, in this chapter, the PESTEL analysis framework was utilised to enhance the process. The framework enables the researcher to identify and categorise criteria based on the six PESTEL domains, offering a broader range of criteria options. It provides an alternative approach for making trade-offs and serves as a reference during criteria selection for decision-making in FMP.

This study contributes practical research to FMP, specifically focusing on macro domain criteria. It expands the pool of criteria options and re-evaluates existing ones. Using the PESTEL analysis framework, new criteria can be integrated, providing decision-makers with a more comprehensive understanding of their respective domains. The conceptual frameworks presented in this study offer structured guidelines for identifying and selecting a wide range of macro domain criteria. Additionally, the framework addresses limitations associated with criteria identification and selection in FMP by applying the PESTEL analysis framework.

The proposed framework enables the creation of a hierarchical structure for criteria in MCDA applications, utilising the criteria identified in the PESTEL domain. Moreover, it can be adapted to other water-related disasters, such as drought or storm surge. It is designed in a generic manner, making it applicable to adaptation in various disciplines of study. By customising Phase 4 to meet the specific needs of a chosen case study, these disciplines can benefit from this framework. For instance:

a. transportation field, the framework can enhance road safety impacted by disaster events, and
b. in the tourism industry, it can improve hotel safety during disaster events.

3.7.2 Recommendation

The proposed framework in this study serves as the initial step in criteria analysis, with the aim of achieving the objectives outlined in this chapter. It also offers valuable insights for future research directions and recommendations, with a particular focus on improving Stage 2, Criteria Analysis. These efforts involved expert participation to evaluate and assess the identified criteria, resulting in improved outcomes for the combined spatial-MCDA decision support system and providing confirmation of criteria identification and selection.

In line with these recommendations, a comprehensive study was conducted to assess and evaluate the criteria, which involved active participation from experts. The findings and discussions related to this study will be presented in Chapter 4.

3.8 Publication

Based on the findings from this study, an extended study was conducted specifically for a case study of the Malaysia Adaptation Index (MAIN), which is a project under NAHRIM. The extended study assisted NAHRIM in identifying macro domain criteria according to the PESTEL macro domain from previous studies on FMP based on the MCDA application. The framework proposed in this study would be used as a guideline in NAHRIM’s R&D work.

Chapter 4

Criteria Analysis for Flood Management Planning based on Analytical Hierarchical Process (AHP) and Quadrant Matrix Analysis (QMA) – An Expert Review

4.1 Chapter Motivation

The motivation behind this chapter is to emphasise the importance of criteria selection in the FMP decision-making process. Knowing that different flood problems require different criteria, experts' opinions are considered crucial in guiding the criteria’s identification and selection. Integrating knowledge and expertise from various domains further enhances the FMP decision-making process.

The chapter aims to conduct criteria analysis by ranking the importance of 40 PESTEL macro domain criteria using the Analytical Hierarchical Process (AHP) technique. Additionally, the Quadrant Matrix Analysis (QMA) method will also be employed to assess the feasibility and practicality of these criteria, considering their certainty and importance. These analyses will highlight the most important flood criteria to be employed in FMP decision-making.

To validate these criteria, the study involved experts from the study described in Chapter 3. Their expertise will contribute to evaluating and validating the criteria, resulting in a set of consensus-driven and affirmative criteria that are pivotal in facilitating FMP decisions.

Overall, this chapter seeks to advance our understanding of the criteria analysis process and its integration into FMP decision-making. By actively incorporating experts, considering diverse domains, and employing robust analytical techniques, the goal is to enhance the FMP decision-making process and promote effective FMP strategies.

4.2 Introduction

Experts played an important role in assessing and evaluating the 40 PESTEL macro domain criteria to determine their importance and certainty level. These criteria underwent ranking and prioritisation using AHP, enabling the identification of the most important criteria for further analysis. Additionally, QMA was employed to examine the criteria’s importance and certainty, providing a comprehensive understanding of the FMP decision-making process. Drawing on the study of Iacovidou et al. (2017), the criteria for the

QMA method were evaluated in terms of their relative importance and certainty as follows:

a. Criteria Importance: To denote how important it is for these criteria to be included in FMP decision-making with respect to the other identified criteria; and
b. Criteria Certainty: The level of confidence in a set of criteria used in FMP decision is based on two factors: (i) criteria that are inherently certain and (ii) criteria that are sufficient and unambiguous.

The details on the analysis methods (AHP and QMA) are discussed in sub-section 4.4.2. The result of the analysis revealed that there was a discrepancy between the AHP and the QMA results. The top three global criteria ranked were P1, L1, and L4, which were categorised in Quadrant 4 (Q4) for P1 and Quadrant 3 (Q3) for L1 and L4. The certainty values for criteria P1, L1, and L4 were 6.0, 6.4, and 6.9, respectively, which were lower than the average of 6.95. Based on these findings, it was indicated that there was a constraint in achieving ideal criteria that is considered both important and certain. Thus, to address this limitation, a conceptual framework was proposed to introduce the criteria reflection stage in the criteria analysis process, aiming to improve the identification and selection of criteria.

4.3 Aim of the Chapter

The aim of this study is to improve the decision results for FMP. The study focused on the criteria analysis based on its importance and certainty to be used for FMP, according to the expert’s review.

4.3.1 Objectives of the Chapter

To achieve this aim, the objectives of this study are as follows:

a. to rank the criteria locally and globally using the AHP technique,
b. to map the criteria based on their degree of importance and certainty using the QMA method; and
c. to construct a criteria-analysis framework.

4.4 Methodology

This section will discuss the methodology used in data collection and analysis for this study, as shown in Figure 4-1.

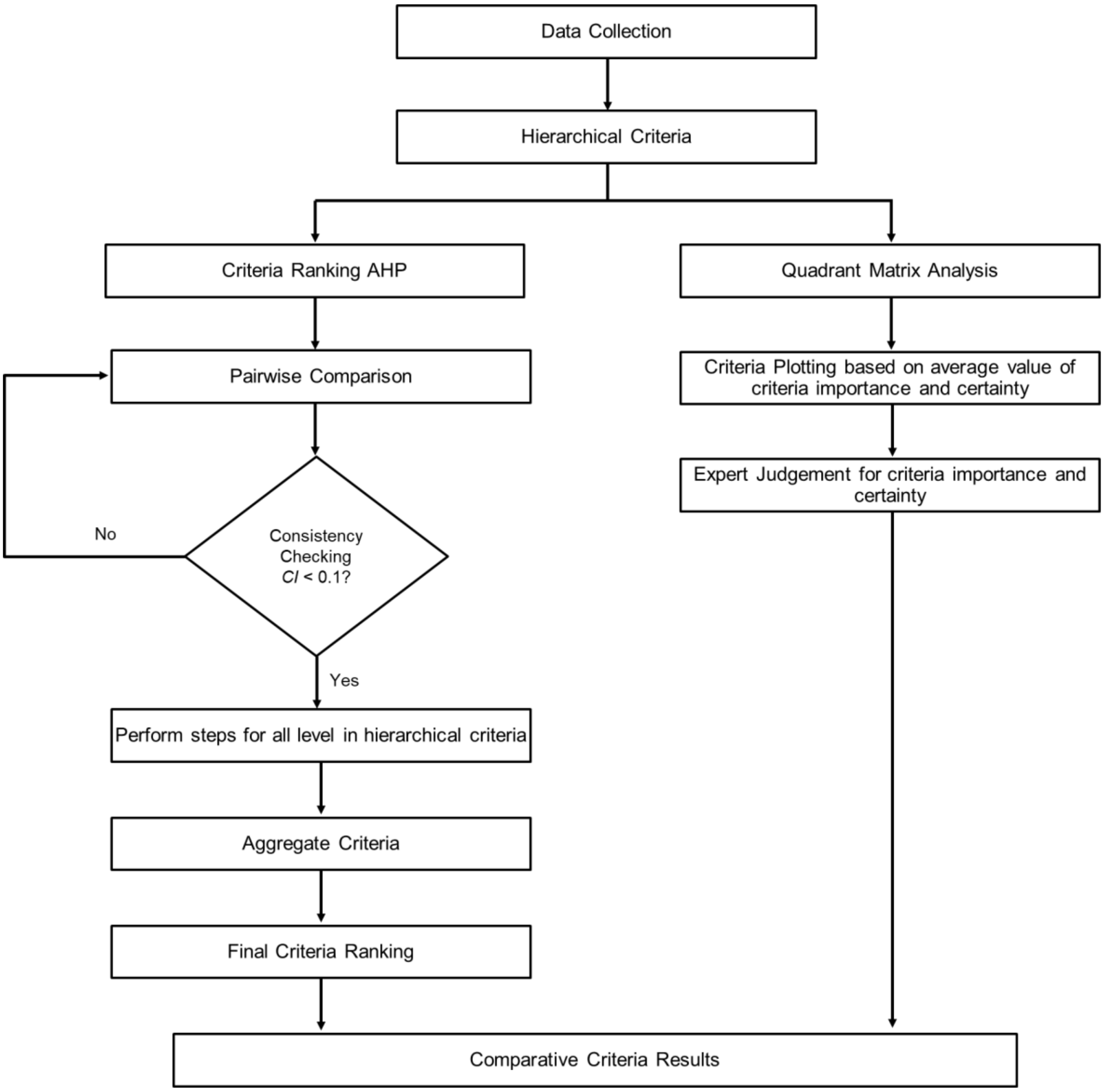


Figure 4-1: Steps Methodology

4.4.1 Data Collection

This study employed the PESTEL criteria identified in Chapter 3. A total of 40 criteria (refer to Table 3-7, Table 3-8, Table 3-9, Table 3-10, Table 3-11, and Table 3-12) were subjected to two types of analysis: (1) criteria ranking using the AHP technique, and (2) assessment of criteria importance and certainty using the QMA method.

For analysis 1, the data was collected from interview session 2, as outlined in Appendix D. Meanwhile, the data for analysis 2 was gathered during interview session 1, as detailed in Appendix C. Both analyses involved the participation of the same group of experts, as listed in Table 3-3, to maintain the study's continuity and ensure consistency in the experts' understanding. The data collection process in this study is summarised in Table 4-1.

Table 4-1: Data Collection Process

Required Data	Type of Analysis	Interview Plan	Survey Form
Criteria Score	Criteria ranking	Appendix D	Appendix E
Criteria Score	Criteria importance and certainty	Appendix C	Appendix B

4.4.1.1 Expert Judgement

In both analyses conducted in this study, the pivotal role of expert judgement is evident, as experts are tasked with providing scores based on their extensive expertise, thoughtful considerations, and comprehensive knowledge within their respective domains. The reliance on expert judgement acknowledges the nuanced and context-specific nature of the analyses, recognising that experts bring a wealth of tacit knowledge and practical insights that contribute to the robustness of the study.

In the AHP component of the study, the process of obtaining expert judgement involves a carefully structured exercise workshop. During this session, experts are required to provide scores based on predefined criteria. The dynamic nature of the AHP process is highlighted by the subsequent negotiation and compromise sessions, emphasising the collaborative effort to achieve a consistent set of scores. The focus on the consistency index underscores the meticulous attention given to refining and aligning expert judgements to ensure the reliability of the overall AHP analysis.

Similarly, in the QMA phase, expert judgement plays a crucial role in the scoring process. Unlike the AHP workshop, QMA relies on one-on-one interview sessions with experts. During these interviews, experts are tasked with assigning scores ranging from 1 to 10 for each identified criterion within the PESTEL domain. This personalised approach recognises the individual perspectives of experts and provides a platform for in-depth discussions, allowing for a nuanced and contextually rich evaluation. Expert judgement in the QMA process contributes to the depth and specificity of the analysis, ensuring a comprehensive understanding of the factors under consideration.

4.4.2 Data Analysis

Two data analysis methods were employed: AHP and QMA. AHP was used to rank the importance of the criteria, while QMA was used to assess and illustrate the degree of criteria importance and certainty based on a priority matrix.

4.4.2.1 Analytical Hierarchical Process (AHP)

AHP, originally proposed by Saaty (Saaty, 1980), is a semi-quantitative technique based on a hierarchy approach consisting of levels of goal, criteria, possible sub-criteria, and alternatives (Saaty and Vargas, 1998). In AHP, the criteria are assumed to be independent of each other, and their impact on alternative selection is also considered independent. In a real-world context, the FMP decision criteria might be interdependent, which will cause challenges for AHP to capture the complex relationship between different criteria. Therefore, it is recommended to carefully consider and select the criteria to be employed. In situations where interdependence between criteria exists and might affect the decision, an additional approach might need to be studied to overcome this situation.

The weight of the criteria is computed using pairwise comparisons in order to prioritise them (Triantaphyllou and Mann, 1995). A quantitative ranking of the criteria is achieved using Saaty's scale (refer to Table 4-2), which ranges from 1 to 9.

Table 4-2: Saaty's Scale (Saaty, 1977)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two elements contribute equally to the objective.
3	Moderate Importance	Experience and judgement slightly favour one element over another.
5	Strong Importance	Experience and judgement strongly favour one element over another.
7	Very Strong Importance	An element is favoured very strongly over another, its dominance is demonstrated in practice.
9	Extremely Strong Importance	The evidence favouring one element over another is one of the highest possible orders or affirmations.
2,4,6,8	Intermediate Values	For a compromise between the above values.

AHP was chosen in this study due to its notable strengths. These strengths encompass its structured approach to the decision-making process and its ability to ensure consistency. Moreover, AHP allows the inclusion of multiple criteria and sub-criteria. Wedley (1990) also highlighted another benefit of this method: its suitability for both quantitative and qualitative criteria. The steps involved in AHP are as follows:

Step 1: Define the decision goal.

a. Create the hierarchical criteria based on the criteria discussed in sub-section 4.4.1 (refer to Table 3-7, Table 3-8, Table 3-9, Table 3-10, Table 3-11, and Table 3-12). Figure 4-2 exhibits the hierarchical criteria employed in this study.

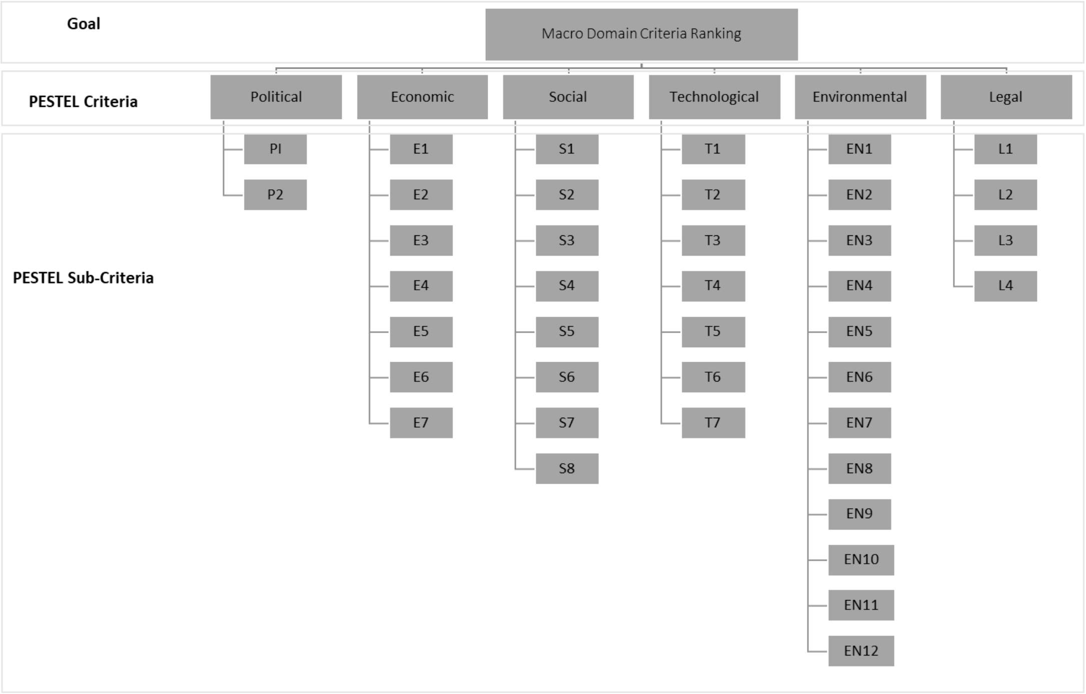


Figure 4-2: Hierarchical Criteria

Step 2: Construct pairwise comparison matrices.

a. Assign weights for each criteria using Saaty's scale. Table 4-3 shows an example of a comparison matrix table. Refer to Appendix E for the complete form of criteria weightage used by the experts.

Table 4-3: Example of Comparison Matrix (A)

	Criteria 1	**Criteria 2**	**Criteria 3**
Criteria 1	1	7	6
Criteria 2	1/7	1	2
Criteria 3	1/6	1/2	1

Step 3: Calculate the weight of the criteria.

a. Normalise matrices where the criteria weight is calculated. Appendix F contains the calculation details.

b. The weight for each criteria was calculated by summing the values in each row and dividing by the total number of criteria, resulting in a total weight of 1 (refer to Table 4-4).

Table 4-4: Example of Normalised Matrix and Weight (W)

	Criteria 1	**Criteria 2**	**Criteria 3**	**Weight (W)**
Criteria 1	0.76	0.82	0.67	0.75
Criteria 2	0.11	0.12	0.22	0.15
Criteria 3	0.13	0.03	0.11	0.10

Step 4: Consistency Check

a. Create matrix AW by multiplying the Comparison Matrix (A) by its Weight (W),
b. Create a vector lamda (λ) by dividing the elements in AW by the corresponding elements in W,
c. Calculate lamda max (λ_{max}) by using the Average method,
d. Calculate the Consistency Index (CI) using the following formula:

$$CI = (\lambda_{max} - n) / (n - 1)$$

where: λ_{max} is the maximum eigenvalue of the pairwise comparison matrix and n is the number of criteria being compared.

e. Calculate the Consistency Ratio (CR); if CR < 0.10, then the matrix is considered consistent. The formula for CR is as follows:

$$CR = CI/RI$$

where:

CI is the Consistency Index and RI is the Random Index. The RI is a constant value determined by the size of the comparison matrix. In this study, Saaty's RI is used, as shown in Table 4-5, which contains the detailed calculation. Table 4-6 shows an example of the calculation for CI and CR.

Table 4-5: Table of Random Index (Saaty, 1980)

n	1	2	3	4	5	6	7	8	9	10	11	12	13
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58	1.56

Table 4-6: Example Calculation for CI and CR

	Criteria 1	**Criteria 2**	**Criteria 3**	**Weight (W)**	**AW**	**lamda**	**CI**	**RI**	**CR**
Criteria 1	0.76	0.82	0.67	0.75	2.39	3.19	0.04	0.58	0.07
Criteria 2	0.11	0.12	0.22	0.15	0.46	3.04			
Criteria 3	0.13	0.06	0.11	0.10	0.30	3.02			
				lamda max (λ_{max})		3.08			

Step 5: Calculate the Global Criteria Weight

a. The formula used to calculate the weight of an option is as follows:

$$Global\ Criteria\ Weight = Criteria\ Weight * W\_1$$

Where;

- Criteria Weight = local criteria weight
- W = criteria weight

4.4.2.2 Quadrant Matrix Analysis (QMA)

QMA was used to analyse the importance and certainty of criteria based on experts' assessments. QMA, commonly used in strategic planning, provides a visual representation of information for a wide range of decisions using user scores. The following steps were taken, based on a study by Lynch et al. (1996), with some modifications made to fit this study:

a. Define the target of interest - decision-makers who are involved in FMP.
b. Specify the interest - flood decision criteria.
c. Determine the nature of the statement - to identify significant and relevant criteria to support decisions in FMP.
d. Establish a research protocol - experts participating as a focus group to score the criteria.
e. Narrowing the criteria list - criteria list based on findings in Chapter 3

f. Pre-test the criteria - conduct a mock-up test with three candidates who are not involved in the rating criteria to ensure the wording used is understandable.

There are many versions of QMA, and it is versatile in various situations. As shown in Figure 4-3, QMA typically uses two dimensions. The first dimension illustrates the criteria certainty, while the second dimension represents their importance. In Figure 4-3, the horizontal axis reflects experts' preferences for criteria importance, and the vertical axis represents the certainty of criteria. Consequently, the quadrant representation would consist of Quadrant 1 (Q1), Quadrant 2 (Q2), Quadrant 3 (Q3), and Quadrant 4 (Q4).

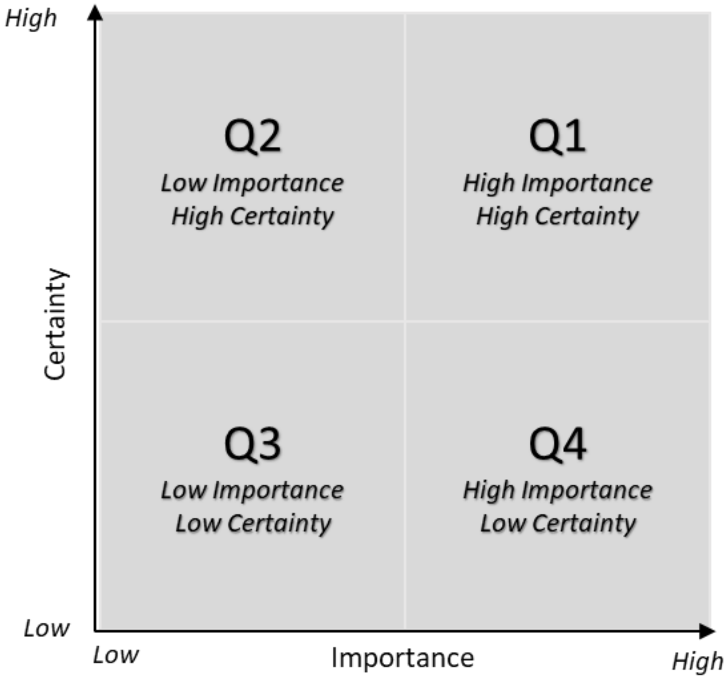


Figure 4-3: Quadrant Matrix Dimension

The classification of criteria into importance-certainty dimensions is entirely subjective. The final 40 criteria will be plotted into one of the four quadrants based on experts' assessments along these two dimensions. To gather the necessary data, experts were requested to score the importance and certainty criteria (based on the revised definition in the study from Iacovidou et al. (2017), as explained in sub-section 4.2 Introduction) using the provided rating scales.

In this study, experts were asked to rate the importance and certainty of the criteria using a series of ten-point scales (refer to Table 4-7). The average importance ratings were used to determine the criteria's horizontal position, while the average certainty ratings were used for their vertical position. These averages serve as coordinates to pinpoint each criteria’s average location within the four quadrants.

Table 4-7: Ten-Point Scale for QMA Score

Score	Definition
1	Not Important/Certain Criteria
2	Slightly Important/Certain Criteria
4	Important/Certain Criteria
6	Strongly Important/Certain Criteria
8	Very Strongly Important/Certain Criteria
10	Extremely Important/Certain Criteria
3,5,7 and 9	For compromise between the above scores

The plotting of criteria on the quadrant priority matrix is based on the average values of their importance and certainty. The following steps were followed to plot the criteria:

a. Calculate the Average Importance and Average Certainty for each criteria;
b. For the x-axis, calculate the Minimum and Maximum of Average Importance;
c. For the y-axis, calculate the Minimum and Maximum of Average Certainty;
d. To determine the vertical axis crossings for the x-axis, calculate the Average; and
e. To determine the horizontal axis crossings for the y-axis, calculate the Average.

Different inferences exist for criteria falling into the four quadrants based on the priority matrix, as shown in Table 4-8. Criteria in Q1 are both highly important and highly certain, making them the most critical. These criteria are considered priority criteria and designated as "Must-Have” and must be included in the decision-making process without question.

Criteria located in Q4 are also important to experts, but their inclusion is not guaranteed. They are considered "Should-Have" criteria, offering support to the decision-making process without being mandatory.

In contrast, criteria in Q2 might have low importance, according to experts, but their high certainty gives them an edge in the decision-making process. They are considered "Could-Have" criteria.

Lastly, criteria in the third quadrant (Q3) hold low importance and certainty in the decision-making process, making them desirable but not necessary. They fall under the “Nice-to-Have" category. Given their lack of importance and certainty, they can be disregarded.

Table 4-8: Quadrant Matrix Priority

Quadrant	Priority Matrix	Expert View
Q1	Must-Have	High Importance High Certainty
Q2	Could-Have	Low Importance High Certainty
Q3	Nice-to-Have	Low Importance Low Certainty
Q4	Should-Have	High Importance Low Certainty

The positioning of criteria within the four quadrants is important for assessing their importance and priority in the decision-making process. This helps streamline the identification and selection of criteria. The interpretation and impact of QMA results hinge on the specific criteria chosen and their assigned scores. Different criteria selections and scores can result in varied interpretations and outcomes. These variations are largely shaped by the preferences and input provided by the experts.

4.5 Data Analysis, Results and Discussion

4.5.1 Criteria Ranking Analysis based on AHP.

The scores provided by the experts were utilised to formulate aggregated matrices and perform calculations using AHP to obtain the ranking. The hierarchical criteria used in this study consist of three levels, as shown in Figure 4-2. The analysis and results for this sub-section are based on the aggregated scores of experts. For detailed individual results, refer to Appendix G. Table 4-9 shows the normalised pairwise comparison matrix, indicating the weights assigned by the experts to the domains.

Table 4-9: Normalised Pairwise Comparison Matrix of PESTEL Domain

Domain	P	EC	S	T	EN	L	Weight	Rank
P	0.2359	0.3290	0.2363	0.2558	0.1956	0.1944	0.2412	1
EC	0.1119	0.1561	0.2432	0.1884	0.1794	0.1493	0.1714	3
S	0.1435	0.0923	0.1438	0.1668	0.1901	0.1636	0.1500	4
T	0.1045	0.0939	0.0976	0.1132	0.1306	0.1408	0.1134	5
EN	0.1395	0.1006	0.0875	0.1003	0.1156	0.1337	0.1129	6
L	0.2647	0.2281	0.1917	0.1755	0.1886	0.2182	0.2111	2
Consistency Index (CI) = 0.0202								
Consistency Ratio (CR) = 0.0163								

From the analytical results presented in Table 4-9, it is evident that the Political domain holds the highest weight of 0.2412, making it the most important domain. The Legal domain (L) follows closely in second with a weight of 0.2111. On the other hand, the Environmental domain (EN) ranks as the least important with a weight of 0.1129. These findings indicate the need for a focused exploration of potential political criteria that are significant for FMP.

Even though floods are frequently associated with environmental concerns, it is intriguing that the EN domain ranks the lowest in this assessment. It is important to note that even though environmental facts and figures may be presented, political influence and interest often intervene, leading to potential conflicts in decisions, as discussed by Porter and Demeritt (2012) and Tariq and van de Giesen (2012).

Moving to the third level of making decisions, the ranking of different sub-criteria within the domain has been conducted. Table 4-10 provides an evaluation of the two sub-criteria, P1 and P2, within the Political domain. The results indicate that P1 holds greater importance compared to P2, with a score of 0.7950 for P1 and 0.2050 for P2.

The top ranking of P1 can be attributed to political intervention, which has the potential to influence how resources are distributed fairly. Political decisions, both at the federal and state levels, might prioritise certain areas or individuals, regardless of their actual needs or the severity of the flood situation. Additionally, political factors, such as voters’ concerns, relationships with certain groups or individuals, and bureaucratic obstacles, also affect how resources are allocated. These factors create obstacles to the fair and efficient distribution of resources.

As a result, some areas or groups may receive an excess of resources, while others lack sufficient means to cope with the flood disaster. Moreover, political intervention can foster corruption and favouritism, worsening the issue of unequal resource distribution.

Table 4-10: Normalised Pairwise Comparison Matrix of Political Domain

Criteria	P1	P2	Weight	Rank
P1	0.79	0.79	0.7950	1
P2	0.21	0.21	0.2050	2
Consistency Index (CI) = 0.0000				
Consistency Ratio (CR) = 0.0000				

As shown in Table 4-11, the Economic domain (EC) highlights the top three criteria as EC7, EC1, and EC5, while EC4 is considered the least significant criteria within this domain. Obviously, the criteria with the most profound impact on FMP decisions is EC7, which addresses the economic loss caused by floods. This emphasis is well-founded due to the devastating economic consequences floods can have on individuals, communities, and entire regions.

The economic effects of floods encompass both direct and indirect losses. Direct losses entail damage to infrastructure, buildings, crops, and other assets. Indirect losses involve disruption in economic activity, income loss, and increased social and economic vulnerability. Incorporating EC7 into FMP decisions might enable the estimation of future losses and the identification of areas requiring mitigation, prevention, and recovery planning.

By leveraging this criteria, decision-makers can make well-informed choices aimed at minimising the economic losses associated with them. As a result, long-term costs related to flood damage and recovery can be lowered while boosting the resilience of economic activities to future floods.

Table 4-11: Normalised Pairwise Comparison Matrix of Economic Domain

Criteria	EC1	EC2	EC3	EC4	EC5	EC6	EC7	Weight	Rank
EC1	0.1718	0.2782	0.2310	0.1946	0.1268	0.1641	0.1344	0.1858	2
EC2	0.0752	0.1217	0.1730	0.1376	0.1474	0.1194	0.1359	0.1300	4
EC3	0.0839	0.0794	0.1128	0.1536	0.1163	0.1470	0.1305	0.1176	6
EC4	0.1015	0.1018	0.0845	0.1150	0.1492	0.1265	0.1268	0.1150	7
EC5	0.1810	0.1104	0.1296	0.1031	0.1336	0.1355	0.1321	0.1322	3
EC6	0.1379	0.1343	0.1011	0.1198	0.1298	0.1317	0.1457	0.1286	5
EC7	0.2487	0.1742	0.1681	0.1764	0.1968	0.1758	0.1945	0.1907	1
Consistency Index (CI) = 0.0222									
Consistency Ratio (CR) = 0.0168									

Table 4-12 shows the result in the Social domain, where S8 (education and awareness) holds the highest importance, followed by S1 (quality of life and human needs) and S4 (religious, cultural, and historical heritage). Conversely, experts consider S5 (personal loss) the least important criteria.

In FMP decisions, it is crucial to prioritise education and awareness alongside the implementation of measures by authorities to lessen flood impacts. These measures aim to sustain and improve the quality of life while meeting human needs. Thus, equipping the public with knowledge on how to react and proactively address flood disasters, both before, during, and after floods, becomes paramount.

When forecasting flood events, relevant agencies share information and issue public alerts and warnings. However, the response remains uncertain. Therefore, promoting public awareness and education becomes imperative to ensure that individuals recognise and respond proactively to the flood impacts. Additionally, the public should be well informed about the necessary actions to take and those to avoid exacerbating flood events.

Table 4-12: Normalised Pairwise Comparison Matrix of Social Domain

Criteria	S1	S2	S3	S4	S5	S6	S7	S8	Weight	Rank
S1	0.1361	0.1875	0.1716	0.1249	0.1256	0.0929	0.1258	0.1475	0.1390	2
S2	0.0862	0.1188	0.1394	0.1166	0.1547	0.1190	0.1258	0.1170	0.1222	5
S3	0.0951	0.1022	0.1199	0.1301	0.1402	0.1190	0.1387	0.1254	0.1213	4
S4	0.1458	0.1365	0.1234	0.1339	0.1503	0.1501	0.1567	0.1019	0.1373	3
S5	0.0990	0.0702	0.0782	0.0814	0.0914	0.1254	0.1010	0.0968	0.0929	8
S6	0.1695	0.1154	0.1165	0.1032	0.0843	0.1157	0.1082	0.1170	0.1162	6
S7	0.1138	0.0993	0.0909	0.0898	0.0952	0.1124	0.1051	0.1269	0.1042	7
S8	0.1545	0.1700	0.1601	0.2201	0.1582	0.1655	0.1387	0.1675	0.1668	1
Consistency Index (CI) = 0.0136										
Consistency Ratio (CR) = 0.0096										

Table 4-13: Normalised Pairwise Comparison Matrix of Technological Domain

Criteria	T1	T2	T3	T4	T5	T6	T7	Weight	Rank
T1	0.1361	0.1381	0.1994	0.1972	0.1565	0.1980	0.1430	0.1669	1
T2	0.1171	0.1188	0.1582	0.1840	0.1460	0.1384	0.1310	0.1419	2
T3	0.0818	0.0900	0.1199	0.1716	0.1611	0.1483	0.1281	0.1287	3
T4	0.0924	0.0865	0.0935	0.1339	0.1256	0.1501	0.1310	0.1161	4
T5	0.0795	0.0744	0.0681	0.0974	0.0914	0.1329	0.1195	0.0947	7
T6	0.0795	0.0993	0.0935	0.1032	0.0796	0.1157	0.1140	0.0978	6
T7	0.1001	0.0954	0.0984	0.1075	0.0804	0.1067	0.1051	0.0991	5
Consistency Index (CI) = 0.0096									
Consistency Ratio (CR) = 0.0073									

According to the analysis results in Table 4-13, T1 (flood early warning system) holds the highest weight at 0.1669, making it the most critical criteria. Following closely is T2 (data collection and analysis), with a weight of 0.1419, as the second most important. The third most important criteria is T3 (flood systems and modelling), with a weight of 0.1287. These top three criteria highlight the important role of technology in supporting FMP decisions.

A flood early warning system emerges as the most important technological criteria, facilitating not only authorities in analysing and forecasting future flood events but also benefiting the public. As a non-structured flood measure, this technology should be recognised as a prevention mechanism aimed at reducing flood losses and impacts.

The flood early warning system offers timely and accurate information about impending floods. This empowers authorities to take the necessary measures to safeguard the publics and their belongings. Authorities can issue timely warnings and evacuate people from vulnerable areas, saving lives and minimising loss. Furthermore, it enhances the preparedness and response of both authorities and the public, leading to more effective FMP decisions.

Moreover, the technological revolution has influenced data collection and analysis methods. In the context of disaster management planning, studies from Zabihi et al. (2023), Towe et al. (2020), and Martínez–Álvarez and Morales–Esteban (2019) have exhibited that the integration of advanced technology like big data, spatial technology, and artificial intelligence enhances the efficiency and reliability of data collection and comprehensive analysis, further strengthening the decision-making process.

In Table 4-14, the Environmental domain (EN) consists of 12 ranked criteria. The most important criteria based on the results is EN12 (biodiversity), with a weight of 0.148. Following closely are EN9 (water structure for flood protection) and EN2 (land use and planning), with weights of 0.0915 and 0.0906, respectively. The least important criteria is EN5 (protection of wildlife habits), ranking last with a weight of 0.0661.

Criteria biodiversity, being ranked as the highest criteria, holds great significance in preserving the health and resilience of the ecosystem. Its importance in preserving ecological balance and functioning likely contributes to its elevated ranking compared to other criteria. The second ranking criteria, EN9 (water structure for protection), owes its position to its effectiveness in preventing flooding when utilised as a structural measure. Water structures are commonly employed to address flood-related challenges, as demonstrated by past flood events. While water structure measures remain essential in flood prevention, decision-makers should also consider incorporating future-oriented measures like nature-based prevention methods into their planning.

Table 4-14: Normalised Pairwise Comparison Matrix for Environmental Domain

Criteria	**EN1**	**EN2**	**EN3**	**EN4**	**EN5**	**EN6**	**EN7**	**EN8**	**EN9**	**EN10**	**EN11**	**EN12**	**Weight**	**Rank**
EN1	0.0693	0.1094	0.0875	0.0575	0.0756	0.0655	0.0507	0.0644	0.0666	0.0594	0.0594	0.0741	0.0699	10
EN2	0.0563	0.0888	0.1397	0.0907	0.1039	0.1089	0.0929	0.0825	0.0894	0.0762	0.0762	0.0813	0.0906	3
EN3	0.0628	0.0504	0.0793	0.0956	0.0969	0.0783	0.1144	0.0844	0.0931	0.0794	0.0794	0.0749	0.0824	6
EN4	0.1020	0.0829	0.0702	0.0846	0.0969	0.0815	0.0892	0.0658	0.0765	0.0989	0.0989	0.0798	0.0856	4
EN5	0.0603	0.0563	0.0538	0.0575	0.0658	0.0593	0.0800	0.0690	0.0820	0.0663	0.0663	0.0763	0.0661	12
EN6	0.0743	0.0572	0.0711	0.0728	0.0778	0.0701	0.0746	0.0600	0.0735	0.0691	0.0691	0.0766	0.0705	8
EN7	0.0992	0.0693	0.0502	0.0687	0.0597	0.0682	0.0725	0.0844	0.0747	0.0753	0.0753	0.0813	0.0732	7
EN8	0.0722	0.0621	0.0655	0.0521	0.0726	0.0774	0.0696	0.0690	0.0705	0.0771	0.0771	0.0766	0.0701	9
EN9	0.0974	0.0973	0.0850	0.1163	0.0863	0.1056	0.0777	0.0904	0.0820	0.0912	0.0912	0.0778	0.0915	2
EN10	0.0734	0.0701	0.0601	0.0780	0.0566	0.0674	0.0684	0.0778	0.0705	0.0637	0.0637	0.0795	0.0691	11
EN11	0.0952	0.0952	0.0816	0.0699	0.0810	0.0829	0.0786	0.0810	0.0904	0.0817	0.0817	0.0745	0.0828	5
EN12	0.1377	0.1610	0.1559	0.1563	0.1270	0.1349	0.1314	0.1714	0.1308	0.1617	0.1617	0.1473	0.1481	1
Consistency Index (CI) = 0.0115														
Consistency Ratio (CR) = 0.0077														

Table 4-15: Normalised Pairwise Comparison Matrix for Legal Domain

Criteria	L1	L2	L3	L4	Weight	Rank
L1	0.3389	0.4483	0.3651	0.2472	0.3499	1
L2	0.1483	0.3389	0.2409	0.2488	0.2442	4
L3	0.2003	0.3036	0.2158	0.2759	0.2489	3
L4	0.3125	0.3105	0.1783	0.2280	0.2573	2
Consistency Index (CI) = 0.0329						
Consistency Ratio (CR) = 0.0365						

In Table 4-15, the Legal domain consists of four criteria ranked by importance. The most important criteria, based on the results, is L1, with a weight of 0.3499, followed by L4 (0.2573), L3 (0.2489), and L2 (0.2442). This ranking indicates that L1 is the most critical criteria, while L2 is considered the least important. The results highlight that L1 and L4 carry more importance compared to L2 and L3 in the context of FMP.

Experts recognised the importance of legal requirements for land ownership for flood protection (L1) due to its potential impact on flood mitigation and prevention projects. For example, if a significant portion of flood-prone land is privately owned, acquiring the necessary land for flood protection infrastructure may be challenging for authorities. Legal disputes over federal land or property rights can further hinder flood management efforts. Therefore, addressing land ownership from a legal standpoint is more complex compared to other criteria (L2, L3, and L4) as it involves multiple entities and extends beyond the direct control of authorities.

A detailed analysis was undertaken to calculate the overall weight of each criteria by multiplying its local weight with its respective global domain weight. Based on their rankings, the criteria were categorised into four colour-coded groups as follows:

a. Very Highly Ranked Criteria (Rank 1-10) - Red
b. Highly Ranked Criteria (Rank 11-20) - Orange
c. Medium Ranked Criteria (Rank 21-30) - Yellow
d. Low Ranked Criteria (Rank 31-40) - Green

In Table 4-16, the overall weights of each criteria were calculated by multiplying their local weight with their global domain weight. This calculation provides a comprehensive assessment of the relative importance of criteria and sub-criteria across the entire PESTEL domain. The application of global ranking in AHP analysis involves a holistic assessment of criteria and sub-criteria, taking into account both their local importance within specific domains and their global relevance to the overall decision-making context. This approach aids decision-makers in identifying and prioritising the key elements that significantly contribute to the success of FMP.

Sub-criteria P1 obtained the highest global weight of 0.1917, followed closely by L1 with a weight of 0.0739 and L4 with a weight of 0.0543. These results highlight the significance of sub-criteria P1, L1, and L4 as the top three most important sub-criteria in the FMP decisions. This information is crucial for decision-makers as it provides a clear ranking of sub-criteria in terms of their overall impact on the decision outcome. The global ranking allows decision-makers to prioritise their focus and resources on the most influential sub-criteria, ensuring that the decisions align with the overarching goals of FMP.

It is noteworthy that all sub-criteria within the Legal domain were unanimously considered very important, as all four of them ranked within the top ten “Very Highly Ranked Criteria”. More than 50% of the “Very Highly Ranked Criteria” came from the Political and Legal domains, while the “Low Ranked Criteria” were predominantly from the Environmental domain. This emphasises the substantial influence of the Political and Legal domains on FMP decisions compared to other criteria.

In FMP decisions, the importance of Political and Legal criteria can be viewed from various perspectives:

a. Political and Legal factors can play a role in engaging stakeholders such as local authorities, government agencies, and communities in the flood plan decision-making process.
b. Compliance with federal and state regulations is crucial to FMP implementation. Adhering to these regulations would prevent legal implications and facilitate the implementation of flood plans. Additionally, considering Political and Legal criteria ensures that FMP decisions align with relevant policies, regulations, and laws.
c. Legal considerations are essential when assessing liability and managing risks associated with flood management decisions. Failure to comply with the regulations and laws would impact FMP decisions, which would lead to overlapping roles, inaction, or legal accountability for damages.

Table 4-16: Aggregate Local & Global Weight and Ranking

Domain	Domain Weight	Domain Criteria	Local Weight	Ranking	Global Weight	Ranking
Political	0.2412	P1	0.7950	1	0.1917	1
		P2	0.2050	2	0.0494	6
Economic	0.1714	EC1	0.1858	2	0.0318	8
		EC2	0.1300	4	0.0223	11
		EC3	0.1176	6	0.0202	15
		EC4	0.1150	7	0.0197	16
		EC5	0.1322	3	0.0227	10
		EC6	0.1286	5	0.0220	12
		EC7	0.1907	1	0.0327	7
Social	0.1500	S1	0.1390	2	0.0208	13
		S2	0.1222	5	0.0183	19
		S3	0.1254	4	0.0188	18
		S4	0.1373	3	0.0206	14
		S5	0.0929	8	0.0139	25
		S6	0.1162	6	0.0174	20
		S7	0.1042	7	0.0156	23
		S8	0.1668	1	0.0250	9
Technological	0.1134	T1	0.1669	1	0.0189	17
		T2	0.1419	2	0.0161	22
		T3	0.1287	3	0.0146	24
		T4	0.1161	4	0.0132	26
		T5	0.0947	7	0.0107	29
		T6	0.0978	6	0.0111	28
		T7	0.0991	5	0.0112	27

Criteria	Domain Weight	Domain Criteria	Local Weight	Ranking	Global Weight	Ranking
Environmental	0.1129	EN1	0.0699	10	0.0079	38
		EN2	0.0906	3	0.0102	31
		EN3	0.0824	6	0.0093	34
		EN4	0.0856	4	0.0097	32
		EN5	0.0661	12	0.0075	40
		EN6	0.0705	8	0.0080	36
		EN7	0.0732	7	0.0083	35
		EN8	0.0701	9	0.0079	37
		EN9	0.0915	2	0.0103	30
		EN10	0.0691	11	0.0078	39
		EN11	0.0828	5	0.0093	33
		EN12	0.1481	1	0.0167	21
Legal	0.2111	L1	0.3499	1	0.0739	2
		L2	0.2442	4	0.0516	5
		L3	0.2489	3	0.0526	4
		L4	0.2573	2	0.0543	3

🟥	Very Highly Ranked Criteria (Rank 1-10)
🟧	Highly Ranked Criteria (Rank 11-20)
🟨	Medium Ranked Criteria (Rank 21-30)
🟩	Low Ranked Criteria (Rank 31-40)

The Economic and Social criteria received lower global weights and rankings, suggesting their lesser significance in FMP decisions. Similarly, Technological and Environmental criteria also received lower global weights and rankings, suggesting their relatively lower importance compared to the Political and Legal criteria. Surprisingly, all sub-criteria under the Environmental domain were ranked the least important, placing them in the bottom ten of all sub-criteria lists. This finding implies that other criteria should be considered alongside environmental criteria in the decision-making process.

By incorporating additional criteria, a more comprehensive understanding can be achieved based on cohesive criteria that hold significance in FMP. Despite flood disaster events being commonly associated with environmental issues, experts agreed that other criteria would overrule and leverage the decision process, potentially altering the course of the decisions.

From another perspective, based on the local ranking of the sub-criteria, the results demonstrate the criteria that should be prioritised within their respective domains for FMP decisions. The aim is to provide decision-makers with a clear understanding of the significance of each sub-criterion in the decision-making process for FMP. The local ranking allows decision-makers to identify which sub-criteria should be prioritised within their specific domains. This information is valuable for making informed decisions related to FMP. For instance, if certain sub-criteria are unavailable or challenging to obtain, decision-makers can refer to the local ranking to determine the next important sub-criteria. This flexibility in selecting alternatives or substitutes based on their importance within the local ranking provides decision-makers with a practical and adaptable approach.

The application of local ranking not only assists in prioritising criteria but also facilitates the decision-making process by offering a layout of options. Decision-makers can use this layout to assess trade-offs and replacements, making the decision-making process more transparent and informed. By incorporating local ranking into the AHP analysis, decision-makers gain a nuanced understanding of the hierarchy of criteria, enabling them to navigate uncertainties and make strategic choices in FMP.

4.5.2 Criteria Importance-Certainty Analysis based on Quadrant Matrix Analysis (QMA)

Based on the scores obtained from the experts' input, the average score for both criteria’s importance and certainty is calculated. The quadrant matrix of the criteria’s importance-certainty is produced using the QMA method based on the calculated averages. A four-quadrant matrix is plotted on the X-Y coordinate plane, considering the two factors of importance and certainty, and can serve as a main guide for improvement strategies (Anderson and Zwelling, 1996; Olfat and Barati, 2013).

Table 4-17 shows the average score of the criteria for importance and certainty. The calculation of the axis cross on Table 4-18 is based on the average of the maximum and minimum values of the criteria's importance and certainty.

Table 4-17: Average Importance and Certainty of Criteria

Criteria	Average Importance	Average Certainty
EC1	9.1	7.5
EC2	9	7.8
EC3	8.9	6.8
EC4	7.9	5.3
EC5	8.8	7
EC6	7.4	5.3
EC7	8.5	7.5
EN1	8.5	7
EN10	8.5	7.3
EN11	9.2	7.8
EN12	8.6	6.6
EN2	8.9	7.9
EN3	9.5	8.5
EN4	9.1	8.2
EN5	8.4	6.5
L2	9.7	8.4
L3	8.5	7.2
L4	8.3	6.9
P1	8.9	6
P2	9.6	6.8
S1	9.4	8.1
S2	9.1	8.6
S3	9	7.4
S4	8.2	6.4
S5	8.9	7.4
S6	8.6	8.4
S7	8.9	7.9
S8	8.4	7.5
T1	9.4	8.3
T2	9.4	8.3

Criteria	Average Importance	Average Certainty	Criteria	Average Importance	Average Certainty
EN6	8.8	7.1	T3	9.4	8.1
EN7	9.4	7.9	T4	8.6	8
EN8	9.4	8	T5	9.1	8.2
EN9	9	8.2	T6	8.9	7.9
L1	7.5	6.4	T7	9.2	8

Table 4-18: Vertical and Horizontal Axis-Cross of Criteria Importance and Certainty

Min Importance	Max Importance	Vertical Axis-Cross	Min Certainty	Max Certainty	Horizontal Axis-Cross
7.4	9.7	8.55	5.3	8.6	6.95

The mapping process grouped criteria into quadrants based on their average scores for importance and certainty. This process involves defining horizontal and vertical axes that connect importance and certainty. The results of this mapping showed that 25 criteria were in Q1, five criteria in Q2, six criteria in Q3, and four criteria in Q4. Figure 4-4 depicts the distribution of criteria across each quadrant.

In Q1, there are 25 criteria, indicating they are both highly important and highly certain, making them “Must Have” criteria for FMP decisions. Among these criteria, Environmental criteria dominated Q1 with eight criteria, followed by Social and Technological criteria with six criteria each. On the other hand, Q3 had six criteria representing low importance and low certainty, making them “Nice to Have” criteria. The criteria in Q3 include L1, L4, EC6, S4, EC4, and EN5.

Comparing the results of L1 and L4 between the two approaches, despite their high ranking in AHP, the QMA findings did not yield the same results. This suggests that negotiation and compromise among experts may have influenced the results in AHP, which were not considered in the QMA approach.

The QMA results enable decision-makers to focus on the criteria in Q1, which are both highly important and highly certain, and prioritise them for further consideration. Additionally, criteria in Q4 can also be considered, although they may require additional resources or innovation to be feasible. Criteria in Q2, while feasible, may be of lower importance and thus lower priority. It is important to pay attention to criteria that are deemed important but have low certainty, aiming to ensure that they fall in Q1, representing the ideal quadrant and the best-case scenario.

By analysing the criteria using a four-quadrant priority matrix, the decision-makers can interpret the current situation of each criteria based on its certainty and importance. The quadrants emphasise the criteria's importance and certainty, providing valuable information to enhance the quality of FMP decisions.

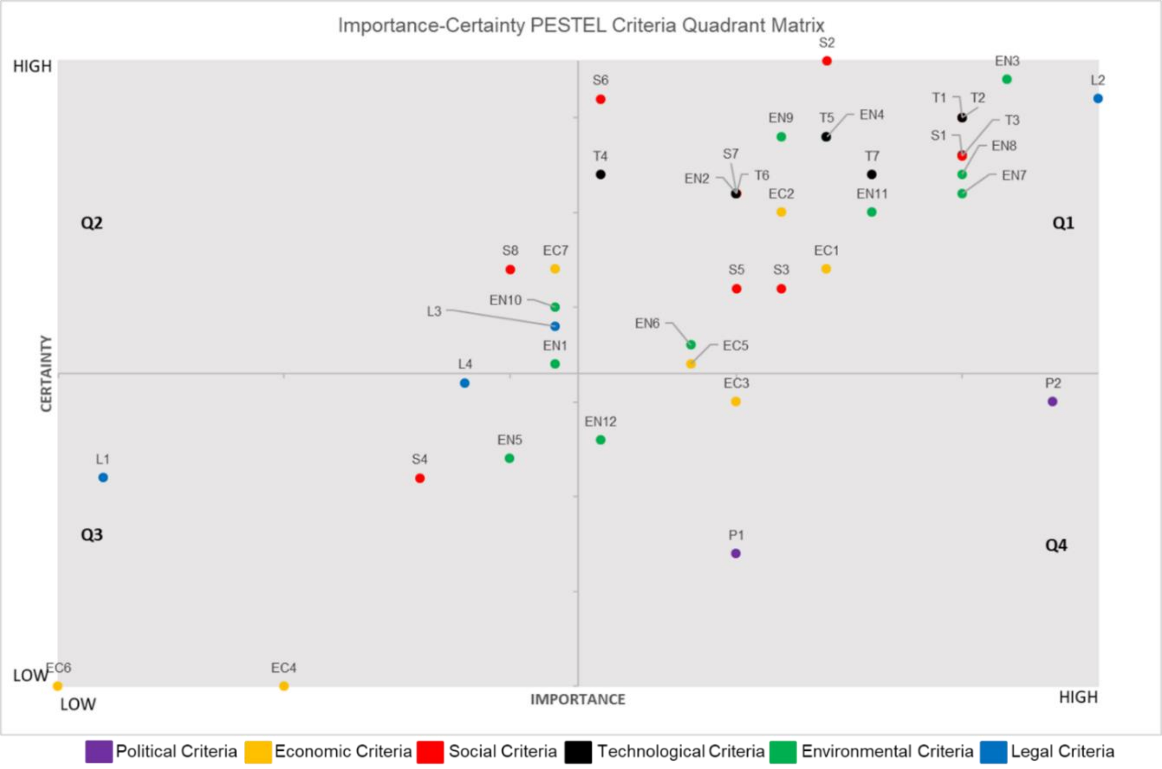


Figure 4-4: Quadrant Matrix Analysis for Criteria Importance and Certainty

The QMA analysis highlighted that criteria in Q1 demand more attention to ensure robust and collaborative FMP decisions. These criteria should be readily accessible and readily available. Interestingly, this contradicts the result of the criteria ranking based on AHP, as none of the top three ranked criteria fell into Q1. Specifically, P1, which held the first position, and P2, ranking sixth, landed in Q4 due to their low certainty despite their high importance. This discrepancy could be attributed to the ambiguity and insufficiency of these criteria. Additionally, L1 and L4, ranked second and third, found their place in Q3, indicating below-average importance and certainty. Further analysis is needed to understand the underlying reasons for this placement.

Table 4-19: Comparative Results between Criteria Ranking AHP and Quadrant Matrix Analysis

Criteria	AHP (Local)	AHP Global)	QMA	Criteria	AHP (Local)	AHP (Global)	QMA	Criteria	AHP (Local)	AHP (Global)	QMA	Criteria	AHP (Local)	AHP (Global)	QMA
P1	1	1	Q4	EC2	4	11	Q1	EN12	1	21	Q1	EN2	3	31	Q2
L1	1	2	Q3	EC6	5	12	Q3	T2	2	22	Q1	EN4	4	32	Q4
L4	2	3	Q3	S1	2	13	Q1	S7	7	23	Q1	EN11	5	33	Q1
L3	3	4	Q1	S4	3	14	Q3	T3	3	24	Q1	EN3	6	34	Q1
L2	4	5	Q2	EC3	6	15	Q4	S5	8	25	Q1	EN7	7	35	Q1
P2	2	6	Q4	EC4	7	16	Q3	T4	4	26	Q1	EN6	8	36	Q1
EC7	1	7	Q1	T1	1	17	Q1	T7	5	27	Q1	EN8	9	37	Q3
EC1	2	8	Q2	S3	4	18	Q1	T6	6	28	Q1	EN1	10	38	Q2
S8	1	9	Q2	S2	5	19	Q1	T5	7	29	Q1	EN10	11	39	Q1
EC5	3	10	Q1	S6	6	20	Q1	EN9	2	30	Q1	EN5	12	40	Q1

Legend:

🟥	Very Highly Ranked Criteria	🟨	Medium Ranked Criteria
🟥	Must Have Criteria	🟨	Could Have Criteria
🟧	Highly Ranked Criteria	🟩	Low Ranked Criteria
🟧	Should Have Criteria	🟩	Nice to Have Criteria

The results from both sets of findings were compared, and the comparative results between criteria ranking and criteria importance-certainty are presented in Table 4-19. AHP primarily focuses on the objectivity of criteria (one dimension-criteria importance), while the QMA approach provides a two-dimensional perspective, considering both importance and certainty. Thus, the results from QMA can complement and support the analysis process of AHP, making it an ideal approach when combined with other methods to enhance the overall analysis.

The same colour code assigned previously for AHP and QMA methods was used to indicate the feasibility of employing criteria for both results, as shown in Figure 4-5. Ideally, criteria should be employed according to the group they fall into.

Group	Paired Colour-Code	Colour-Code Explanation	Group	Paired Colour-Code	Colour-Code Explanation
1	🟥 🟥	Very Highly Ranked and Must-Have Criteria	9	🟨 🟥	Medium Ranked and Must-Have Criteria
2	🟥 🟧	Very Highly Ranked and Should-Have Criteria	10	🟨 🟧	Medium Ranked and Should-Have Criteria
3	🟥 🟨	Very Highly Ranked and Could-Have Criteria	11	🟨 🟨	Medium Ranked and Could-Have Criteria
4	🟥 🟩	Very Highly Ranked and Nice-to-Have Criteria	12	🟨 🟩	Medium Ranked and Nice-to-Have Criteria
5	🟧 🟥	Highly Ranked and Must-Have Criteria	13	🟩 🟥	Low Ranked and Must-Have Criteria
6	🟧 🟧	Highly Ranked and Should-Have Criteria	14	🟩 🟧	Low Ranked and Should-Have Criteria
7	🟧 🟨	Highly Ranked and Could-Have Criteria	15	🟩 🟨	Low Ranked and Could-Have Criteria
8	🟧 🟩	Highly Ranked and Nice-to-Have Criteria	16	🟩 🟩	Low Ranked and Nice-to-Have Criteria

Figure 4-5: Ideal Group Criteria Selection

Based on findings in Table 4-19, the criteria considered ideal for use fall into the groups of "Very Highly Ranked Criteria" and “Must-Have Criteria”. This situation can be attributed to the certainty score, which significantly affects the final distribution of the criteria. The results suggest that three criteria, namely L3, EC7, and EC5, should ideally be employed. This is due to their high certainty scores, as the top three ranked criteria (P1, L1, and L4) have certainty scores below the average. Therefore, it can be concluded that certainty plays a crucial role in the identification and selection of criteria. A criterion that is assumed to be realistic may not be chosen if it lacks certainty for use.

Different expert opinions can influence the results of this study, as experts may exhibit favouritism towards criteria that are preferable, convenient, or familiar to them. However, these findings offer an opportunity to explore the factors contributing to this scenario and propose strategies to overcome it. By utilising these approaches, decision-makers can attain a more comprehensive understanding of the criteria and their relative importance in FMP. This helps reduce the risk of overlooking critical and important criteria or overemphasising less important ones.

Moreover, the comparative analysis of the results enables decision-makers to identify and address any inconsistencies or contradictions. For instance, if criteria is ranked highly in one methodology but falls into a low quadrant in the other methodology, decision-makers can investigate further to understand the reason behind this discrepancy and assess its impacts on the decision-making process.

Decision-makers can use the results to prioritise criteria based on their certainty and importance and identify potential trade-offs among different criteria. This enables decision-makers to develop well-structured and informed FMP decisions, considering the availability and certainty of different criteria. To ensure the highest level of decision quality in FMP, it is essential to evaluate and analyse the importance and certainty of the identified criteria based on experts' opinions regarding their utilisation in the decision-making process.

4.5.3 Development of the Proposed Criteria Hierarchy Structure

The comparative analysis of criteria using AHP and QMA, as presented in Table 4-19, leads to the proposal of a hierarchical structure for criteria, illustrated in Figure 4-6. This structure establishes a three-level hierarchy of macro domain criteria for FMP. The main goal is to determine the significant macro domain criteria to be employed.

The criteria hierarchy structure represents the problem by arranging the components in a hierarchical manner. At the top level, the overall goal of "Macro Domain Criteria Ranking" is positioned. At the middle level, the focus is on the six macro domains: Political, Economic, Social, Technological, Environmental, and Legal. Finally, the sub-criteria associated with each domain are placed at the bottom of the hierarchy.

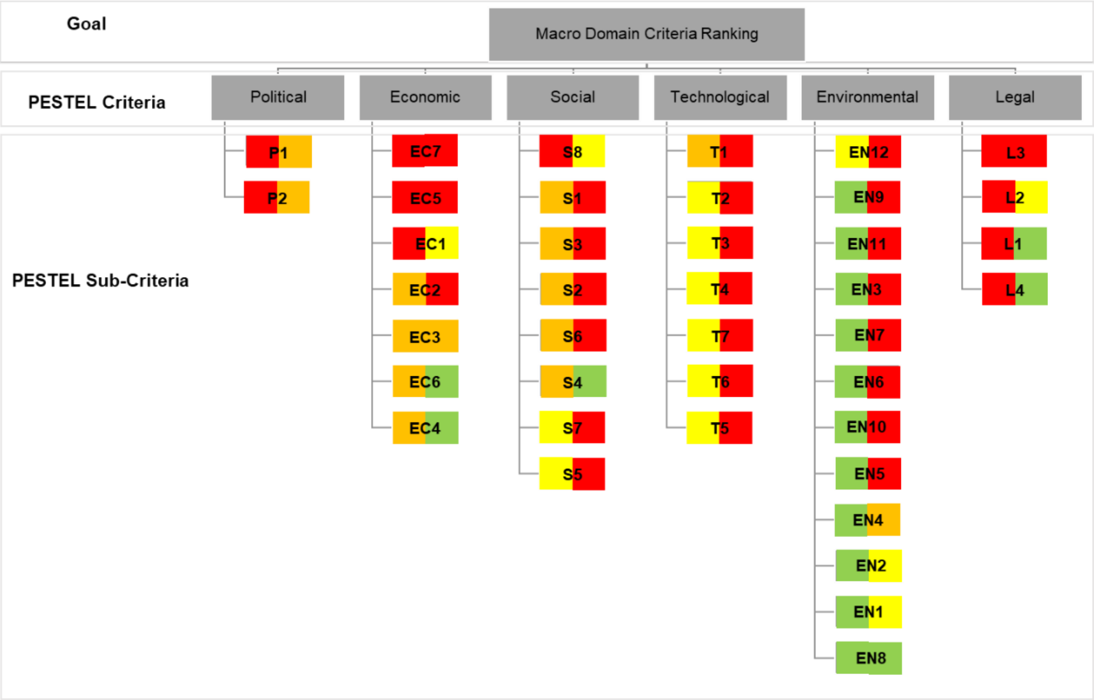


Figure 4-6: Proposed Criteria Hierarchy Structure

In the proposed criteria hierarchy, the sequence of criteria for each domain was based on the combined results of AHP and QMA. These results identify the optimal criteria from the ideal criteria group (refer to Figure 4-5) that decision-makers should consider in FMP decisions.

The criteria P1, EC7, S8, T1, EN12, and L3 are deemed the most important criteria for the PESTEL macro domain. Therefore, they should be incorporated into the decision-making process based on their importance and certainty of being employed. Each domain also includes a list of sub-criteria, which helps decision-makers understand the rationale behind criteria selection. This information allows decision-makers to re-assess and re-evaluate the strategies required to ensure the identified criteria fall into the categories of “Very Highly Ranked Criteria” and “Must-Have Criteria” for future decision-making processes.

Even though the proposed hierarchical criteria are based on forty criteria from previous studies, decision-makers should review and re-evaluate these criteria considering the current flood situation.

4.5.4 Proposed Macro Domain Criteria Analysis Framework for Flood Management Planning

The findings from both criteria analyses in subsections 4.5.1 and 4.5.2 have led to the proposal of a macro domain criteria analysis framework, which serves as a guideline for criteria identification and selection in future work. This framework addresses the discrepancy between criteria ranking based on AHP analysis and criteria mapping based on QMA. Such discrepancies may result from expert interpretations that differ due to their perceptions, preferences, data accessibility, data availability, and ideas during the criteria analysis stage. The proposed framework aims to enhance the current methodology used in this study (Figure 4-1) for future data collection and analysis.

The framework, shown in Figure 4-7, encompasses five stages: Stage 1: Criteria Identification and Selection; Stage 2: Expert Review, Stage 3: Criteria Analysis, Stage 4: Criteria Reflection, and Stage 5: Criteria List. Each stage is detailed in Table 4-20. Notably, Stage 4 is identified as a crucial stage, where criteria reflection serves as a validating layer before finalising the criteria list.

According to the study by Mann et al. (2009), reflection is a critical evaluation of knowledge and experience with the goal of gaining greater understanding and meaning. This definition is based on the works of Dewey (1933), Boud et al. (1985), and Moon (1999). The same study also presents various conceptualizations of reflection from Schön (1983), Schön (1987), Boud et al. (1985), Dewey (1933), Hatton et al. (1995), and Moon (1999). In Table 4-21, an extended model named ‘Weather’ from Maclean (2016) is introduced to facilitate a better understanding of differences and similarities among the steps involved.

In the Criteria Reflection stage, the Weather model developed by Maclean (2016) was chosen over the other models due to its simplicity and direct process, making it suitable as guidance in the reflection process. The model was developed based on the analogy of English weather, where assessing the different weather conditions facilitates decision-makers to further understanding of the result. The inclusion of the Weather model in this framework is significant as it ensures that all criteria are thoroughly evaluated and accepted as a final consensus before proceeding with future works and analyses.

The inclusion of a reflection stage in the framework adds an additional layer of rigour and critical analysis. Experts are encouraged to reflect on the criteria selection process, examining the underlying assumptions, biases, and potential limitations. This reflective exercise helps ensure that the selected criteria are robust, relevant, and aligned with the objectives of FMP.

The proposed conceptual framework guides the process of criteria identification and selection where conflicts or insignificant criteria are present. It provides decision-makers with a systematic and informed approach to criteria selection in FMP. By incorporating specific steps, including experts' reviews, the calculation of criteria scores, and reflections from experts, it would significantly improve the quality of the criteria in FMP.

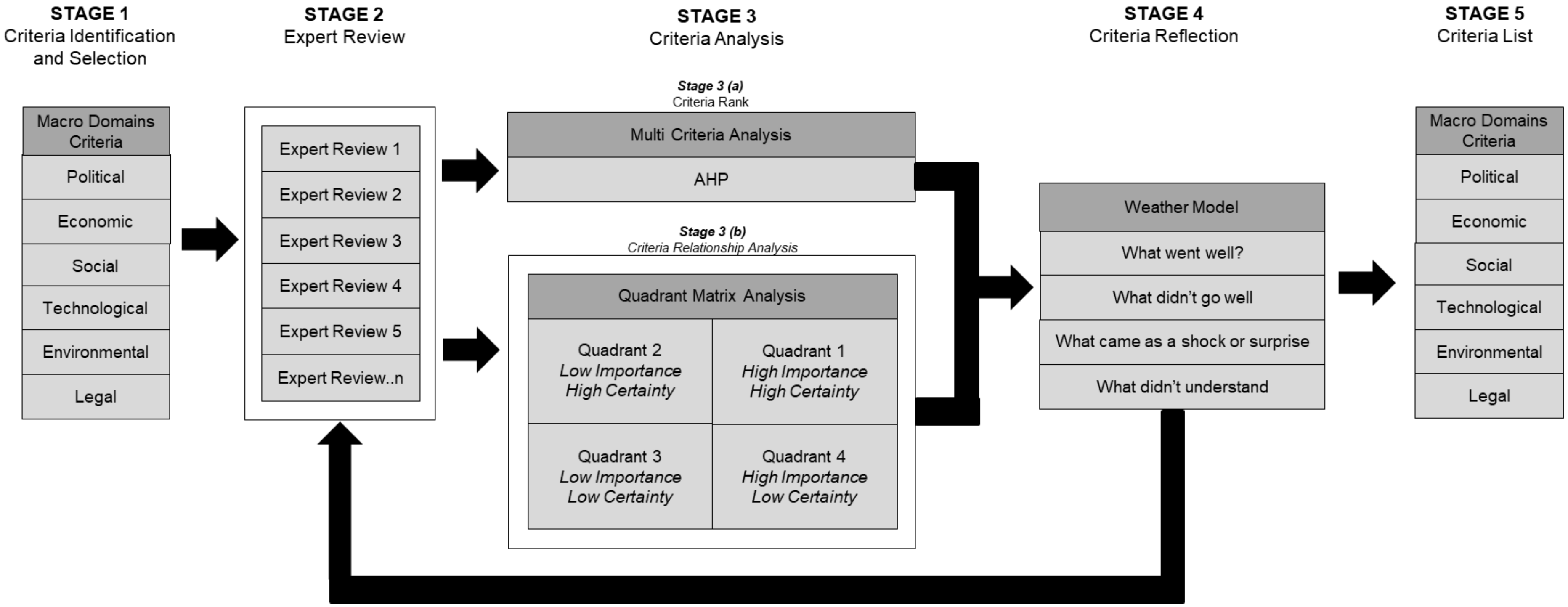


Figure 4-7: Macro Domain Criteria Analysis Framework for Flood Management Planning

Table 4-20: Stages in proposed framework

Stage	Stage Process	Explanation
Stage 1	Criteria Identification and Selection	Identifying and selecting macro domain criteria could be done by referring to criteria from previous works which was conducted on the same domain or case study. In addition, expert opinion would be a valuable input to enrich the process of criteria identification and selection. These criteria will be clustered into six macro domain PESTEL.
Stage 2	Expert Review	The identified criteria will be reviewed by an expert. Experts will assess and evaluate the criteria by scoring each of the criteria based on their expertise, knowledge, and experience.
Stage 3	Criteria Analysis	Stage 3 (a) Criteria ranking is conducted using Multi criteria analysis method.
		Stage 3 (b) Criteria analysis between importance and certainty is conducted based on quadrant matrix analysis.
Stage 4	Criteria Reflection	a. Criteria Reflection was introduced as a stage where there is a process to reflect on the criteria results by referring them back to experts for revisiting and reassessing until consensus criteria are achieved and accepted; and b. Criteria reflection based on Weather model developed by Maclean (2016). The reflection helps in criteria selection by using the following steps: 1. What went well? (Sunshine) 2. What did not go well? (Rain) 3. What came as a shock or surprise? (Lightening) 4. What did not understand? (Fog)
Stage 5	Criteria List	List of confirmed criteria according to macro domain

Table 4-21: Models of reflection and reflective practice (Source: Extended from Mann et al. (2009)

Author	Type of Model	Steps/Process
Schön (1983), Schön (1987)	Iterative Practice	1. Knowing-in-action, 2. Surprise, 3. Reflection-in-action, 4. Experimentation, 5. Reflection-on-action
Boud et al. (1985)		1. Returning to experience, 2. Attending to feelings, 3. Re-evaluation of experience, 4. Outcome/Resolution

Author	Type of Model	Steps/Process
Dewey (1933)	Vertical Practice	1. Content and process reflection, 2. Premise reflection/critical reflection
Mezirow (1991)		1. Habitual action, 2. Thoughtful action/Understanding, 3 3. Reflection, 4. Critical reflection
Boud et al. (1985)		1. Association, 2. Integration, 3. Validation 4. Appropriation
Hatton et al. (1995)		1. Description, 2. Descriptive reflection, 3. Dialogic reflection, 4. Critical reflection
(Moon, 1999)		1. Noticing, 2. Making sense, 3. Making meaning, 4. Working with meaning, 5. Transformative learning
Maclean (2016)	Vertical Practice	1. What went well in the lesson/task? What was successful? 2. What didn't go so well? What was challenging? 3. Was there a point where you couldn't see clearly, or weren't sure what to do? 4. Was there something you saw differently during the lesson? What was it? 5. What came as a surprise? 6. Did anything change the course of the lesson, or cause you to change what you had planned to do? 7. Was there any conflict during the lesson? What caused it? How did you respond to it?

4.6 Conclusion

This study highlights the active engagement of experts in decision-making processes concerning complex decisions in FMP, specifically focusing on criteria within the macro domain. By conducting a PESTEL criteria analysis, decision-makers can make more informed decisions by identifying potential criteria for comprehensive and collective choices. The effectiveness of AHP and QMA has been demonstrated in their criteria ranking and identification for comprehensive and informed decisions.

The focal point of this study is criteria analysis, with expert participation playing a vital role in confirming the criteria to be utilised in supporting and facilitating FMP decisions. Different perceptions and judgements regarding the criteria can influence the selection of criteria. Therefore, to improve the criteria selection process, it is crucial to establish a structured and refined approach that leads to the selection of the most ideal criteria.

The findings of this study can contribute to the development of more effective FMPs and policies, which ultimately help in the mitigation of the negative impacts of floods on communities and the environment. Prioritising domains based on their weights can facilitate decision-making processes by identifying which domains require greater emphasis and which ones can be assigned lower priority. In situations where there are problems accessing or obtaining certain criteria, having alternative options and considering criteria trade-offs can prove valuable in the decision-making process.

The significance of this study lies in its ability to provide valuable insights to decision-makers in FMP decisions. The proposed conceptual framework can serve as a valuable guide, enabling decision-makers to enhance the criteria identification and selection process before employing it in the decision-making process.

In conclusion, the findings of this study have the potential to contribute to the development of comprehensive and robust FMP decisions. Further research can build upon these results by examining how the prioritised criteria are utilised in FMP and exploring the implications of their application.

4.6.1 Limitation

Subjective judgement in decision-making methodologies like the AHP and QMA encounters additional challenges that impact the reliability and robustness of the analysis. Firstly, AHP may face an exhaustive session due to the substantial number of criteria that need assessment and evaluation.

This can lead to decision fatigue among experts, potentially compromising the quality and accuracy of their judgements. Moreover, experts might compromise between them to ensure the achievement of a reasonable consistency index in the AHP methodology. While this compromise is made to enhance consistency, it introduces the risk of influencing the final criteria list, potentially skewing the overall decision-making process.

In the case of QMA, the challenges extend to expert bias, preferences, and criteria familiarization. Expert bias can significantly influence the scoring process, as personal inclinations may unconsciously impact how experts evaluate criteria and alternatives. Additionally, individual preferences can introduce subjectivity into the analysis, making it challenging to maintain an objective and unbiased assessment. Furthermore, experts' familiarity with certain criteria may lead to biassed assessments, affecting the fairness and comprehensiveness of the analysis. These challenges underscore the need for robust methodologies to address biases, enhance consistency, and ensure the validity of subjective judgements in decision-making processes.

4.6.2 Contribution

The study offers several important contributions to the field of FMP and related disciplines. Evidence from extensive literature reviews supports the idea that there is an existing gap in studies that focus on reflecting identified criteria in various contexts prior to their application in FMP. Therefore, to address this gap, the conceptual framework proposed in this study (refer to Figure 4-7) can be utilised to enhance the criteria identification and selection process through criteria reflection as an improvement step. The study’s recommendations in Chapter 3, sub-section 3.7.2, emphasised the need for further analysis to refine the criteria identification and selection before finalising the criteria in Phase 2: Criteria Analysis (refer to Figure 3-6 and Table 3-17). Thus, the proposed framework aligns with these suggestions and recommendations.

In addition, this study provides valuable insights into identifying the most suitable criteria for FMP decisions. The approach can guide decision-makers in making more informed decisions based on robust structural planning and reliable data, thereby minimising the risk of errors and uncertainty in decisions. The integration of criteria ranking and a criteria quadrant matrix highlights the insufficiency of ranking criteria alone and emphasises the importance of considering criteria certainty in the process.

The study shows the significance of considering criteria certainty in the FMP decision-making process. The results revealed that criteria certainty significantly influences criteria selection. While certain criteria may be deemed highly important based on their ranking, uncertainties surrounding those criteria could obscure their effective utilisation. Merely recognising the importance of criteria without considering their certainty can potentially undermine the decision-making process and compromise the outcomes. Therefore, the study recommends the inclusion of criteria certainty as a crucial factor when selecting criteria for FMP.

Furthermore, the study highlights the importance of considering trade-off criteria in FMP. This approach enables decision-makers to balance competing interests and priorities, allowing them to allocate their efforts and resources effectively. By employing this approach, the utilisation of resources can be optimised, leading to improved outcomes and results.

Finally, the proposed conceptual framework holds potential for application in other domains for future studies, including health facility management, transportation management, tourism, and hospitality. It can aid in analysing identified potential criteria and guiding decision-making processes within these domains.

4.6.3 Recommendation

Further studies should be conducted to explore the feasibility and practicality of the proposed framework and determine whether significant differences exist in the results. The study should incorporate multiple iterations of reflection, as outlined in Stage 4 of the proposed framework. Additionally, alternative MCDA techniques, in addition to the AHP technique, could be employed to compare and identify the most practical and achievable approach. Furthermore, the introduction of different reflection models in Stage 4 of the framework may yield varied findings that could have an impact on the final selection of criteria.

By exploring the feasibility and practicality of the study, potential limitations and challenges can be identified, allowing for necessary adjustments and improvements. Meanwhile, incorporating multiple iterations of reflection, as recommended, would enable a thorough examination of criteria and promote a deeper understanding of them, thus facilitating informed decision-making.

Comparing alternative MCDA techniques with AHP provides valuable insights into the different approaches applied. This comparative analysis enables decision-makers to identify the ideal method that could enhance the overall effectiveness of the framework. Moreover, the introduction of different reflection models offers the opportunity to explore diverse perspectives and generate varied findings. This exploration is essential as it highlights the influence of the reflection models on the final selection of criteria.

In summary, the recommendations highlight the need to consider a mechanism to improve the process of criteria selection, which would provide decision-makers with reliable and effective tools for criteria selection in various domains.

4.7 Publication

The study conducted for this chapter has been successfully presented at the 5th Sintok International Conference on Social Science and Management (17th-18th October 2023). This conference provides an opportunity to disseminate the findings and engage with a broader academic audience. The inclusion of this study in the conference underscores its relevance and potential impact within the realm of social science and management, establishing it as a valuable addition to the academic discourse in this domain. This paper is available in e-proceeding. e-ISSN: 3009-1330, ISBN: 3009-1349.

Chapter 5

Development of Conceptual Framework for Combined Spatial-MCDA Decision Support System based on Macro Domain Criteria for Flood Management Planning

5.1 Chapter Motivation

The findings from Chapters 3 and 4 revealed that the PESTEL criteria and the combined spatial-MCDA technique are very important in the context of FMP. These findings have led to further investigation of the potential benefits of amalgamating these components to develop a combined spatial-MCDA decision support system that aids decision-making. To accomplish this, a structured process and comprehensive requirements are necessary to guide the input, process, and output of the system.

The research data available at NAHRIM encompasses a diverse range of data types and formats, including grid data. This presents an opportunity to explore the utilisation of grid data in the development of the combined spatial-MCDA decision support system.

The study on MCDA and spatial as decision-making tools offers complementary benefits, which can be regarded as a transformation and combination of spatial data and value judgements from experts to obtain information for decision-making (Malczewski, 2010). To fully tap into these advantages, involving experts from NAHRIM is crucial. Their input will help comprehend the specific requirements, analyses, and anticipated outcomes and decisions to develop the combined spatial-MCDA decision support system.

To attain this goal, it is imperative to establish a structured framework that provides guidance for the development of the prototype system. The study in Chapter 5 will present a detailed investigation and propose a conceptual framework that illustrates the relationship between the identified stages within the input, process, and output contexts. This framework will serve as a reference point for the development of the combined spatial-MCDA decision support system.

5.2 Introduction

The results from Chapter 3 demonstrate the importance of utilising the PESTEL analysis framework as a tool for organising and categorising the identified criteria across different domains. Meanwhile, in Chapter 4, the results highlight the crucial and pragmatic application of MCDA and QMA methods as instruments for revising and refining criteria with the support of experts.

The Flood Management Plan (FMP) is a complex and multifaceted process where spatial technology plays a significant role in facilitating the FMP strategy's implementation. Chapter 3's study underscores the importance of spatial technology in improving FMP decisions. A structured framework is needed to give guidelines for building the system in order to combine the PESTEL analysis framework, the MCDA technique, and spatial technology into a decision support system.

Previous studies have revealed a lack of established frameworks that clearly outline the steps needed to combine these elements in the context of FMP. The reason behind this gap is that most studies have focused on just one domain, or at most five, without covering all criteria of the PESTEL domains and how to process, analyse, and visualise them within the decision support system.

The crucial elements gleaned from the extensive investigations conducted in Chapter 3 and Chapter 4 emerge as the primary driving forces shaping the development of the conceptual framework. These chapters stand as foundational pillars, contributing essential insights that profoundly influence the subsequent phases of framework development.

In Chapter 3, the proposed criteria identification and selection framework takes centre stage. This framework gives a structured and organised way to find the right PESTEL criteria to use strategically in MCDA for FMP. The insights and methodologies elucidated in Chapter 3 lay the groundwork for a robust and comprehensive approach to criterion identification, ensuring that the resultant conceptual framework is anchored in a thorough understanding of the macro domain factors impacting FMP.

Simultaneously, the revelations coming from Chapter 4 play a crucial role in stimulating the conceptual framework. AHP and QMA are two different methods that strengthen this criteria-choosing process. The findings not only validate the efficacy of this dual methodology but also illuminate how the proposed framework enhances criteria analysis. A noteworthy enhancement is introduced in the form of the Reflection Stage, injecting a nuanced layer into the analysis process.

Putting together Chapter 3's structured criteria identification framework and Chapter 4's dual-methodology-driven findings makes a conceptual framework that is ready to become more complex and useful. The proposed framework is not merely an amalgamation but a refined synthesis that harmonises diverse methodologies to elevate the analysis and selection of criteria, ultimately contributing to the advancement of FMP decision-making processes.

This study proposes a conceptual framework for a combined spatial-MCDA decision support system. The framework is based on the fundamental principles of Input, Process, and Output, and is structured into five distinct stages. In Stage 1, the focus is on the data collection as the input. Following this, there are three consecutive stages: data pre-processing, data processing, and data analysis. Finally, the fifth focuses on data visualisation, which presents the output of the system.

The proposed conceptual framework was formulated to clarify the processes involved in system development. It integrates spatial analysis with the MCDA technique and relies on a comprehensive set of criteria using the PESTEL macro domains analysis framework. The proposed framework demonstrates conceptual distinctions between decision criteria and the MCDA technique within the decision support system for FMP. It is designed to illustrate the variables connectivity and can be a useful tool for exploring ideas and expanding on them in future studies.

This work makes three important contributions. First, the proposed conceptual framework offers a structured approach to combined spatial-MCDA decision support system development based on multiple approaches. Second, the conceptual framework has the potential to improve the data management process in the PESTEL macro domain for future studies. Lastly, the framework is dynamic and expandable, enabling its replication, adaptation, and evolution for various domains and future application development.

5.3 Aim of the Chapter

The aim of this chapter is to improve the FMP's decisions. This study focuses on offering structured guidelines for the combined spatial-MCDA decision support system's development. The system would serve as a platform to facilitate decision-making by utilising PESTEL macro domain criteria as the decision criteria.

5.3.1 Objectives of the Chapter

To achieve the aim of this chapter, the following objectives have been set:

a. to identify the input, process, and output involved in the development of a spatial decision support system; and
b. to develop a conceptual framework for spatial decision support system development.

5.4 Related Works

As discussed in sub-section 3.5.2.1 Flood Measures, recent studies have been emphasising the integration of spatial analysis and the MCDA technique. These studies have demonstrated the practical application of this integration in supporting decision-making across different phases of disaster management. This integration empowers decision-makers to factor in spatial factors, assess multiple criteria, and visualise spatial data effectively. Consequently, it has paved the way for more effective disaster management strategies.

The combined spatial-MCDA application can be beneficial during three phases of FMP strategies: pre-, during-, and post-disasters. In the pre-disaster FMP phase, it facilitates decision-makers in analysing various spatial data factors, such as hydrological data, land use, and population density. This information optimises resource allocation and coordination, including emergency response teams, equipment, and evacuation routes. It also supports flood assessment by evaluating vulnerability areas, identifying high-risk zones, and assessing flood impacts. This information is vital for targeted flood prevention strategies.

Meanwhile, during a flood disaster, the application aids decision-makers in making timely, informed decisions. It supports real-time monitoring and evaluation of flood situations, helping to allocate resources effectively. It also prioritises actions based on factors like flood severity, population density, and infrastructure vulnerability. This guides attention to the most critical areas needing immediate action.

Post-flood disaster events present a unique challenge, and an efficient FMP is needed. The application can help decision-makers assess the flood's damage. For example, spatial analysis and MCDA help to evaluate affected areas, find critical infrastructure, and understand the flood's socio-economic impacts. This includes figuring out the value of damaged assets and aiding people affected by the flood in relocating.

Spatial analysis involves techniques like modelling and analysis used to examine, interpret, and understand patterns and relationships in spatial data. It plays a crucial role in creating maps that aid FMP decisions, such as flood hazard maps and maps of flood-prone areas. Different types of spatial data yield various maps and information, which are valuable for supporting decision-makers in FMP.

Table 5-1 summarises the spatial analysis application for different stages of DMP based on prior studies. These studies focused more on the mitigation phase than other phases. Despite this uneven focus, it is evident that spatial analysis improves decision-making. Its efficacy lies in the location analysis and the ability to visualise outcomes, which help decision-makers comprehend the situation before reaching a conclusion.

The combined spatial-MCDA application proves effective in achieving multiple flood decision goals. Decision-makers can benefit from comprehensive data and information through spatial maps, streamlining the decision-making process.

Table 5-1: Spatial Application based on the Disaster Management Plan

Flood Measure	DMP Phase	No. of Studies	Previous Work
Spatial	Mitigation	15	(Papaioannou et al., 2015; Rahmati et al., 2016; Song and Chung, 2016; Gigovic et al., 2017; Alves et al., 2018; Mirzaei et al., 2018; Sepehril et al., 2019); Toosi et al. (2019); (Vojtek and Vojtekova, 2019; Abdrabo et al., 2020; Bouamrane et al., 2020; Morea and Samanta, 2020; Nachappa et al., 2020; Stavropoulos et al., 2020; Ziarh et al., 2021)
	Preparedness	4	(Sukcharoen et al., 2016; Kim et al., 2019; Abu El-Magd et al., 2020; Ajjur and Mogheir, 2020)
	Response	2	(Xenarios and Polatidis, 2015; Wang, Y. et al., 2019)
Spatial & Assessment	Mitigation	18	(Chung and Lee, 2009; Wang, Y.M. et al., 2011; Madhuri et al., 2013; Ahmadisharaf et al., 2016; Mahmoud, S. H. and Gan, T. Y., 2018; Rincon et al., 2018; Arabameri et al., 2019; Azareh et al., 2019; Feloni et al., 2019; Nigusse and Adhanom, 2019; Sepehril et al., 2019; Abdelkarim et al., 2020; Costache et al., 2020; Hadipour et al., 2020b; Komolafe et al., 2020; Mishra

Flood Measure	DMP Phase	No. of Studies	Previous Work
			and Sinha, 2020; Tella and Balogun, 2020; Vignesh et al., 2020)
	Preparedness	4	(Franci et al., 2016; Vogel, 2016; Hammami et al., 2019; Souissi et al., 2019)
	Response	1	(Afifi et al., 2019)

Table 5-2 summarises the combined spatial-MCDA approach employed in previous studies to achieve various flood decision goals. It's worth noting that many of these studies have focused on the goal of assessing flood vulnerability. This emphasis likely arises from the recognition of the importance of understanding and addressing vulnerabilities in communities and infrastructure to reduce the impacts of floods. By prioritising vulnerability, decision-makers can create targeted strategies to enhance resilience and minimise flood impacts.

Table 5-2: Combined Spatial-MCDA Application for Flood Management Planning based on Flood Decision Goals

Flood Measures	Decision Goals	No. of Studies	Previous Work
Spatial	Reduce Vulnerability	13	(Papaioannou et al., 2015; Song and Chung, 2016; Alves et al., 2018; Mirzaei et al., 2018; Vojtek and Vojtekova, 2019; Wang, Y. et al., 2019; Abdrabo et al., 2020; Abu El-Magd et al., 2020; Ajjur and Mogheir, 2020; Bouamrane et al., 2020; Morea and Samanta, 2020; Nachappa et al., 2020; Stavropoulos et al., 2020)
	Reduce Hazards	5	(Rahmati et al., 2016; Gigovic et al., 2017; Kim et al., 2019; Sepehril et al., 2019; Toosi et al., 2019)
	Reduce Risk	2	(Sukcharoen et al., 2016; Ziarh et al., 2021)
	Improve Resilience	1	(Xenarios and Polatidis, 2015)
Spatial & Assessment	Reduce Vulnerability	14	(Chung and Lee, 2009; Madhuri et al., 2013; Mahmoud, S. H. and Gan, T. Y., 2018; Afifi et al., 2019; Arabameri et al., 2019; Azareh et al., 2019; Feloni et al., 2019; Hammami et al., 2019;

Flood Measures	Decision Goals	No. of Studies	Previous Work
			Nigusse and Adhanom, 2019; Souissi et al., 2019; Costache et al., 2020; Hadipour et al., 2020b; Tella and Balogun, 2020; Vignesh et al., 2020)
	Reduce Hazards	3	(Franci et al., 2016; Sepehril et al., 2019; Komolafe et al., 2020)
	Reduce Risk	2	(Wang, Y.M. et al., 2011; Rincon et al., 2018)
	Improve Resilience	2	(Ahmadisharaf et al., 2016; Vogel, 2016)
	Reduce Vulnerability & Improve Resilience	1	(Abdelkarim et al., 2020)
	Reduce Risk & Reduce Vulnerability	1	(Mishra and Sinha, 2020)

The current efforts in the combined spatial-MCDA are often tailored to address specific issues and are dependent on the specific context in which they were developed. This causes complications and inefficiencies in their use, as there is no standard guideline. However, there is a lack of a comprehensive review to guide and provide a complete understanding of the essential aspects of developing and using these applications. The absence of such guidance leads to challenges like a lack of standardisation, difficulties in merging data, complexity, adaptation issues in different contexts, and limits to replicating and scaling up these applications.

As a result, there is a need for a structured framework that can represent the generic processes and steps required. By closing this gap, such a framework would provide a unified approach and facilitate more effective and efficient utilisation of the combined spatial-MCDA application in FMP.

5.5 Discussion: Conceptual Framework

This study proposes a generic conceptual framework following the Input, Process, and Output model. Its objective is to fill a gap in studies by systematically analysing the combined spatial-MCDA application, specifically when incorporating criteria from the PESTEL macro-domain into a decision support system.

The proposed conceptual framework is highly relevant as it offers a comprehensive overview, helping researchers and practitioners understand the essential steps and guidance for developing the application. By utilising this framework, they can improve their understanding and facilitate the effective development of the combined spatial-MCDA application within a decision support system.

In this study, the proposed framework is constructed based on the Input, Process, and Output model, which comprises five stages. The first stage focuses on Data Collection as Input. The subsequent stages, which are Data Pre-Processing (Stage 2), Data Processing (Stage 3), and Data Analysis (Stage 4), fall under the Process category. Finally, the fifth stage, Data Visualisation, is dedicated to Output.

In Stage 1, the data collection involved the identification and selection of criteria from the PESTEL macro domain, which had been discussed and deliberated in Chapters 3 and 4.

Stage 2 encompasses data pre-processing, including data quality checking, data cleansing, data transformation, and data validation. Meanwhile, in Stage 3, data processing entailed the preparation of selected spatial data, such as maps. In this stage, spatial software such as ArcGIS or QGIS can aid the preparation process.

Stage 4 focused on data analysis, which includes the computation of identified criteria such as distance, risk score, and others. Additionally, a MCDA calculation based on the selected technique will be performed. The final stage (Stage 5) focuses on data visualisation, where a multilayer spatial visualisation will be developed using several layer maps of identified criteria. The objective of this stage is to develop a dashboard that facilitates the visualisation of the analysis's outcomes.

The conceptual framework depicted in Figure 5-1 illustrates a concise overview of the main components and processes involved. While the framework does not offer an exhaustive process for Stages 2, 3, and 4, it can be adjusted to meet the specific requirements of system development.

This conceptual framework serves as a flexible guide for planning and developing combined spatial-MCDA decision support systems. It offers a cognitive structure for considering input, process, and expected output, helping to manage complexity and clarify the development steps. It's a flexible tool that can be adapted and modified as needed.

5.6 Conclusion and Future Works

This study introduced a comprehensive conceptual framework that systematically guides the development of a combined spatial-MCDA decision support system tailored to the specific PESTEL macro domain criteria in FMP. This framework comprises five distinct stages, offering a clear roadmap of the involved steps and their interconnections.

By developing this framework, the study has successfully mapped the criteria, data processing, analysis, and visualisation steps, along with their corresponding relationships. As a result, researchers and practitioners can utilise this framework as a structured resource to familiarise themselves with domain-specific knowledge. In addition, this proposed framework serves as a practical toolkit, facilitating the development of the application and thereby improving the FMP decision-making process.

Considering the increasing prevalence of combined spatial-MCDA decision support systems, this framework will be employed to evaluate a case study, as discussed in Chapter 6. Furthermore, this proposed conceptual framework holds the potential to serve as a guideline for developing similar platforms in various multidisciplinary studies. Hence, it is imperative and advantageous to keep this conceptual framework regularly updated.

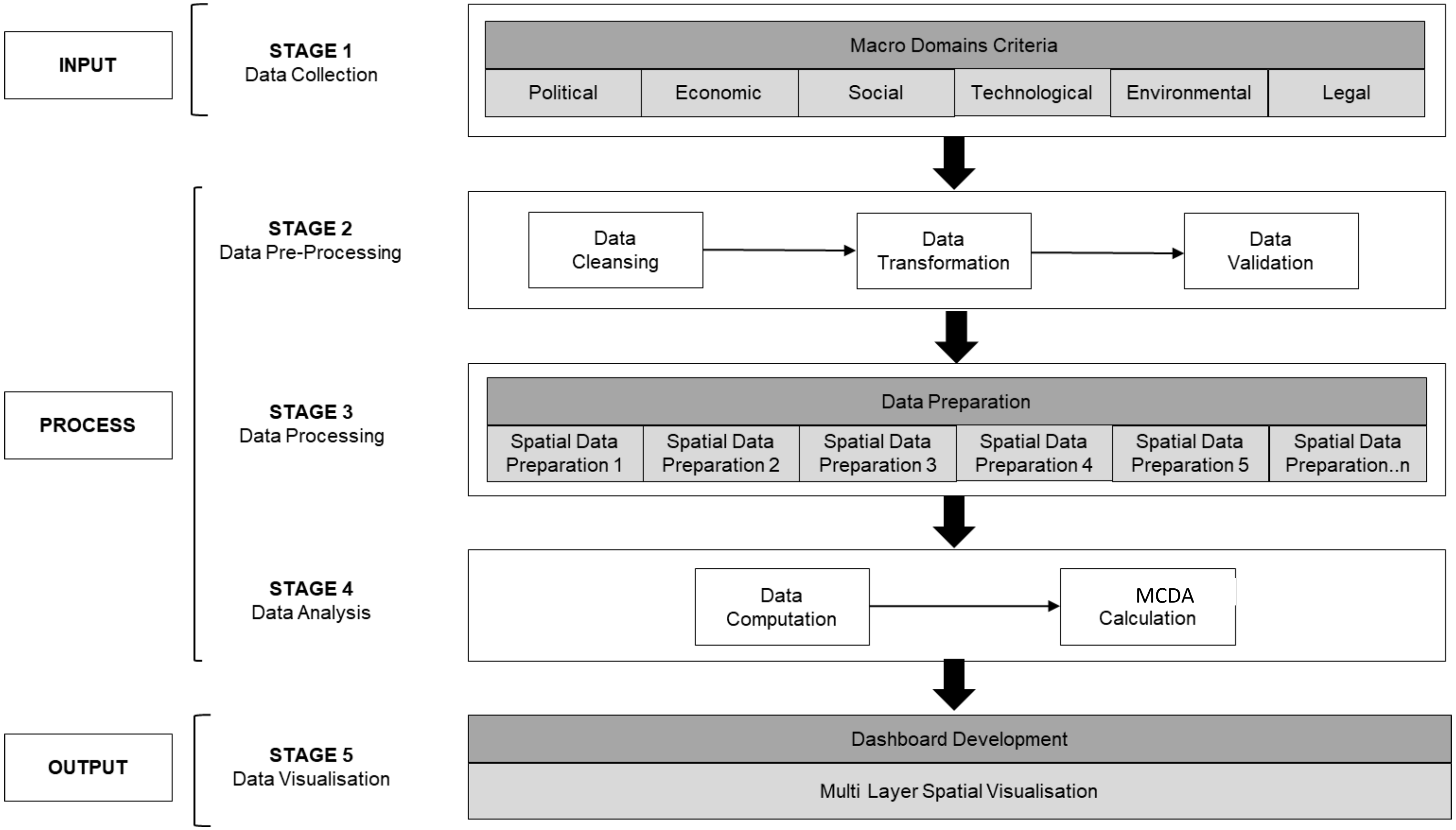


Figure 5-1: Conceptual Framework for Spatial Decision Support System on Macro Domains Criteria using Multi-criteria Decision Analysis.

Chapter 6

Exploratory Case Study for Health & Safety Facility Management in Kelantan, Malaysia: Identify New Location for Hospital Construction

6.1 Chapter Motivation

The motivation for this chapter arises from the findings and recommendations presented in Chapters 3 and 5. Chapter 3 revealed the importance of incorporating PESTEL macro domain criteria into the FMP. Chapter 5 provides a structured framework for implementing a combined spatial-MCDA decision support system in FMP. Thus, this motivates a study to develop a prototype that facilitates the decision-making process for decision-makers, including analysis, assessment, and evaluation through informative visualisation.

Using an exploratory case study, an assessment will be conducted on the effectiveness of the prototype based on the selected criteria. This case study will leverage available data from NAHRIM and DID Malaysia, demonstrating the prototype’s capabilities using spatial technology and the MCDA technique. With the participation of experts, an analysis and evaluation will be conducted, ultimately validating the prototype's practicability and feasibility.

Drawing from historical flood events in Kelantan, this study will centre on facility management, specifically concerning health and safety facilities. These facilities hold significant importance both during and after flood events, underscoring the critical need to maintain their service continuity.

6.2 Introduction

Based on historical flood events in Kelantan, this study focuses on health and safety (H&S) facilities, such as hospitals, clinics, and evacuation centres. These facilities are critical during and after floods, so it's vital to maintain their feasibility, accessibility, and safety for uninterrupted service. Given their vulnerability to future floods, an evaluation of their current locations is necessary. This assessment informs strategic FMPs, including facility relocation, construction in flood-prone areas, or flood protection measures. The expected outcomes are:

a. reduce facility damages in future flood disaster events,
b. reduce costs related to facility management (maintenance, construction, restoration, etc.),
c. ensure the safety of facilities during flood events,
d. identify suitable areas for potential new H&S facilities; and
e. identify suitable areas for relocating H&S facilities.

Chan (2015) recommended the utilisation of spatial technology to improve FMP in Malaysia and improve the policy on healthcare centre facilities being flood-proof and resilient against flood disasters. Noraini and Khairul (2017) identified a lack of long-term planning as one of the challenges associated with flooding in Malaysia. In line with this, the report by IGRSM et al. (2022) emphasised the importance of spatial technology in facilitating decision-making for FMP.

This chapter showcases a case study using a spatial decision support system (SDSS) prototype. The main goal is to assess current H&S facilities' vulnerability and resilience to future floods in Kelantan. The prototype employs rainfall data (observed and projected), land use data, and H&S location data with input from NAHRIM experts. Kelantan is chosen as the study location, focusing on existing hospital vulnerabilities, and proposing a new location based on the criteria identified. The case study focused on ranking and prioritising potential locations for constructing a new hospital building in an area prone to flooding. Based on the observed rainfall data from 2015–2019, certain hospitals were situated in areas with high rainfall volumes. This condition suggests that these hospitals are vulnerable to flooding, posing a potential disruption to the provision of health services during and after flood events.

Data from NAHRIM and DID Malaysia is used for the prototype. NAHRIM experts proposed three locations based on observed rainfall data. Two case studies were conducted for hospital construction: one within a 12-km radius of the current location and one farther away, in low-risk flood areas.

The analysis considers the Northeast Monsoon season (November to March) in Malaysia, using six criteria: Rainfall Risk Score (RRS), Rainfall Volume (RV), Land Use Risk Score (LRS), Urban Land Use Size Area (ULSA), Access to H&S Facility Risk Score (AFRS), and Distance from Current Facility (DF). Although criteria are limited, the prototype can adapt to additional criteria. The selection of these criteria was based on experts' opinions and data availability. Although there are limitations to the chosen criteria, the prototype has the flexibility to incorporate additional criteria in the future, either for the analysis of the same case study or for adaptation in different domains.

The RRS was calculated using the Rainfall Vulnerability Index (RVI), and the RV amount in millimetres (mm) was determined based on projected rainfall data provided by NAHRIM. The value of the LRS was derived based on experts' opinions, while the ULSA was extracted from a spatial land use map. The AFRS index value was calculated based on the distance between the proposed location and the current facility, where a greater distance indicates higher risk. The DF value was obtained by measuring the distance in kilometres (km) between the proposed location and the current facility. The details on data preparation and processing, including the calculation step and value, are explained in sections 6.5.1 Phase 2: Data Pre-Processing and 6.5.2 Phase 3: Data Processing.

Four MCDA techniques were employed to rank the proposed locations based on six identified criteria: Weight Sum Model (WSM), Analytical Hierarchical Process (AHP), the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje – Multi criteria Optimization and Compromise Solution). According to Zardari et al. (2015), no single MCDA technique can be considered superior for all decision-making problems.

Therefore, in this study, WSM was chosen for its simplicity, while AHP and TOPSIS are among the top three MCDA techniques commonly used in managing flood disaster events. VIKOR was selected based on its promising trend in flood disaster management, as highlighted by Abdullah, M.F. et al. (2021). Following the MCDA results, further analysis was conducted to propose a final recommendation, which was then validated by eleven experts from relevant agencies that would benefit from its implementation.

The prototype analyses the proposed locations and provides a recommendation for the most feasible location. The findings from this work enable the assessment of location feasibility and its potential impacts, thereby facilitating discussion among decision-makers prior to finalising any decisions. Additionally, the prototype addresses the gap in MCDA application in other phases of the DMP, as highlighted by Abdullah, M.F. et al. (2021).

This case study holds great significance as it contributes to the improvement of health services and ensures their uninterrupted delivery during and after future flood events. In accordance with the report by IGRSM et al. (2022), PLANMalaysia has emphasised the importance of proactively identifying future risk areas for the next 10 to 20 years as part of its mitigation measures plan.

6.3 Aim of the Chapter

The aim of this chapter is to improve the decision results for FMP. The study focused on an exploratory case study based on health and safety facility management.

6.3.1 Objectives of the Chapter

To achieve the aim of the chapter, the following are the objectives of this study:

a. To develop a combined spatial-MCDA prototype as a decision support system platform,
b. To analyse the proposed locations and recommend feasible locations for constructing a new hospital building, and
c. To validate the recommended location based on experts' participation using the Content Validity Index (CVI) method.

6.4 Methodology

The methodology adopted in this study is based on the conceptual framework developed in Chapter 5.

6.4.1 Study Area

This study focuses on Kelantan, situated in eastern Peninsular Malaysia (see Figure 6-1). Kelantan was chosen due to its history of significant flood events and its consistently high annual rainfall during the Northeast Monsoon, which takes place from November to March. In 2014, a major flood affected three states in eastern Malaysia, including Kelantan (see Figure 6-2), resulting in a total of USD 50 million in damages (MalayMail, 2015). The Public Works Department of Malaysia (PWD, 2015) reported that the cost of repairing infrastructure damages in Kelantan alone amounted to USD 50 million.

Figure 6-1: Case Study Location

Figure 6-2: Flood Event in Kelantan 2014

Floods in Kelantan, pose a recurring and formidable challenge, particularly during the Northeast Monsoon season, which spans from November to March annually. The 2014 flood highlights the urgent need to address these concerns in a thorough manner and create methods that reduce the impact on communities during similar climatic occurrences.

The 2014 flood, colloquially known as "bah kuning," stands out as the worst flood to hit Malaysia in the past five decades. It wreaked havoc not only in Kelantan but also in neighbouring states, including Terengganu, Pahang, and Johor. As per the National Disaster Management Agency (NADMA) report (NADMA, 2018), the human toll was devastating, resulting in the loss of 25 lives and the displacement of a significant population. A staggering total of

541,896 victims from 136,447 families sought refuge in 1,335 evacuation centres, underscoring the scale of the disaster. The housing infrastructure bore a severe impact, with 2,076 houses completely destroyed and 6,696 sustaining varying degrees of damage. The financial consequences were substantial, with estimated losses reaching a staggering RM2.9 billion. The 2014 flood highlights the urgent need to address these concerns in a thorough manner and create methods that reduce the impact on communities during similar climatic occurrences.

Additionally, Kelantan's susceptibility to the monsoon flood, which is a result of prolonged and heavy rainfall during the Northeast Monsoon (MTL), gets worse. The annual observation of this phenomenon between November and March highlights the region's vulnerability to changes in climate, emphasising the need for continuous endeavours to strengthen disaster preparedness, response systems, and infrastructure resilience.

According to the special report on the impact of floods in Malaysia for the year 2022 by the Department of Statistics Malaysia (DOSM), (DOSM, 2023), Kelantan has undergone significant and far-reaching consequences across various sectors. The extent of these impacts encompasses substantial losses in living quarters, vehicles, business premises, manufacturing, agriculture, and infrastructure. The cumulative financial toll resulting from these repercussions surpassed RM 150 million. This marked contrast is particularly notable when compared to the total losses incurred in the preceding year, 2021, which amounted to RM 21 million, as detailed in Table 6-1 of the report. The substantial increase in losses highlights the severity of the flood impact on Kelantan's socio-economic landscape during the specified period.

Table 6-1: Value of Flood Losses for Kelantan

	2021 (RM)	**2022 (RM)**
Loss in Living Quarters	15,992,000.00	44,434,000.00
Loss of Vehicles	1,456,000.00	2,033,000.00
Loss of Business Premises	4,535,000.00	18,323,000.00
Loss in Manufacturing	Not Available	1,154,000.00
Loss in Agriculture	Not Available	66,034,000.00
Loss in Infrastructure	Not Available	21,140,000.00
Total Loss	21,984,000.00	153,120,000.00

As of 2014, NAHRIM data indicates that there were nine operational hospitals in Kelantan providing healthcare services (refer to Table 6-2 and Figure 6-3 for hospital names and locations).

Table 6-2: Hospital List in Kelantan

No	Hospital ID	Hospital Name	Longitude	Latitude
1	H1	Hospital Tumpat	102.1572	6.189896
2	H2	Hospital Tengku Anis, Pasir Puteh	102.3875	5.832866
3	H3	Hospital Tanah Merah	102.1525	5.809696
4	H4	Hospital Raja Perempuan Zainab II, Kota Bharu	102.2457	6.125567
5	H5	Hospital Pasir Mas	102.1191	6.014316
6	H6	Hospital Machang	102.2249	5.763276
7	H7	Hospital Kuala Krai	102.1993	5.535636
8	H8	Hospital Jeli	101.8445	5.701156
9	H9	Hospital Gua Musang	101.9547	4.858255

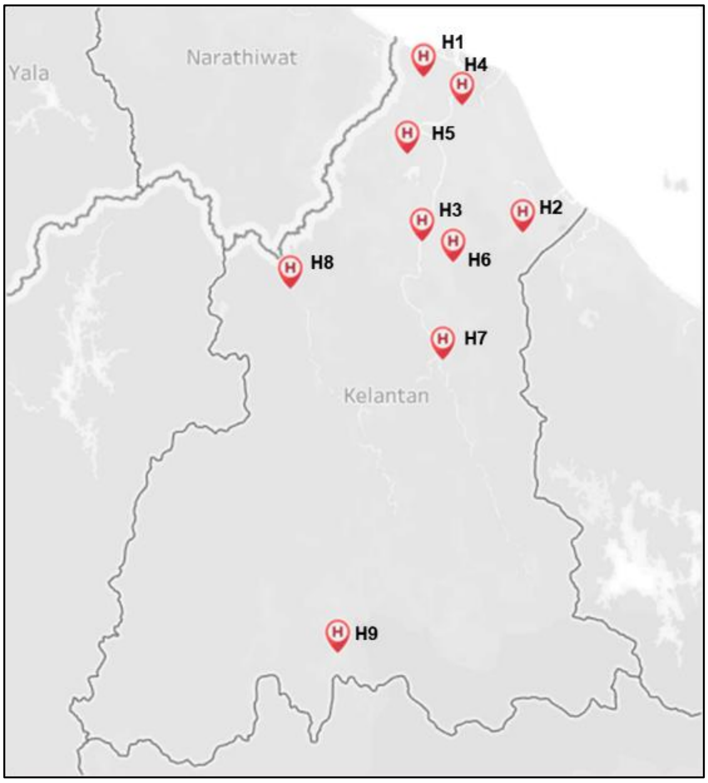


Figure 6-3: Hospital Location in Kelantan

6.4.2 Criteria Identification and Selection

In this study, criteria were determined based on six factors derived from previous research and consultation with NAHRIM experts. The criteria of rainfall volume and land use size area were selected based on studies conducted by Hammami et al. (2019), Khosravi, Khabat et al. (2019), Toosi et al. (2019), Lyu et al. (2019), Mahmoud, Shereif H and Gan, Thian Yew (2018), and Pilon (2002). These studies recognise the importance of considering rainfall intensity and area size in FMP. Additionally, studies by Kansal et al. (2019), Lin, Lin et al. (2019), de Brito et al. (2018), and Levy et al. (2007) have demonstrated the importance of distance in flood mitigation and susceptibility studies within the FMP.

Three criteria were introduced in this study based on consultation with NAHRIM experts: rainfall risk score, land use risk score, and access to facility risk score. By inverting the method from Huang et al. (2022), Adnan and Zainol (2022) recommended using the Rainfall Variability Index (RVI) to derive the criteria for the rainfall risk score. Zainol (2022) proposed the land use risk score and the access to facility risk score, with the former based on expert determination and the latter on average distance. Table 6-3 provides a summary of the criteria employed in this study, and in subsection 6.5.3.1 Rainfall Risk Score (RRS) Index Calculation, the details of the criteria for risk score calculation are explained.

Table 6-3: Criteria Selection

No	Criteria	Reference
1	Rainfall Volume	Hammami et al. (2019), Khosravi, K. et al. (2019), Toosi et al. (2019), Lyu et al. (2019),Mahmoud, S. H. and Gan, T. Y. (2018) and Pilon (2002)
2	Land use Size Area	
3	Distance from current facility	Kansal et al. (2019), Lin, Lin et al. (2019), de Brito et al. (2018) and Levy et al. (2007)
4	Rainfall Risk Score	Adnan and Zainol (2022)
5	Land use Risk Score	Zainol (2022)
6	Access to Facility Risk Score	

6.4.3 Data Source

6.4.3.1 Observed Rainfall Data

The Department of Irrigation and Drainage of Malaysia (DID Malaysia) collected observed rainfall data on rainfall intensity from various rainfall stations on an hourly basis. This data, spanning from 2000 to 2019, includes both annual and monthly rainfall intensities. The data was gathered from 75 rainfall stations, but after data quality checks, only 30 stations were used. The details of this process are discussed in subsection 6.5.2 Phase 3: Data Processing. To determine monthly and yearly rainfall intensities for each grid in Kelantan, an interpolation tool in ArcGIS 10.5 was employed.

6.4.3.2 Projected Rainfall Data

The projected rainfall data for Kelantan was obtained from the Malaysia Climate Change Knowledge Portal (N-HyDAA), developed by NAHRIM. The N-HyDAA provides downscaled projected data for Malaysia, presented in a gridded format with a cell size of 6 km x 6 km. These data are derived from Peninsular Malaysia AR5 Precipitation Daily Data (PM-AR5), a downscaled dataset originating from the Global Climate Model (GCM) and provided by the Intergovernmental Panel on Climate Change (IPCC), an intergovernmental body of the United Nations. This dataset includes a 100-year projection of rainfall.

The same methodology used to calculate monthly and annual rainfall intensity for observed rainfall data was applied to the projected rainfall data. The projected data was prepared based on the Representative Concentration Pathway (RCP). RCP is based on four different climate scenarios based on different assumptions about population, economic growth, energy consumption and sources, and land use over this century (AgriMetSoft, 2020). These scenarios are named RCP2.6, RCP4.5, RCP6, and RCP8.5. NAHRIM employs these models for modelling and predicting future climate in various projects related to the environment, water resources, and climate change. For more detailed information on these climate models, please refer to Table 6-4.

Table 6-4: Climate Model

No	Climate Model	Explanation
1	RCP 2.6	Low emissions
2	RCP 4.5	Intermediate emissions
3	RCP 6.0	Intermediate emissions
4	RCP 8.5	High emissions

6.4.3.3 Land use Data

The land use data for 2020 used in this study was obtained from DID Malaysia and contains information on various land use activities. Initially, the data included seven land use categories: (1) Forest, (2) Livestock & Aquaculture, (3) Mining, (4) Water Body, (5) Agricultural, (6) Urban Land, and (7)

Miscellaneous. However, after consultation with NAHRIM, six specific land use activities were selected for this study.

It is acknowledged that the land use data used in this study is outdated for two main reasons. Firstly, the data is considered highly confidential, leading to restricted access and requiring approval, potentially causing delays in the data acquisition process. Secondly, the data was simply unavailable at the time of conducting this study. Thus, to avoid delays and interruptions, data provided by DID Malaysia was used. It's important to note that the prototype used has the capability to update the land use map layer if a newer and more current version becomes available in the future. The details of the pre-processing of land use data are discussed in subsection 6.5.2.3 Land use Data.

6.4.3.4 Health and Safety (H&S) Facility Data

The Health and Safety (H&S) facility data collected from NAHRIM includes location information for six categories of facilities: (1) Evacuation Centres; (2) Major Specialist Hospitals; (3) Non-Specialist Hospitals; (4) State Hospitals; (5) Government Clinics; and (6) Community Clinics. Although these facilities served different purposes, for this study, they were grouped into three major categories:

a. Evacuation Centre;
b. Clinic; and
c. Hospital

While the hospital in Kelantan is the main case study in this study, other facilities have also been processed and may be subject to future analysis. Based on the data provided, the total number of H&S facilities in Kelantan is 511 (refer to Table 6-5). Detailed information on the data processing of H&S facility data is discussed in subsection 6.5.2.4 Health and Safety (H&S) Facility Data.

Table 6-5: List of H&S Facilities in Kelantan

No	Health & Safety Facility Category	Total
1	Evacuation Centre	248
2	Clinic	254
3	Hospital	9
Total		511

6.4.3.5 Gridded Map of Peninsular Malaysia and Kelantan

Gridded maps of Peninsular Malaysia and Kelantan served as the base maps during the data pre-processing and processing stages, as shown in Figure 6-4 and Figure 6-5. These maps were used to prepare data in gridded format for the following purposes:

a. to calculate RSS index value for observed and projected rainfall,
b. to obtain data on observed and projected rainfall amounts,
c. to determine LRS index value for each land use category,
d. to calculate an ULSA value, and
e. to calculate an AFRS index value.

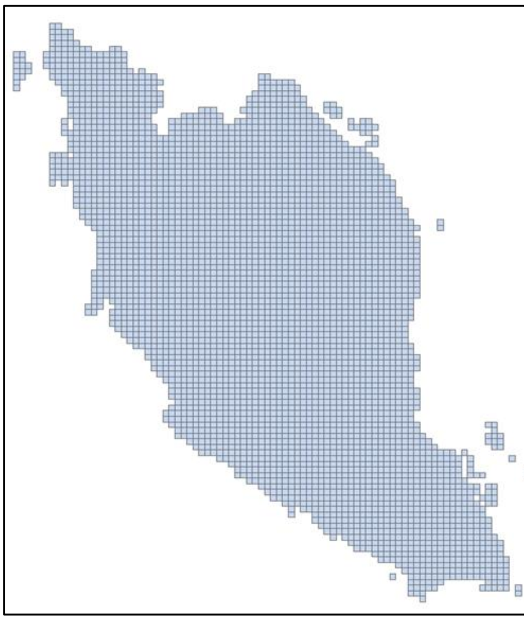


Figure 6-4: Peninsular Malaysia Gridded Map (3990 grid)

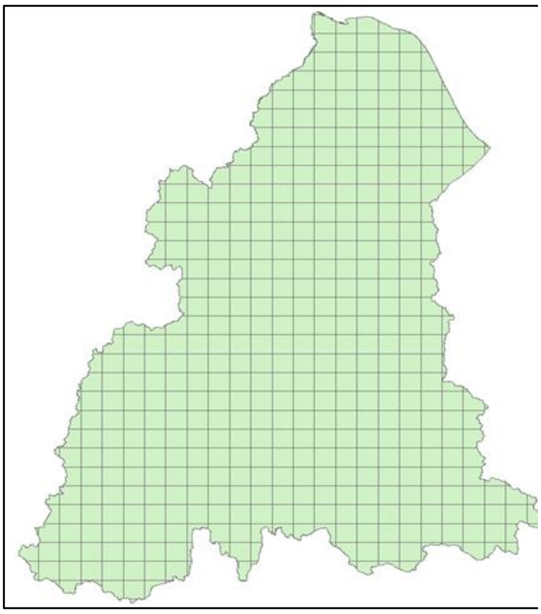


Figure 6-5: Kelantan Gridded Map (497 grid)

The data utilised in this study, including the year, format, and data owner, are summarised in Table 6-6.

Table 6-6: List of Data Source

No	Data	Year	Data Format	Data Owner	Explanation
1	Observed Rainfall	2000-2019	Non-spatial tabular data in CSV format	DID Malaysia	Observed rainfall data collected from a rainfall stations in Kelantan (refer to Table 6-11: Rainfall Station in Kelantan)

No	Data	Year	Data Format	Data Owner	Explanation
2	Projected Rainfall (downscaled from Global Climate Model Data)	2010-2099	Tabular data in CSV format	IPCC (UN) & NAHRIM (Malaysia)	Projected rainfall data (AR5) based on gridded 6 km x 6 km
3	Propose Land use 2020	2020	Spatial (vector-polygon)	DID Malaysia	Describe the various types of land use activities
4	Health and Safety Facility	2014	Spatial Data (vector-points)	NAHRIM Malaysia	Location of 3 types of H&S facilities (hospital, clinic, and evacuation centre)

6.4.4 Prototype Validation: Content Validity Index (CVI)

The Content Validity Index (CVI) was utilised as a tool to validate the recommended location, utilising an expert's participatory approach. The validation process relied on the judgement of experts. CVI assesses the degree to which an instrument includes an appropriate sample of items for the construct being measured (Polit and Beck, 2006). Content validity is achieved by clearly conceptualising the underlying construct of a test or instrument and defining clear evidence of the operational components (Polit et al., 2007).

The suggestion to use the CVI was motivated by its ease of use and straightforward steps, which facilitate the incorporation of experts' opinions when validating the recommended location. The objective of the expert evaluation was to validate and assess the potential utility and adaptability of the prototype in the decision-making process.

6.4.4.1 Context Validity Index (CVI)

For validation purposes, the CVI validation items were configured to enable experts to rate them based on their knowledge and expertise. The focus was directed towards the case study criteria, resulting in the identification of the six specific validation items listed in Table 6-7.

Table 6-7: Content Validity Index Item

No	Validation Item	Item ID
1	The amount of projected rainfall in the proposed location is acceptable.	I1
2	The rainfall risk score of the proposed location is acceptable.	I2
3	The land use risk score of the proposed location is acceptable.	I3
4	The size of the urban area of the proposed location is acceptable.	I4

5	The risk score of the proposed location to access the nearest health and safety facilities is acceptable.	I5
6	The distance of the proposed location with nearest health and safety facility is acceptable.	I6

6.4.4.2 Content Validity Index Steps

To conduct the CVI, the study followed the five steps outlined below:

Step 1: The content validation form was prepared.

Step 2: Experts were identified.

Step 3: Content validation was conducted through face-to-face and online interactions.

Step 4: The experts critically reviewed and validated the items.

Step 5: The CVI is calculated.

Experts were chosen through a combination of individuals from previous studies in Chapters 3 and 4 and the addition of new experts to gather fresh insights and opinions. The selection of experts encompassed multidisciplinary backgrounds, all with involvement in FMP across various contexts. The list of experts is provided in Table 6-8.

Table 6-8: Experts for Validation

No	Expert	Years of Experience	Agency
1	Expert 1	14	Centre of Data and Information Universiti Malaysia Sabah
2	Expert 2	15	Research Centre for Technology and Management, Universiti Kebangsaan Malaysia
3	Expert 3	13	National Water Research Institute of Malaysia (NAHRIM)
4	Expert 4	14	National Water Research Institute of Malaysia (NAHRIM)
5	Expert 5	13	National Water Research Institute of Malaysia (NAHRIM)
6	Expert 6	14	Ministry of Health Malaysia
7	Expert 7	20	National Water Research Institute of Malaysia (NAHRIM)
8	Expert 8	14	Department of Irrigation and Drainage Malaysia (DID, Malaysia)
9	Expert 9	15	Malaysian Administrative Modernisation and Management Planning Unit (MAMPU)
10	Expert 10	15	Ministry of Health Malaysia
11	Expert 11	11	Universiti Sultan Zainal Abidin

Based on the validity items listed in Table 6-7, experts were tasked with providing scores and feedback to evaluate the relevance of each item (refer to Appendix H for the CVI form). The scoring for these items ranged from 1 to 4, where 1 indicated “Not Agree”, 2 indicated “Somewhat Agree”, 3 indicated “Quite Agree”, and 4 indicated “Strongly Agree”. Upon receiving the scores, the scale was recoded (refer to Figure 6-6, Recode Scale), and the CVI was calculated. Figure 6-6 explains the steps involved in the CVI calculation. The calculation of the CVI involves two formulas, which are:

a. Formula 1: Calculate the Item-Content Validity Index (I-CVI)

$$\textit{I-CVI} = \frac{\textit{Agreed Item}}{\textit{Number of Experts}}$$

Where Agreed Item = is an item where there is a consensus among the experts that it effectively captures the concept being measured and is suitable for inclusion in the instrument

b. Formula 2: Calculate the Scale-Content Validity Index (S-CVI)

$$\textit{S-CVI} = \frac{\textit{Sum I-CVI}}{\textit{Number of Items}}$$

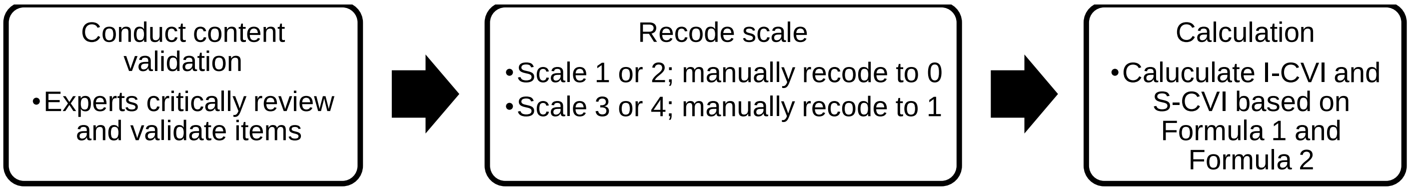


Figure 6-6: Step for CVI Calculation

Table 6-9 displays the number of experts and its implications for the acceptable cut-off score of the CVI.

Table 6-9: CVI Acceptable Cut-Off Score

Number of Experts	Acceptable CVI Values	Source of Recommendation
Two experts	At least 0.80	Davis (1992)
Three to five experts	Should be 1	Polit and Beck (2006), Polit et al. (2007)
At least six experts	At least 0.83	Polit and Beck (2006), Polit et al. (2007)
Six to eight experts	At least 0.83	Lynn, M. (1986)
At least nine experts	At least 0.78	Lynn, M. (1986)

6.5 Development of Combined Spatial-MCDA Decision Support System

This subsection discusses the development of the SDSS prototype, which served as the platform and tool to aid decision-makers in the case study analysis. The development process consisted of five phases: 1) Data Collection, 2) Data Pre-Processing, 3) Data Processing, 4) Data Analysis, and 5) Data Visualisation, with each phase involving specific activities.

Throughout the development, three software packages were utilised: ArcGIS 10.5, Alteryx, and Tableau. ArcGIS 10.5 was employed for spatial data processing tasks in the Data Pre-Processing and Data Processing phases. Alteryx and Tableau were extensively used in the Data Analysis phase, including the calculation of the RRS index, LRS values, and AFRS index. Additionally, these software packages were used in computing the weight and rank of the proposed location using the proposed MCDA techniques.

In the fifth phase, Data Visualisation, Tableau was also employed to create a dashboard-style presentation of the results. This dashboard offered an analysis of location rankings and displayed information from the six criteria through the multi-layer maps feature. For a detailed explanation of these phases, activities, and software used in the prototype development, refer to Table 6-10.

Table 6-10: Prototype Development Phase and Software Used

No	Development Phase	Activity	Software
1	Data Collection	Determine the availability and feasibility of the data.	Not Applicable
2	Data Pre-Processing	Perform data quality checking, which involves: a. Data Cleansing; b. Data Transformation; and c. Data Validation	ArcGIS 10.5
3	Data Processing	Prepare gridded maps of observed and projected rainfall data based on average rainfall volume.	ArcGIS 10.5
		Prepare a gridded map of land use data based on six land use categories.	
		Prepare a gridded map of health and safety facilities based on three health and safety facility categories.	

No	Development Phase	Activity	Software
4	Data Analysis	Calculation of the Rainfall Risk Score (RRS) Index for observed and projected rainfall data based on the RVI method	Alteryx and Tableau
		Calculation of the Land use Risk Score (LRS) Index for land use data based on the average risk value for each land use size area over the number of land use categories	
		Calculation of the Access to Health and Safety (H&S) Facility Risk Score (AFRS) Index for access to health and safety facility data based on the distance from the nearest H&S facility	
		Rank the proposed locations using four MCDA techniques: WSM, AHP, VIKOR, and TOPSIS.	
5	Data Visualisation	Dashboard development based on multi-layer maps that visualise the ranking result, risk score, and data of the six criteria	Tableau

The next subsection will explain in detail the activities involved in Phases 2, 3, 4, and 5 for the data employed in this development. As for Phase 1: Data Collection, the data used will be based on the discussion in subsection 6.4.3 Data Source.

6.5.1 Phase 2: Data Pre-Processing

6.5.1.1 Observed Rainfall Data

As discussed in subsection 6.4.3.1 Observed Rainfall Data, it was determined that only 30 rainfall stations had complete data for the 20-year period from 2000 to 2019, as illustrated in Figure 6-7. Based on the data from these rainfall stations, a spatial analysis tool called the interpolation method was applied to estimate the rainfall data value for each cell. Interpolation is a method used to estimate or assume values at a location without measuring the data (Aminu et al., 2015; Narany et al., 2016). The final list of rainfall stations is listed in Table 6-11.

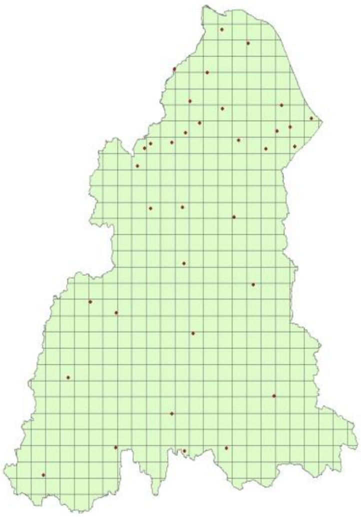


Figure 6-7: Kelantan Rainfall Station Location

Table 6-11: Rainfall Station in Kelantan

No	Station ID	Station Name	Long.	Lat.
1	6122064	Stor JPS. Kota Bharu	102.2569	6.10833
2	6021010	Rumah Pam Repek	102.1028	6.0125
3	6019004	Rumah Kastam.	101.9792	6.0236
4	5923081	Tok Ajam	102.3819	5.90417
5	5824081	Sg. Petai	102.4152	5.8306
6	5824080	Kg. Beris	102.4944	5.8597
7	5823077	Ldg. Cherang Tuli	102.3639	5.81806
8	5821007	Stn. Keretapi Bkt. Panau	102.1583	5.89167
9	5820006	Bendang Nyior	102.0736	5.84444
10	5820005	Pej.P'Tani Btg. Merbau	102.0208	5.8125
11	5723056	Telusan	102.3222	5.75833
12	5722057	JPS Machang	102.2194	5.7875
13	5719001	Kg. Durian Daun	101.9681	5.78056
14	5718002	Air Lanas	101.8889	5.775
15	5718001	Kg. Gemang Bahru	101.8667	5.76111

No	Station ID	Station Name	Long.	Lat.
16	5522047	JPS Kuala Krai	102.2028	5.53194
17	5520001	Ulu Sekor	102.0083	5.56389
18	5518035	Lubok Bungor	101.8889	5.56111
19	5322044	Kg. Lalok	102.275	5.3083
20	5320038	Dabong	102.0153	5.3778
21	5217001	Pasik	101.7597	5.2139
22	5216001	Gob	101.6625	5.25139
23	5120025	Balai Polis Bertam	102.0486	5.14583
24	4923001	Kg. Aring	102.3528	4.9375
25	4915001	Chabai	101.5792	5
26	4819027	Gua Musang	101.9694	4.8792
27	4721001	Upper Chiku	102.1736	4.76528
28	4720026	Ldg. Mentara	102.0167	4.75556
29	4717001	Blau	101.7569	4.76667
30	4614001	Brook	101.4847	4.67639

6.5.1.2 Projected Rainfall Data

In this phase, the Kelantan gridded map and PM-AR5 precipitation data served as input data. Using the ArcGIS 10.5 software, these input data were joined to generate CSV-formatted data for Kelantan AR5 projected data. Figure 6-8 and Figure 6-9 depict examples of projected rainfall data patterns for Kelantan (monthly) during the periods of 2010–2039 and 2040–2069. The projected rainfall data was based on four climate scenarios (RCP2.6, 4.5, 6.0, and 8.5), focusing on Northeast Monsoon months.

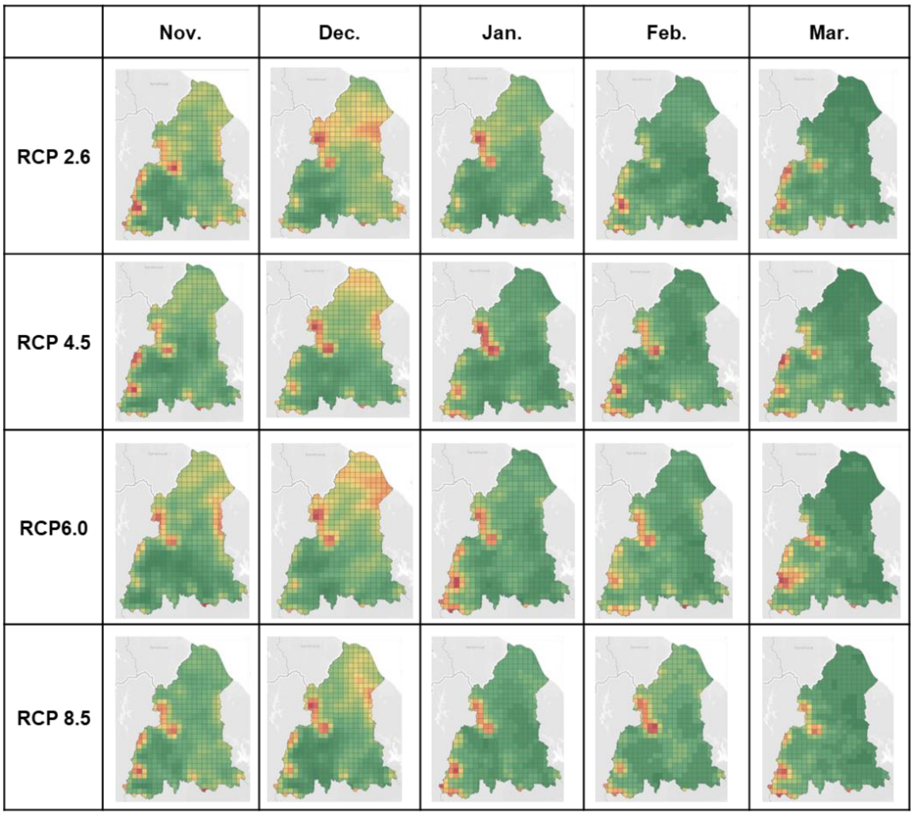


Figure 6-8: Projected Rainfall Pattern for 2010-2039

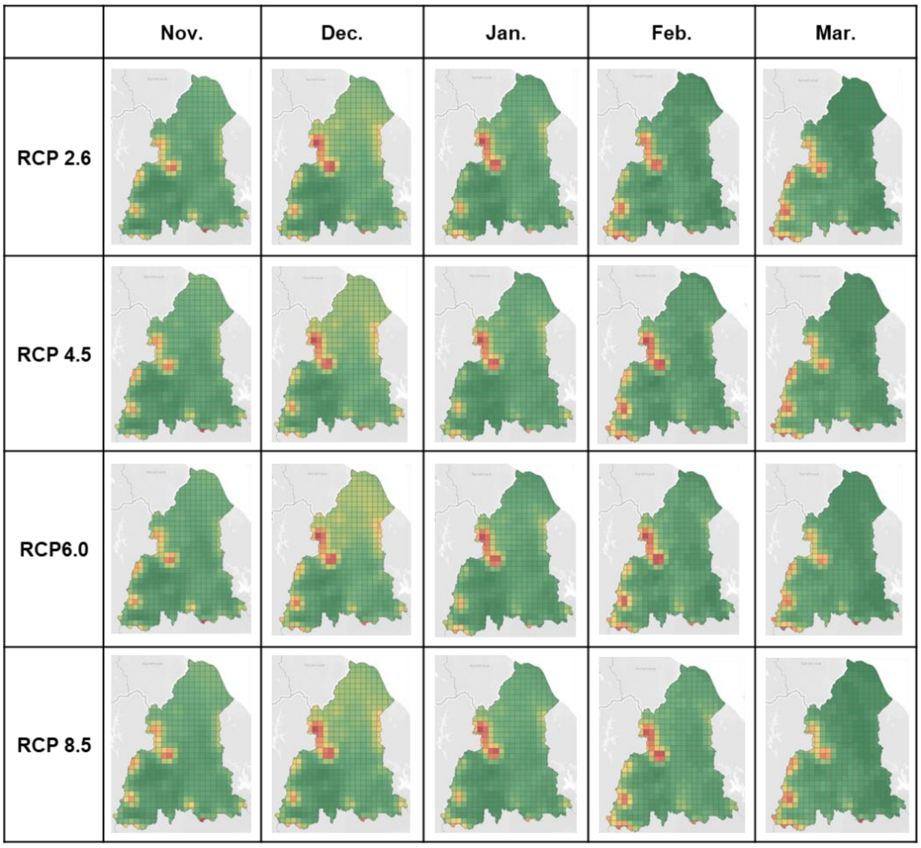


Figure 6-9: Projected Rainfall Pattern for 2040-2069

6.5.2 Phase 3: Data Processing

6.5.2.1 Observed Rainfall Data

In this phase, the focus is on preparing yearly and monthly gridded maps in shapefile format based on average rainfall. For observed rainfall data, the Average Yearly and Monthly values were calculated using a 5-year interval (2000–2004, 2005–2009, 2010–2014, and 2015–2019), in alignment with the approach currently utilised by NAHRIM. The steps involved in preparing the Yearly and Monthly gridded maps in shapefile format are as follows:

a. Calculate the Yearly and Monthly averages for each 5-year period (2000–2004, 2005–2009, 2010–2014, and 2015–2019),
b. Perform interpolation to convert point rainfall data to gridded rainfall data,
c. Extract points (centroids) from the interpolated map for each grid; and
d. Joint Kelantan grid polygon with extracted points to create a Yearly and Monthly gridded map in shapefile format for Kelantan.

6.5.2.2 Projected Rainfall Data

Similar activities were carried out for projected rainfall data, but the Average Yearly and Monthly values were calculated based on a 30-year interval (2010–2039, 2040–2069, and 2070–2099) as recommended by NAHRIM. The steps involved in preparing the Yearly and Monthly gridded maps in shapefile format for projected rainfall data are as follows:

a. Calculate the Yearly and Monthly averages over a 30-year period (2010-2039, 2040-2069, and 2070-2099);
b. Perform interpolation to convert point rainfall data to gridded rainfall data;
c. Extract points (centroids) from the interpolated map for each grid; and
d. Joint Kelantan grid polygon with extracted points to create a yearly and monthly gridded shapefile for Kelantan.

6.5.2.3 Land use Data

Based on the discussion in subsection 6.4.3.3 Land use Data, for the purpose of this study, only six significant land use categories were considered. These revised land use categories are as follows:

a. Urban;
b. Transport;
c. Institutional and Public;
d. Water Body;
e. Agricultural; and
f. Forest

Figure 6-10 exhibits the original map of proposed land use data for 2020, while Figure 6-11 shows the revised land use map used for this study. The details on land use categories are tabulated in Table 6-12, and Figures 6-12 through 6-17 illustrate each land use category in Kelantan based on the revised map.

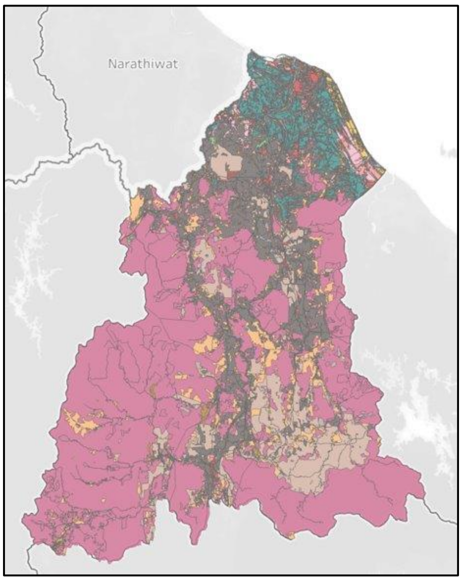


Figure 6-10: Propose Kelantan Land use 2020 (original)

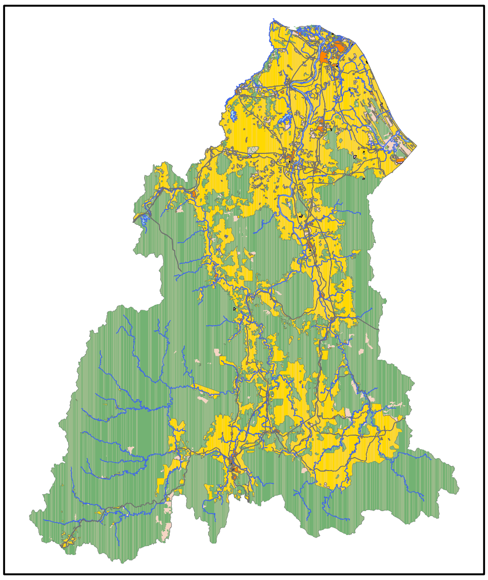


Figure 6-11: Kelantan Revised Land use Data

Table 6-12: Land use Activities in Kelantan

No	Land use Category	Area Size (km2)	Percentage (%)
1	Forest	9,258.91	63.28
2	Agricultural	5,003.27	34.20
3	Water Body	182.85	1.25
4	Urban	100.67	0.69
5	Transport	77.92	0.53
6	Institutional & Public	7.45	0.05
Total		14,631.07	100

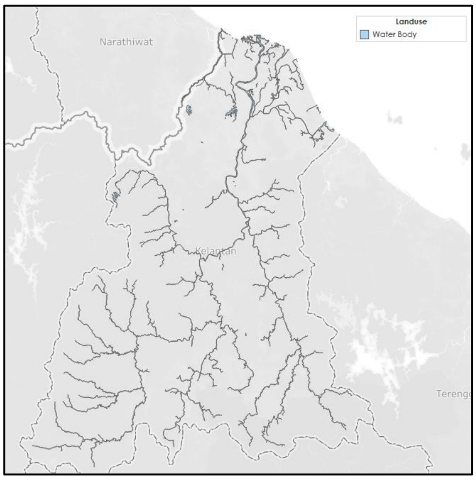


Figure 6-12: Kelantan Water Body Area

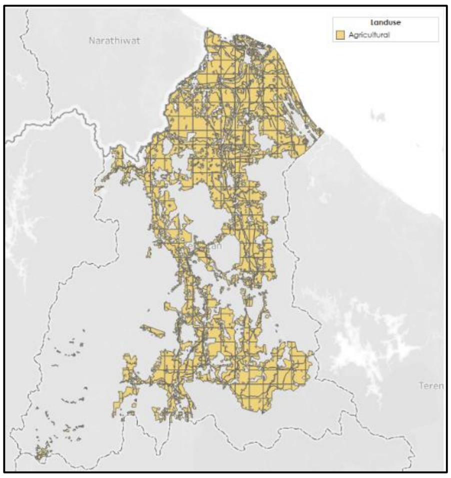


Figure 6-13: Kelantan Agriculture Area

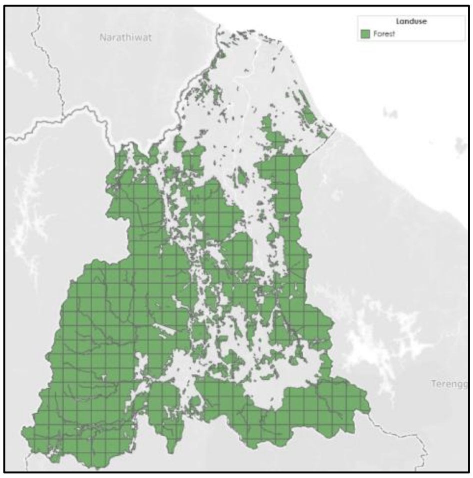


Figure 6-14: Kelantan Forest Area

Figure 6-15: Kelantan Institutional & Public

Figure 6-16: Kelantan Transport Area

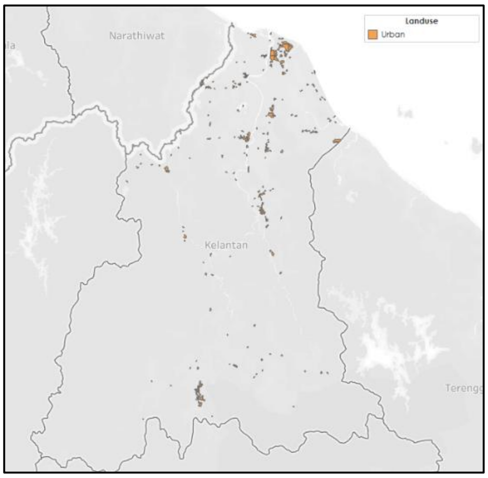


Figure 6-17: Kelantan Urban Area

6.5.2.4 Health and Safety (H&S) Facility Data

Based on the H&S facility data as shown in Table 6-5, the location of 511 H&S facilities in Kelantan has been mapped in spatial format, as shown in Figure 6-18, Figure 6-19, and Figure 6-20. The location of each facility is based on longitude and latitude data. While the hospital is the primary focus of this case study, data on evacuation centres and clinics is also available for potential future case studies.

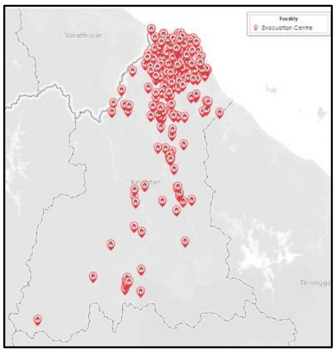


Figure 6-18: Evacuation Centre Location

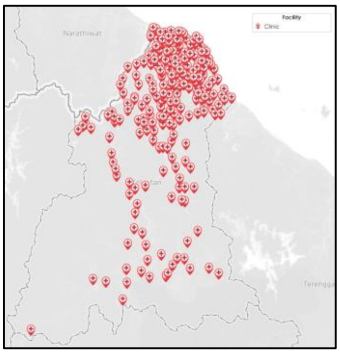


Figure 6-19: Clinic Location

Figure 6-20: Hospital Location

6.5.3 Phase 4: Data Analysis

The Data Analysis phase involved the computation of the risk score index for observed and projected rainfall, land use, and access to H&S facilities. For rainfall data (observed and projected), the RRS for each grid cell was calculated using the Rainfall Variability Index (RVI) method. The LRS was calculated by taking the average of the risk values for each land use category within a grid cell, considering the size of the area and the number of land use categories. The risk value for each land use category was determined by experts. The AFRS, on the other hand, was calculated based on the distance to the nearest facility, determining the risk score index for each grid cell.

Additionally, computations were performed to rank the proposed locations using the selected MCDA techniques. Detailed information on these calculations can be found in subsection 6.5.3.4.

6.5.3.1 Rainfall Risk Score (RRS) Index Calculation

The RRS index was calculated to assess the risk level in each grid, with higher RRS values indicating a higher vulnerability to flooding. The RRS was calculated using both observed and projected rainfall data.

The Rainfall Vulnerability Index (RVI) was used as a tool for precipitation analysis, categorising the study time series into four climatic stages: Extreme Dry, Dry, Normal, and Wet periods (Gocic and Trajkovic, 2013). As recommended by NAHRIM's experts, these four climate stages were adjusted to Extreme Wet, Wet, Normal, and Dry.

The steps involved in calculating the RRS for observed and projected rainfall are as follows:

a. Calculate the average rainfall and standard deviation,
b. Calculate RVI and assign it to the corresponding RVI category,
c. Determine the maximum and minimum RVI values; and
d. Normalise the RVI value.

The mathematical equation for calculating the RVI is as follows:

(i) RVI Calculation

$$RVI = \frac{Rainfall \ - \ Rainfall\,Average}{Rainfall\,Standard\,Deviation}$$

where:

Rainfall: actual rainfall value,

Rainfall Average: the average or mean of rainfall values over a given period of time,

Rainfall Standard Deviation: the measure of the amount of variation or dispersion of rainfall values from the average.

(ii) RVI Normalised

$$RVI = \frac{(RVI - RVI_{min})}{(RVI_{max} - RVI_{min})}$$

where:

- RVI: the original RVI value calculated using the formula RVI,
- RVI_{min}: the minimum value of RVI observed,
- RVI_{max}: the maximum value of RVI observed.

6.5.3.2 Land use Risk Score (LRS) Index Calculation

The LRS index was computed to assess the level of risk in each grid cell, with higher LRS values indicating a higher vulnerability to flooding. The LRS is dynamic, meaning that the risk value can change based on the expertise and knowledge of the experts. The objective of the LRS is to identify risk areas on the gridded map and determine the degree of risk based on land use categories.

Different land use activities have varying effects on surface runoff, which contributes to flooding. The nature of land use, such as urban development or agricultural practices, plays a crucial role in altering the natural flow of water. Improper land use can lead to increased surface runoff, exacerbating the risk of flooding as water is not effectively absorbed or channelled, posing challenges for flood management and mitigation efforts. A LRS provides a quantifiable measure of the potential impact of different land use activities on surface runoff and, consequently, flooding. By assigning scores to various land use types based on their risk levels, decision-makers can prioritise areas for targeted interventions or implement land use planning strategies that mitigate flood risk. Using the land use gridded map prepared in the Data Pre-Processing phase, the following steps were taken to calculate the LRS:

a. Experts determined the risk value for each land use category.
b. Data layers were merged and combined.
c. The area size for each land use category in each grid was calculated.
d. The LRS was calculated.

The LRS was calculated using the average area of land use risk values for each land use category in each grid. In this study, the LRS is dynamic, meaning the risk value can change based on the expertise and knowledge of the experts.

The mathematical equation to calculate the LRS is as follows:

(i) Calculate Land use Area Size

$$\text{Land use Risk Score} = \Sigma\ (\text{Risk Value x Area Size}) \,/\, \text{Total Size Area}$$

where:

- Σ indicates the sum of the individual products of *Risk Value* and *Area Size* for each land use category.
- *Risk Value* is the value assigned to a specific land use category based on its level of risk.
- *Area Size* is the size of the land area covered by the particular land use category.
- *Total Size Area* is the total size of the area being evaluated, which is the sum of the sizes of all the land use categories.

In this formula, the LRS is calculated by summing the product of Risk Value and Area Size for each land use category and then dividing this sum by the total size of the area being evaluated. This calculation provides a single numerical value that represents the overall risk associated with the different land use categories in the area.

6.5.3.3 Access Facility Risk Score (AFRS) Index Calculation

The AFRS index is calculated with the assumption that a grid cell is more vulnerable to flooding as its AFRS value rises. The purpose of calculating the AFRS is to determine the degree of risk for each grid based on its proximity to H&S facilities. A higher AFRS score for a specific grid suggests either a lack of H&S facilities in the vicinity or a substantial distance from existing facilities.

The AFRS index increases as the distance between the centre of the grid and the nearest H&S facility increases, signifying a higher level of risk. Conversely, the AFRS index decreases as the distance to an existing H&S facility decreases, indicating a lower level of risk for that grid. This assessment helps identify areas that may have limited access to critical health and safety facilities during flood events. The steps involved in calculating the AFRS are as follows:

a. Create a Voronoi or Thiessen polygon,
b. Identify the largest polygon created,
c. Determine the longest distance from the largest polygon and assign it a score of 1,
d. Identify additional locations and assign a risk score based on their distances from the longest distance (with scores ranging from 0 to 1),
e. Perform interpolation,
f. Extract multiple values to point; and
g. Convert data points into gridded data.

6.5.3.4 Multi-criteria Decision Analysis Computation

Four MCDA techniques were employed in this study: WSM, AHP, VIKOR, and TOPSIS. These techniques were applied to rank the proposed locations using the same criteria and input from experts. Subsequently, a recommended location was identified, which underwent additional analysis and validation by experts to evaluate its feasibility for the construction of a new hospital.

6.5.3.4.1 Weight-Sum Model (WSM)

The WSM is a simple and common technique used in MCDA. Its popularity stems from its simplicity, transparency, and adaptability to various decision-analysis problems.

In the WSM, each criteria is treated as independent and equally important. Weights are assigned to each criteria to reflect its relative importance. These weights are determined based on the perceived significance of each criterion in the decision-making process. The weighted scores for each option are then calculated by combining the scores for each criteria, resulting in a final score or ranking for each option (Abdullah, L. and Adawiyah, 2014).

The WSM provides a clear and explicit way to assess and rank options based on multiple criteria, allowing decision-makers to easily understand and modify the weights and scores to align with their preferences and priorities. The steps involved in the WSM are as follows:

a. Step 1: Define the decision problem and criteria - Identify the decision problem and the relevant criteria that will be used to evaluate the options.
b. Step 2: Assign weights to criteria - Assign weights to each criteria based on their relative importance to the decision-makers. The weights should add up to 1.
c. Step 3: Evaluate the options - Evaluate each option on each criteria and assign a score to each option. The scores should be based on objective data or expert opinion and should be scaled consistently across all criteria.
d. Step 4: Calculate the weighted scores - Multiply each criteria score by its corresponding weight and sum up the weighted scores for each option.
e. Step 5: Rank the options - Rank the options based on their total weighted score, from highest to lowest. The option with the highest score is considered the best option.

The mathematical equation for WSM is expressed as:

$$S(i) = w1 * x1(i) + w2 * x2(i) + \dots + wn * xn(i)$$

where;

- $S(i)$ is the final score or ranking for option i,
- $w1, w2 \dots wn$ are the weights assigned to criteria $1, 2 \dots n$ respectively, and
- $x1(i), x2(i), \dots, xn(i)$ are the scores or values assigned to option i for criteria $1, 2, \dots, n$ respectively.

6.5.3.4.2 AHP

The same technique that was employed in Chapter 4, sub-section 4.4.2.1 Analytical Hierarchical Process (AHP), is also being used in this case study.

6.5.3.4.3 TOPSIS

The TOPSIS technique is widely recognised and utilised by decision-makers as a valuable tool for evaluating and ranking options in a transparent and objective manner (Zhao et al., 2022). One notable advantage of TOPSIS is its versatility in accommodating both qualitative and quantitative criteria, enabling decision-makers to incorporate a diverse range of factors into their decision-making process (Rouyendegh and Saputro, 2014). This flexibility empowers decision-makers to make more informed and comprehensive decisions.

The fundamental principle underlying the TOPSIS technique is to rank options based on their proximity to the ideal solution while simultaneously being distant from the negative ideal solution (Behzadian et al., 2012). By considering both the positive and negative ideal solutions for each criteria, TOPSIS ensures a comprehensive evaluation of the options. This approach facilitates decision-makers identification of the most favourable option that possesses the optimal combination of criteria and is farthest from the least desirable outcomes.

The steps involved in TOPSIS are as follows:

a. Step 1: Define the decision problem and criteria by identifying the decision problem and the relevant criteria that will be used to evaluate the options.
b. Step 2: Normalise the decision matrix to eliminate the effect of different units or scales used for each criteria. This involves dividing each value in the decision matrix by the corresponding maximum criteria.
c. Step 3: Construct the weighted normalised decision matrix by multiplying each normalised value in the matrix by its corresponding weight, reflecting its relative importance to the decision-makers.
d. Step 4: Determine the ideal and negative ideal solutions. Identify the ideal solution, which represents the best possible performance on each criteria, and the negative ideal solution, which represents the worst possible performance on each criteria.
e. Step 5: Calculate the distance from the ideal and negative ideal solutions. Calculate the Euclidean distance from each option to the

ideal solution and the negative ideal solution. The distance is calculated as the square root of the sum of the squared differences between each criteria value for the option and the ideal or negative ideal value.

f. Step 6: Calculate the relative closeness to the ideal solution. Calculate the relative closeness of each option to the ideal solution as the ratio of the negative ideal distance to the sum of the ideal and negative ideal distances. The relative closeness ranges from 0 to 1, with values closer to 1 indicating a higher relative ranking.

g. Step 7: Rank the options: Rank the options based on their relative closeness to the ideal solution, from highest to lowest. The option with the highest relative closeness is considered the best option, according to the decision-makers.

The mathematical equation for each step is as follows:

Step 1: Define the decision problem and identify the criteria.

Step 2: Normalise the decision matrix.

$$r_{ij}(\mathrm{x}) = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad i = 1, \dots, m \;\; ; j = 1, \dots \;\; , n$$

where;

- i indexes the options being evaluated.
- j indexes the criteria being considered.
- n is the total number of criteria being evaluated.
- m is the total number of options being evaluated.
- x_{ij} is the raw score or value of option i on criteria j.

Step 3: Construct the weighted normalised decision matrix.

$$v_{ij}(\mathrm{x}) = w_j r_{ij}(x) \qquad i = 1, \dots, m \;\; ; j = 1, \dots \;\; , n$$

where;

- i indexes the options being evaluated.
- j indexes the criteria being considered.
- n is the total number of criteria being evaluated.
- m is the total number of options being evaluated.

- w_j is the weight assigned to criteria j, representing its relative importance in the decision-making process.
- $r_{ij}(x)$ is the normalised value of alternative i on criteria j.

Step 4: Determine the positive ideal (A^+) and negative (A^-) ideal solutions

$$A^+ = (v_1^+, v_2^+, \dots, v_n^+)$$

where;

- vj^+ is the maximum weighted normalised value across all options for criteria j.

$$A^- = (v_1^-, v_2^-, \dots, v_n^{-+})$$

So that

$$v_j^+ = \{(max\, v_{ij}(x) \big|\, j \epsilon j_1), (min\, v_{ij}(x) \big|\, j \epsilon j_2)\} \;\; i = 1, \dots, m$$

$$v_j^- = \{(min\, v_{ij}(x) \big|\, j \epsilon j_1), (max\, v_{ij}(x) \big|\, j \epsilon j_2)\} \;\; i = 1, \dots, m$$

where;

- vj^- is the minimum weighted normalised value across all options for criteria j.

Step 5: Calculate the distance from the positive ideal (d_i^+) and negative ideal (d_i^-) solutions

$$d_i^+ = \sqrt{\sum_{j=1}^{n} [v_{ij}(x) - v_j^+(x)]^2} \;\; , \;\; i = 1, \dots, m$$

where;

- d_i^+ is the distance of option i to the positive ideal solution.
- $v_{ij}(x)$ is the weighted normalised value of alternative i on criteria j.
- $v_j^+(x)$ is the j -th element of the positive ideal solution vector v^+

$$d_i^- = \sqrt{\sum_{j=1}^{n} [v_{ij}(x) - v_j^-(x)]^2} \;\; , \;\; i = 1, \dots, m$$

where;

- d_i^- is the distance of option i to the negative ideal solution.
- $v_{ij}(x)$ is the weighted normalised value of option i on criteria j..
- $v_j^-(x)$ is the j-th element of the negative ideal solution vector v_j^-.

Step 6: Calculate the relative closeness degree of alternative to the ideal solution.

$$\mathrm{C}_i = \frac{d_i^-}{(d_i^+ + d_i^-)} \quad , \quad i = 1, \dots, m$$

where;

- C_i is the relative closeness of the option i to the ideal solution.
- $d_i^-$is the distance of the option i to the negative ideal solution.
- d_i^+ is the distance of the option i to the positive ideal solution.

Step 7: Rank the options based on their relative closeness to the positive ideal solution, from highest to lowest.

6.5.3.4.4 VIKOR

The VIKOR technique was developed to provide a compromise solution for decision-making problems with conflicting criteria, which is its strength. It proves to be particularly useful in situations where trade-offs need to be made between criteria. The main objective of the VIKOR method is to select a solution that exhibits the closest proximity to the ideal level across each criteria. This allows for the evaluation and ranking of options based on their respective measures of "closeness" to the "ideal" solution.

The steps involved in VIKOR are as follows:

a. Step 1: Define the problem and criteria – Clearly define the decision problem and criteria to be employed in the evaluation.
b. Step 2: Normalise the decision matrix – Normalise the data for each criteria to common scale.
c. Step 3: Determine the best (f_i^*) and worst (f_i^-) benefits of each criteria – Determine the best and worst outcome for each criteria
d. Step 4: Calculate the S_i and R_i values, which is S_i and R_i represent the group utility and individual regret.
e. Step 5: Calculate the value Q_i, which represent the VIKOR index for each option.
f. Step 6: Rank the options, sorting by the S, R and Q values.
g. Step 7: Propose a compromise solution.
    i. Condition 1. Acceptable advantage: $Q(A^{(2)}) – Q(A^{(1)}) >$ //(m-1), where $A^{(1)}$ is the alternative with first position and $A^{(2)}$ is the alternative with second position in the ranking list by Q. m is number of alternatives.

ii. Condition 2. Acceptable stability in decision making: The alternative $A^{(1)}$ must also be the best ranked by S or/and R.

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consist of:

Solution 1. Alternatives $A^{(1)}, A^{(2)}, \ldots, A^{(M)}$ if Condition 1 is not satisfied; Alternative $A^{(M)}$ is determined by $Q\left(A^{(M)}\right) - Q\left(A^{(1)}\right) < 1/(m-1)$ for maximum M (the positions of these alternatives are "in closeness").

Solution 2. Alternatives $A^{(1)}$ and $A^{(2)}$ if only condition 2 is not satisfied.

Solution 3. Alternative with the minimum Q value will be selected as the best Alternative if both conditions are satisfied.

The mathematical formula involve are as follows:

Step 1: Define the decision problem and identify the criteria.

Step 2: Normalise the decision matrix.

$$f_{ij}(\mathrm{x}) = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad i = 1, \ldots, m \quad ; j = 1, \ldots \ , n$$

where;

- i indexes the options being evaluated.
- j indexes the criteria being considered.
- n is the total number of criteria being evaluated.
- m is the total number of options being evaluated.
- x_{ij} is the raw score or value of option i on criteria j.

Step 3: Determine the best (f_i^*) and worst (f_i^-) benefits of each criteria.

If the criteria is positive, then

$$f_j^* = Max_i f_{ij} \ \ , \ \ f_j^- = Min_i f_{ij} \quad ; \quad j = 1,2, \ldots, n$$

If the criteria is negative, then

$$f_j^* = Min_i f_{ij} \ \ , \ \ f_j^- = Max_i f_{ij} \quad ; \quad j = 1,2, \ldots, n$$

where;

- f_j^* is the maximum value of the criteria j among all options i=1,...,m.
- f_j^- is the minimum value of the criteria j among all options i =1,...,m.
- f_{ij} is the normalised value of the option i on criteria j.
- i =1,...,m is the index for the options.
- j =1,..., n is the index for the criteria.

The positive ideal solution (f^*) and negative ideal solution (f^-) can be expressed as follows:

$$f^* = \{f_1^*, f_2^*, f_3^*, \dots, f_n^*\}$$

$$f^- = \{f_1^-, f_2^-, f_3^-, \dots, f_n^-\}$$

Step 4: Calculate the S_i and R_i values.

$$S_i = \sum_{j=1}^{n} w_j \frac{(f_j^* - f_{ij})}{(f_j^* - f_j^-)}$$

$$R_i = Max_j \left[w_j \frac{\left(f_j^* - f_{ij}\right)}{\left(f_j^* - f_j^-\right)} \right]$$

where;

- S_i represent the overall score of the i-th option.
- R_i represents the relative closeness of the i-th option to the ideal solution.
- f_j^* represent the best values of the j-th criteria.
- f_j^-represent and worst values of the j-th criteria.
- f_{ij} represents the performance of the i-th option on the j-th criteria.
- w_j denotes the weight of the criteria.

Step 5: Calculate the value Q_i

$$Q_i = \gamma \frac{(S_i - S^*)}{(S^- - S^*)} + (1 - \gamma) \frac{(R_i - R^*)}{(R^- - R^*)}$$

where;

- Q_i represents the overall performance of the i-th option.
- $S^* = Min_i\{S_i\}$; $S^- = Max_i\{S_i\}$; $R^* = Min_i\{R_i\}$; $R^- = Max_i\{R_i\}$
- γ is the maximum group utility represented by value 0.5.

Step 6: Rank the options, sorting by the S, R and Q values.

Step 7: Propose a compromise solution. The option $A^{(1)}$, which is the best ranked by the measure Q (minimum) if the following two conditions are satisfied:

- Condition 1. Acceptable advantage: $Q(A^{(2)}) - Q(A^{(1)}) \geq 1/(m-1)$, where $A^{(1)}$ is the option with first position and $A^{(2)}$ is the option with second position in the ranking list by Q. m is number of options.
- Condition 2. Acceptable stability in decision making: The option $A^{(1)}$ must also be the best ranked by S or/and R.

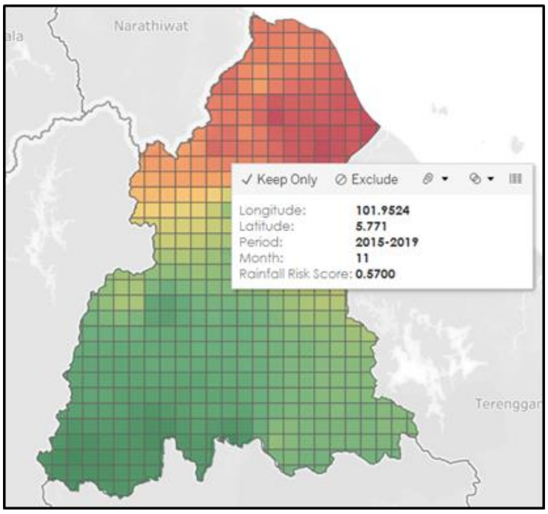
If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consist of:

- Solution 1. Options $A^{(1)}, A^{(2)}, \ldots, A^{(M)}$ if Condition 1 is not satisfied; Option $A^{(M)}$ is determined by $Q\left(A^{(M)}\right) - Q\left(A^{(1)}\right) < 1/(m-1)$ for maximum M (the positions of these options are ''in closeness'').
- Solution 2. Options $A^{(1)}$ and $A^{(2)}$ if only condition 2 is not satisfied.
- Solution 3. Option with the minimum Q value will be selected as the best Option if both conditions are satisfied.

6.5.4 Phase 5: Data Visualisation

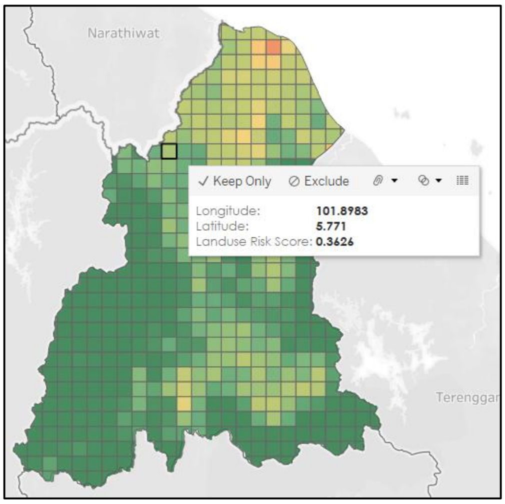
In data visualisation, the prototype provides users with information for each selected criteria, enhancing the visibility and aesthetic presentation of the data for better user understanding. The concept involves assigning specific information to each grid based on the layers selected by the users. Users have the flexibility to view and access this information according to their assessment and analysis preferences.

For the RRS criteria, the grid is colour-coded to indicate the various ranges of the risk index. Green indicates low risk, while red represents high risk. Each grid includes the period, the month, and the index score (refer to Figure 6-21). The identical approach was applied to the LRS (Figure 6-22), AFRS (Figure 6-23), DF (Figure 6-24) and RV (Figure 6-25). As illustrated in Figure 6-26, each land use category for ULSA is represented by a unique colour code.



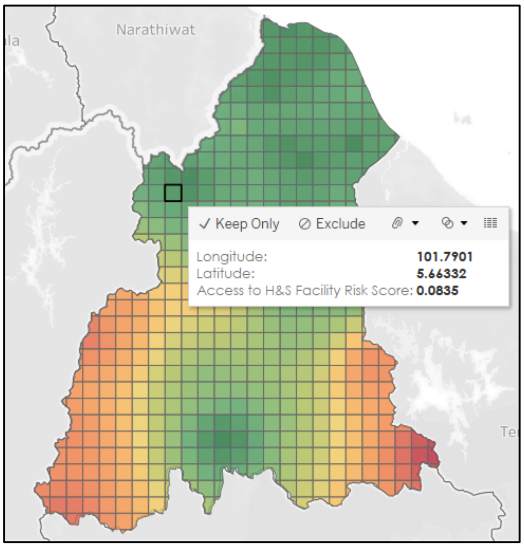
Longitude: 101.9524
Latitude: 5.771
Period: 2015-2019
Month: 11
Rainfall Risk Score: 0.5700

Figure 6-21: Rainfall Risk Score Index Criteria Visualisation



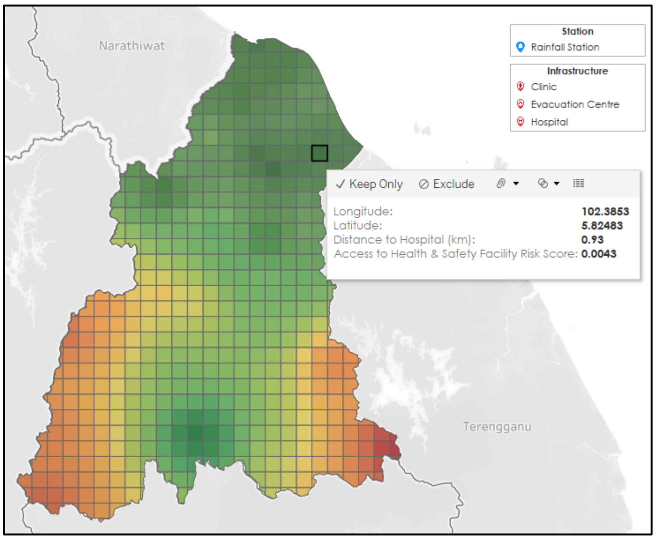
Longitude: 101.8983
Latitude: 5.771
Landuse Risk Score: 0.3626

Figure 6-22: Land use Risk Score Index Criteria Visualisation



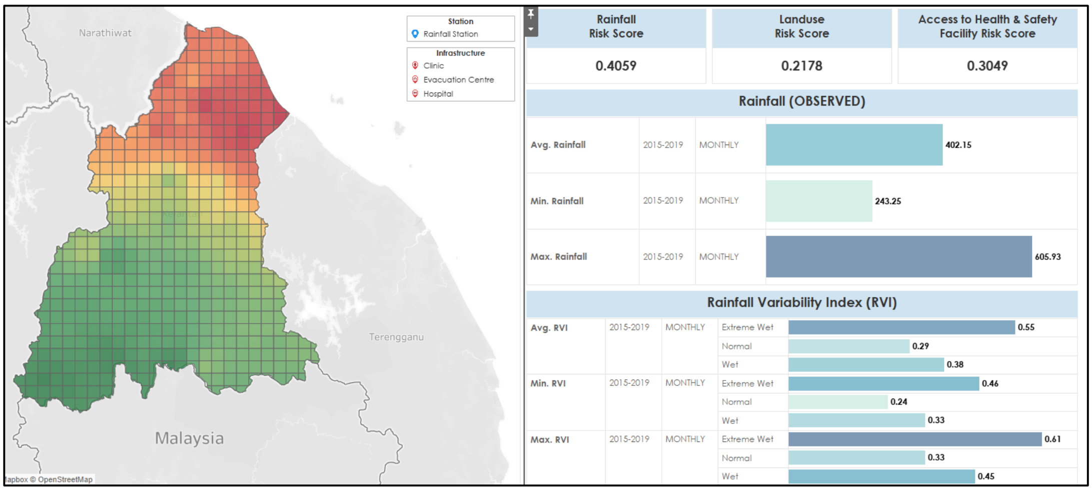
Longitude: 101.7901
Latitude: 5.66332
Access to H&S Facility Risk Score: 0.0835

Figure 6-23: Access to H&S Facility Risk Score Index Criteria Visualisation



Longitude: 102.3853
Latitude: 5.82483
Distance to Hospital (km): 0.93
Access to Health & Safety Facility Risk Score: 0.0043

Figure 6-24: Distance to Nearest Facility Criteria Visualisation



Rainfall Risk Score	Landuse Risk Score	Access to Health & Safety Facility Risk Score
0.4059	0.2178	0.3049

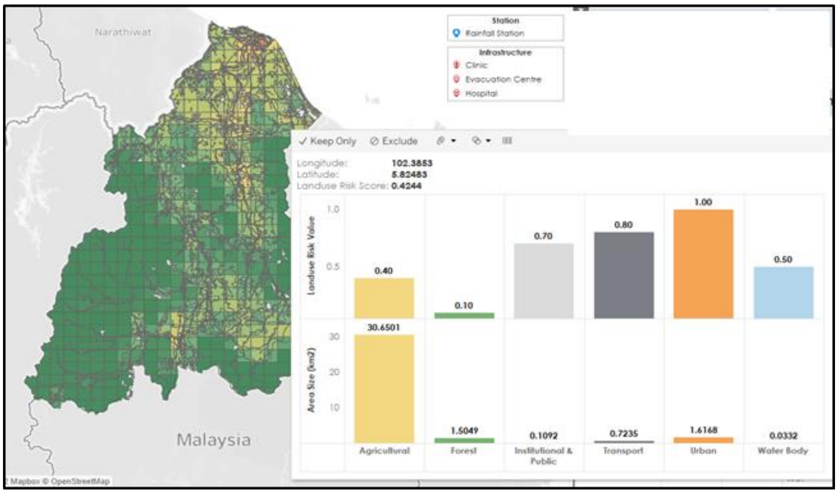
Rainfall (OBSERVED)

Avg. Rainfall	2015-2019	MONTHLY	402.15
Min. Rainfall	2015-2019	MONTHLY	243.25
Max. Rainfall	2015-2019	MONTHLY	605.93

Rainfall Variability Index (RVI)

Avg. RVI	2015-2019	MONTHLY	Extreme Wet	0.55
			Normal	0.29
			Wet	0.38
Min. RVI	2015-2019	MONTHLY	Extreme Wet	0.46
			Normal	0.24
			Wet	0.33
Max. RVI	2015-2019	MONTHLY	Extreme Wet	0.61
			Normal	0.33
			Wet	0.45

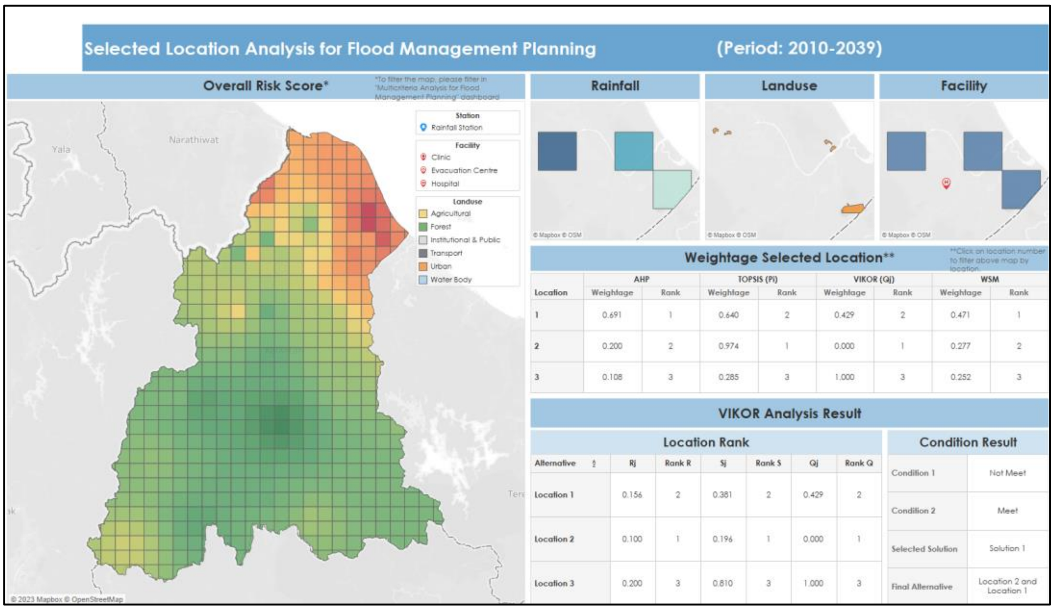
Figure 6-25: Rainfall Volume Criteria Visualisation



Longitude: 102.3853
Latitude: 5.82483
Landuse Risk Score: 0.4244

Figure 6-26: Urban Land use Size Area Criteria Visualisation

The ranking results of the proposed locations based on the MCDA techniques are presented individually. The calculation value and rank for the proposed locations are shown to facilitate user visibility and comparison of the results. Figure 6-27 illustrates the visualisation of MCDA results.



Selected Location Analysis for Flood Management Planning (Period: 2010-2039)

Overall Risk Score*

*To filter the map, please filter in "Multicriteria Analysis for Flood Management Planning" dashboard

Weightage Selected Location**

**Click on location number to filter above map by location.

	AHP		TOPSIS (Pi)		VIKOR (Qj)		WSM	
Location	Weightage	Rank	Weightage	Rank	Weightage	Rank	Weightage	Rank
1	0.691	1	0.640	2	0.429	2	0.471	1
2	0.200	2	0.974	1	0.000	1	0.277	2
3	0.108	3	0.285	3	1.000	3	0.252	3

VIKOR Analysis Result

Location Rank

Alternative	Rj	Rank R	Sj	Rank S	Qj	Rank Q
Location 1	0.156	2	0.381	2	0.429	2
Location 2	0.100	1	0.196	1	0.000	1
Location 3	0.200	3	0.810	3	1.000	3

Condition Result

Condition 1	Not Meet
Condition 2	Meet
Selected Solution	Solution 1
Final Alternative	Location 2 and Location 1

Figure 6-27: Data Visualisation for MCDA Ranking Results

6.6 Case Study Setting

Based on the observed rainfall data from the period 2015-2019 and overlaying the hospital locations (Figure 6-28) with the monthly RRS, it becomes apparent that Hospital Tengku Anis (H2) is situated in an area highly vulnerable to flooding events due to the volume of rainfall it received. This vulnerability is particularly evident during the months of November, December, and January, as depicted in Figures 6-29 (a), (b) and (c). Understanding the importance of health and safety facilities during flood events, it is important for decision-makers to strategically plan future actions that need to be taken based on the long-term impact of climate change.

To provide context, during the Northeast monsoon season, the months of November, December, and January were categorised as "Extremely Wet", while February and March were classified as "Dry". Rainfall volume during these extremely wet months ranged between 54 mm and 86 mm. Detailed information regarding rainfall volume, RRS values, and their corresponding status during the monsoon period from 2015 to 2019 can be found in Table 6-13.

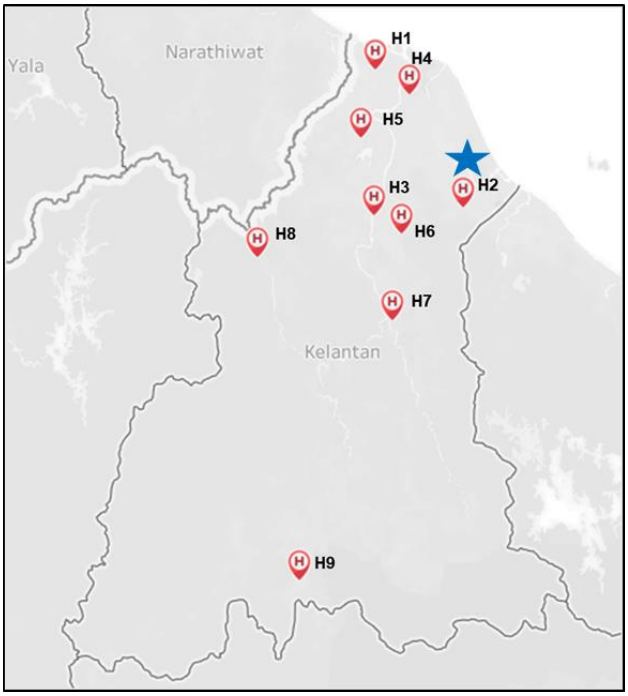
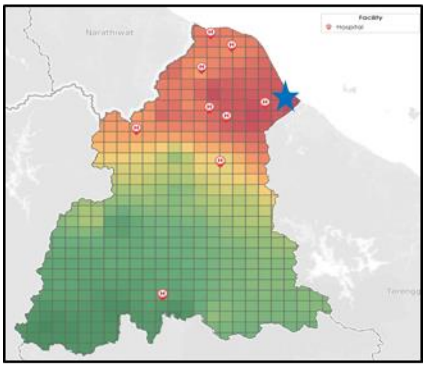
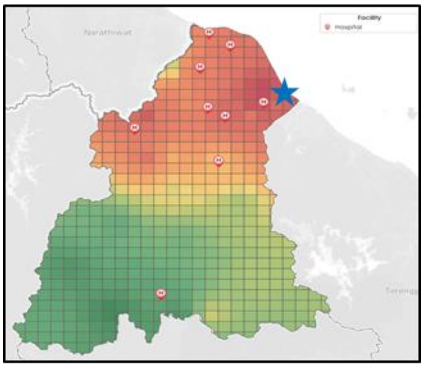


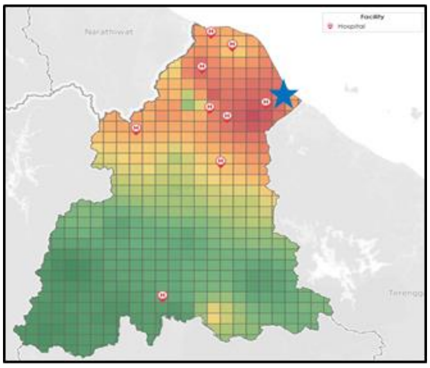
Figure 6-28: Location of Hospital Tengku Anis (H2)



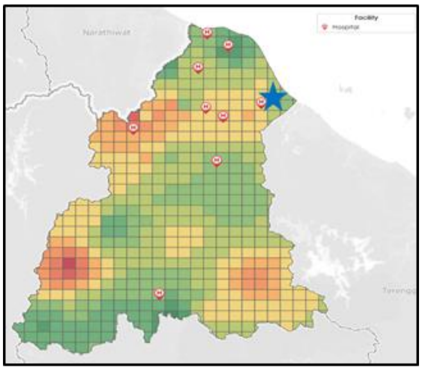
RRS for Nov. 2015-2019 (a)



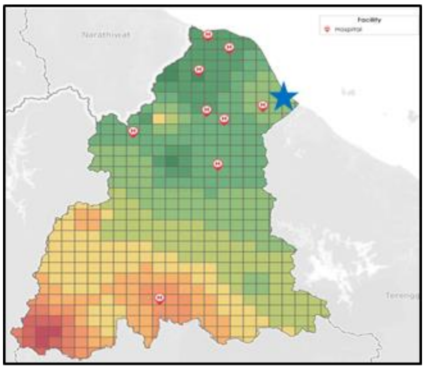
RRS for Dec. 2015-2019 (b)



RRS for Jan. 2015-2019 (c)



RRS for Feb. 2015-2019 (d)



RRS for Mar. 2015-2019 (e)

Figure 6-29: Analysis on H2 based on Monthly Rainfall Risk Score (Nov, Dec, Jan, Feb, & Mac) for 2015-2019

Table 6-13: H2 monthly rainfall (average) and Risk Score for period 2015-2019

Hospital Location	Month	Rainfall (mm)	Rainfall Risk Score	RVI Status
H2	Nov.	588.32	0.60	Extreme Wet
	Dec.	574.09	0.58	Extreme Wet
	Jan.	489.09	0.49	Extreme Wet
	Feb.	86.56	0.08	Dry
	Mar.	54.88	0.05	Dry

Based on the initial assessment mentioned above, two case studies have been conducted:

a. In Case Study 1, experts have proposed three new hospital locations near H2, all within a 12-km radius of H2. These proposed locations are denoted as L1, L2, and L3, and their positions are depicted in Figure 6-30.
b. In Case Study 2, experts have suggested three new hospital locations located at a considerable distance from H2, more than a 12-km radius. The proposed locations in Case Study 2 are also labelled L1, L2, and L3, and their positions are illustrated in Figure 6-31.

For both case studies, it's assumed that the proposed locations should be situated in urban areas with a mix of residential and urban populations.

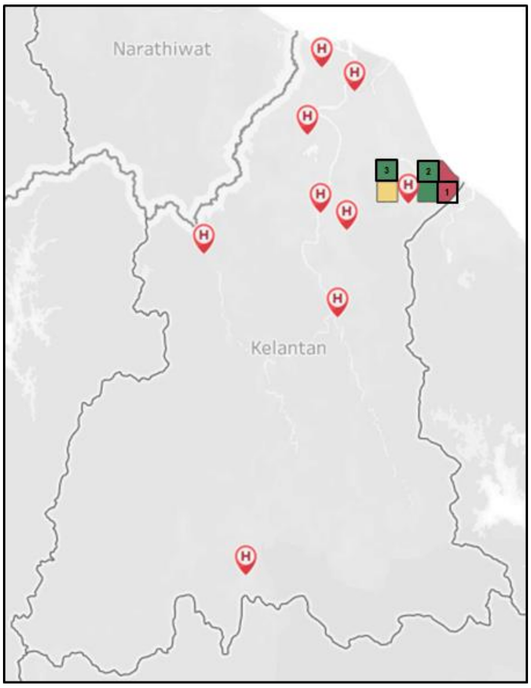


Figure 6-30: Proposed location of L1, L2 and L3 for case study 1

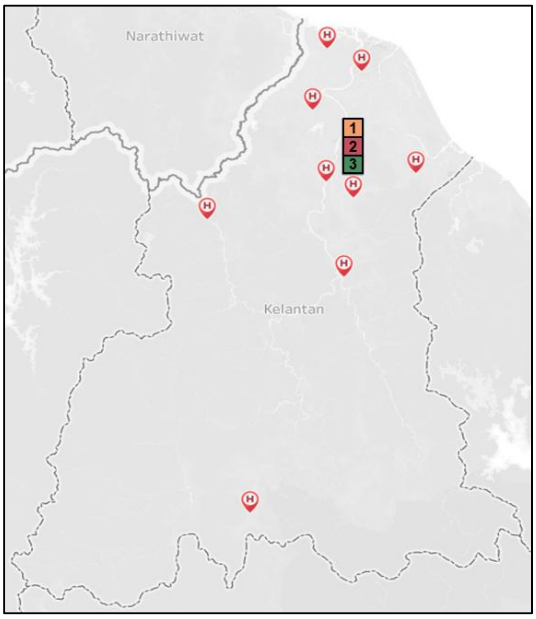


Figure 6-31: Proposed location of L1, L2 and L3 for case study 2

The case studies involved the following steps, as illustrated in Figure 6-32:

1. Experts proposed three feasible hospital locations based on the provided information.
2. The analysis spanned two different 40-year periods, covering 2010-2039 and 2040-2069.
3. Each period was analysed using four climate scenarios: RCP 2.6, 4.5, 6.0, and 8.5.

4. The analysis focused on the Northeast Monsoon season, running from November to March each year.
5. Four MCDA techniques (WSM, AHP, VIKOR, and TOPSIS) were applied to rank the proposed locations for each month.
6. The recommended location was identified by calculating the frequency of Rank 1 for each proposed location across all scenarios and months.
7. The final recommended location underwent validation by experts using the CVI method.

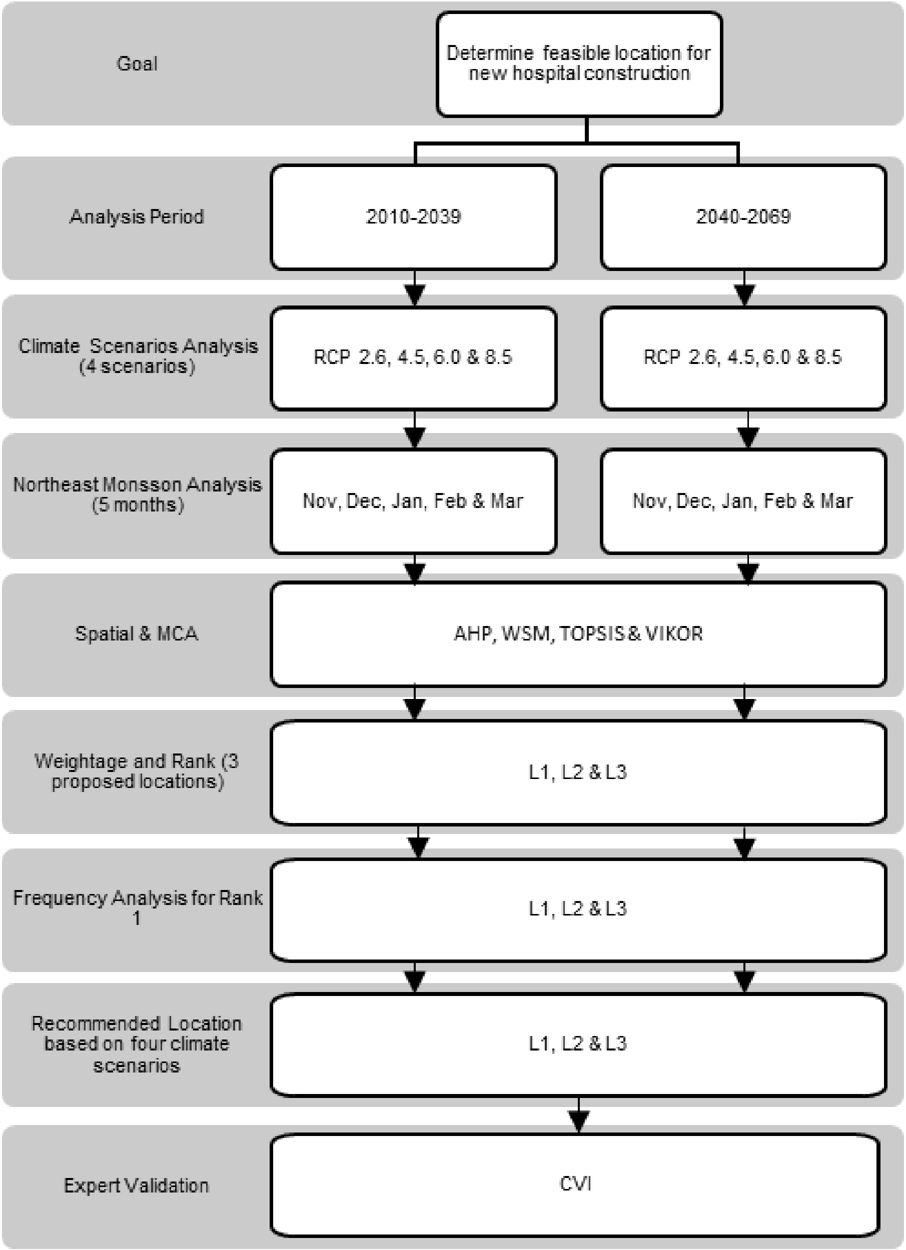


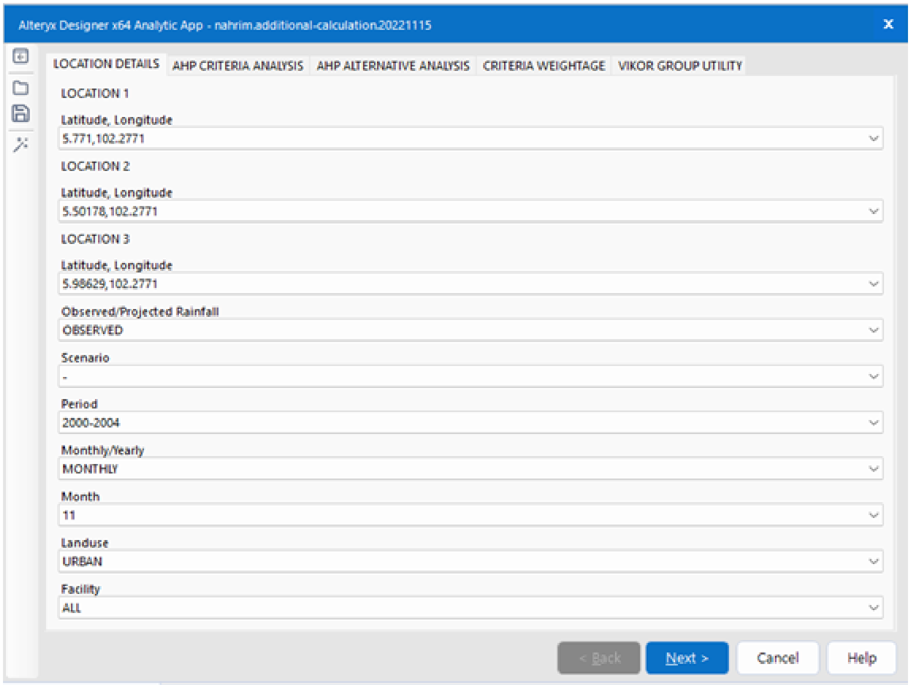
Figure 6-32: Main Steps for Case Study Assessment

These steps allowed for a comprehensive assessment and selection of the most suitable hospital location under varying climate scenarios and over different time frames. The assessment and analysis of the proposed locations were conducted using the prototype, while the analysis and validation of the recommended location were conducted using Excel.

The details on the criteria RRS, RV, LRS, ULSA, DF, and AFRS for each proposed location based on four scenarios (RCP 2.5, 4.5, 6.0, and 8.5) for the periods 2010–2039 and 2040–2069 can be found in Appendix I3-Appendix I10 and Appendix J3-Appendix J10.

The prototype requires experts to provide the input for the location to be analysed, as shown in Figure 6-33. As for the AHP technique, the weight is calculated based on the scores given by experts for each criteria. Experts are required to provide input consensually to conduct criteria and alternative analysis (refer to Figure 6-34 and Figure 6-35). In AHP, the criteria weights were determined through an objective evaluation, avoiding subjective judgement from decision-makers within a certain framework (Akay and Baduna Koçyiğit, 2020).

For the WSM, VIKOR, and TOPSIS techniques, experts must agree on how to use the given interface (refer to Figure 6-36). For the group utility value for VIKOR, experts must also agree on how to provide, as shown in Figure 6-37.


Alteryx Designer x64 Analytic App - nahrim.additional-calculation.20221115

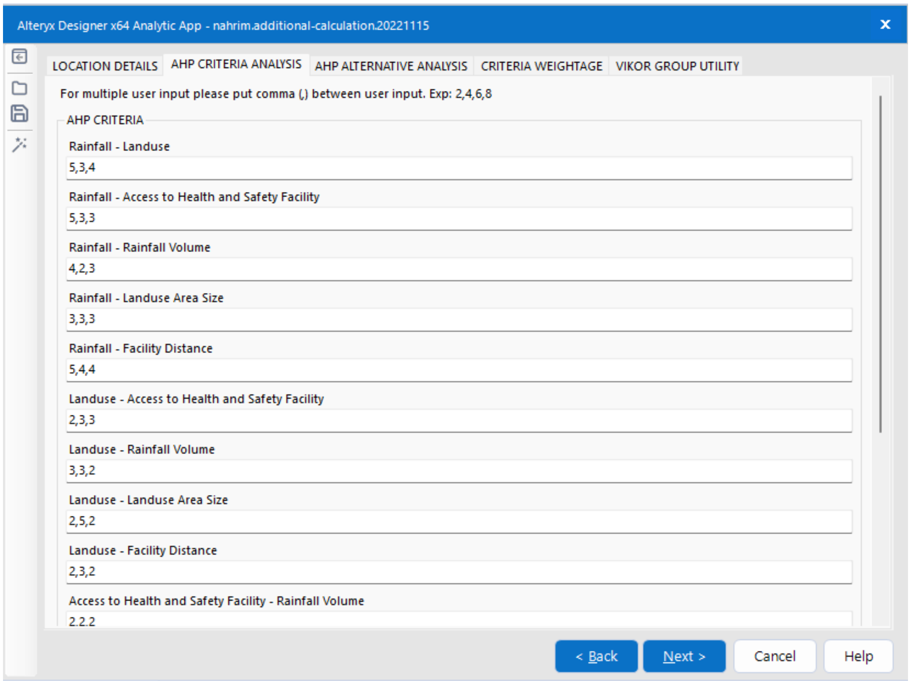
LOCATION 1
Latitude, Longitude: 5.771,102.2771

LOCATION 2
Latitude, Longitude: 5.50178,102.2771

LOCATION 3
Latitude, Longitude: 5.98629,102.2771

Observed/Projected Rainfall: OBSERVED
Scenario: -
Period: 2000-2004
Monthly/Yearly: MONTHLY
Month: 11
Landuse: URBAN
Facility: ALL

Figure 6-33: Interface for analysis (location, scenario model, period, monthly/yearly, month, land use and facility)



For multiple user input please put comma (,) between user input. Exp: 2,4,6,8

AHP CRITERIA

Rainfall - Landuse
5,3,4

Rainfall - Access to Health and Safety Facility
5,3,3

Rainfall - Rainfall Volume
4,2,3

Rainfall - Landuse Area Size
3,3,3

Rainfall - Facility Distance
5,4,4

Landuse - Access to Health and Safety Facility
2,3,3

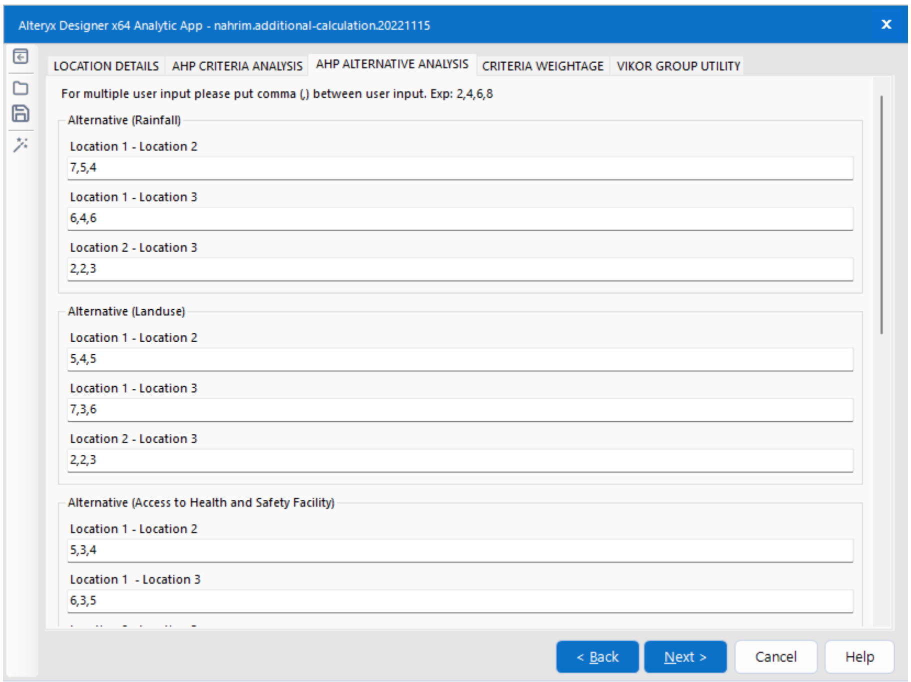
Landuse - Rainfall Volume
3,3,2

Landuse - Landuse Area Size
2,5,2

Landuse - Facility Distance
2,3,2

Access to Health and Safety Facility - Rainfall Volume
2.2.2

Figure 6-34: Interface for criteria analysis using AHP.



For multiple user input please put comma (,) between user input. Exp: 2,4,6,8

Alternative (Rainfall)

Location 1 - Location 2
7,5,4

Location 1 - Location 3
6,4,6

Location 2 - Location 3
2,2,3

Alternative (Landuse)

Location 1 - Location 2
5,4,5

Location 1 - Location 3
7,3,6

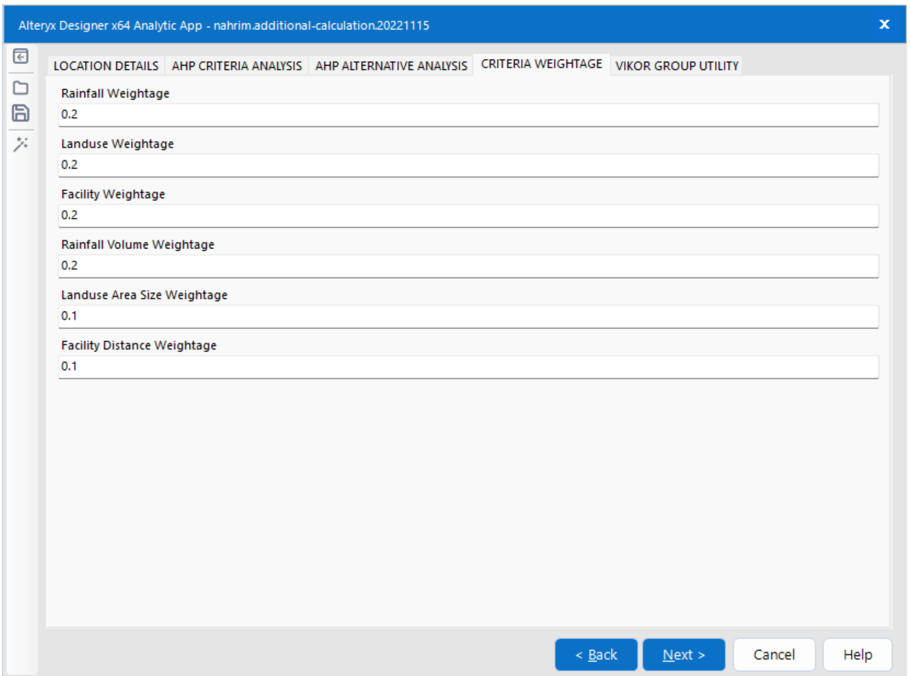
Location 2 - Location 3
2,2,3

Alternative (Access to Health and Safety Facility)

Location 1 - Location 2
5,3,4

Location 1 - Location 3
6,3,5

Figure 6-35: Interface for alternative analysis using AHP.



Rainfall Weightage
0.2

Landuse Weightage
0.2

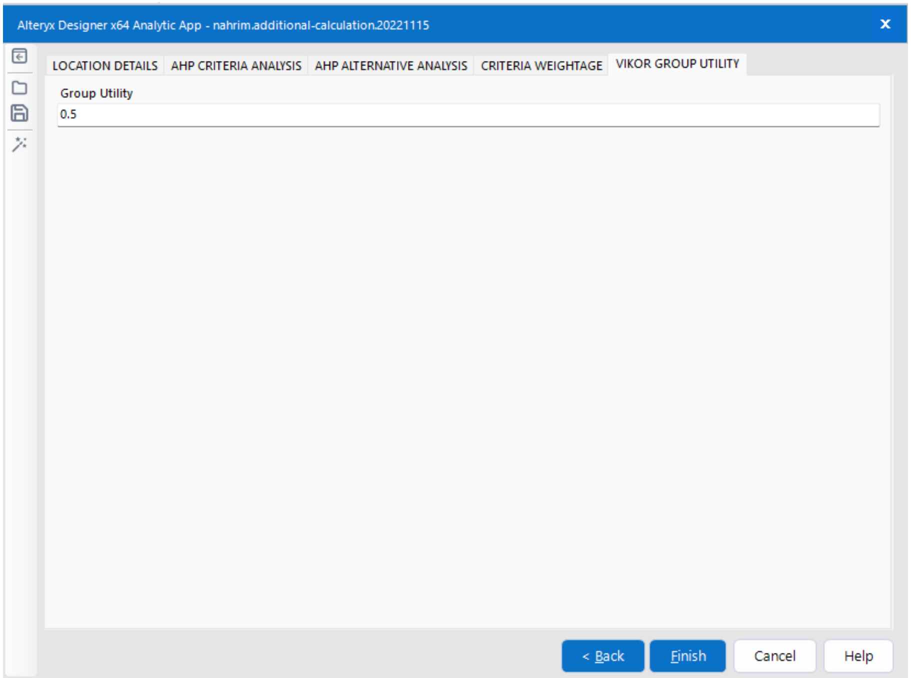
Facility Weightage
0.2

Rainfall Volume Weightage
0.2

Landuse Area Size Weightage
0.1

Facility Distance Weightage
0.1

Figure 6-36: Interface for criteria weightage for WSM, VIKOR and TOPSIS.



Group Utility
0.5

Figure 6-37: Interface for VIKOR Group Utility

In WSM and TOPSIS, the criteria RRS, LRS, AFRS, RV, and DF were considered costs, while the criteria ULSA was considered a benefit. Based on the experts' recommendations, the criteria weightages for WSM, VIKOR, and TOPSIS were set consensually, as shown in Table 6-14. Due to a lack of information on the weight of the selected criteria, experts agreed to set the weight according to their subjective judgement based on their experience with previous project. If the experts would like to change the weight setting, they can do so. A future study on this weighting would facilitate and support the criteria weighting, apart from depending on expert judgement.

Table 6-14: Criteria Weightage set for WSM, TOPSIS and VIKOR

Criteria	Weightage
Rainfall Risk Score	0.2
Land use Risk Score	0.2
Access to H&S Risk Score	0.2
Rainfall Volume	0.2
Land use Size Area (Urban)	0.1
Distance Current Facility	0.1

Table 6-15 shows the calculation of the criteria weightage result for the AHP technique. The pairwise matrix used to calculate the AHP weightage and the final weightage for each proposed location are presented in Table 6-16, Table 6-17, Table 6-18, Table 6-19, Table 6-20, Table 6-21, and Table 6-22. Furthermore, Table 6-23 and Table 6-24 provide an explanation of the priority matrix and the final AHP weightage for each proposed location.

Table 6-15: Criteria Weightage based on AHP Technique

Criteria	Weightage
Rainfall Risk Score	0.38
Land use Risk Score	0.20
Access to H&S Risk Score	0.14
Rainfall Volume	0.13
Land use Size Area (Urban)	0.09
Distance Current Facility	0.06

Table 6-16: Pairwise Comparison Matrix Criteria

Criteria	RRS	LRS	AFRS	RV	ULSA	DF	Priority Matrix	Rank
RRS	1	4	3 5/9	2 8/9	3	4 1/3	0.38	1
LRS		1	2 8/9	2 5/8	2 5/7	2 2/7	0.20	2
AFRS			1	2	2	2 8/9	0.14	3

Criteria	RRS	LRS	AFRS	RV	ULSA	DF	Priority Matrix	Rank
RV				1	2 5/8	3 1/3	0.13	4
ULSA					1	2 2/7	0.09	5
DF						1	0.06	6
Consistency Index (CI) = 0.0981								
Consistency Ratio (CR) = 0.0791								

Table 6-17: Pairwise Comparison Matrix of RRS

Criteria	Location 1	Location 2	Location 3	Priority Matrix
Location 1	1	5 1/5	5 1/4	0.71
Location 2	1/5	1	2 2/7	0.19
Location 3	1/5	3/7	1	0.11
Consistency Index (CI) = 0.0381				
Consistency Ratio (CR) = 0.0656				

Table 6-18: Pairwise Comparison Matrix of LRS

Criteria	Location 1	Location 2	Location 3	Priority Matrix
Location 1	1	4 2/3	5	0.69
Location 2	2/9	1	2 2/7	0.20
Location 3	1/5	3/7	1	0.11
Consistency Index (CI) = 0.0319				
Consistency Ratio (CR) = 0.0550				

Table 6-19: Pairwise Comparison Matrix of AFRS

Criteria	Location 1	Location 2	Location 3	Priority Matrix
Location 1	1	4	4 1/2	0.66
Location 2	1/4	1	2 5/8	0.23
Location 3	2/9	3/8	1	0.12
Consistency Index (CI) = 0.0388				
Consistency Ratio (CR) = 0.0669				

Table 6-20: Pairwise Comparison Matrix of RV

Criteria	**Location 1**	**Location 2**	**Location 3**	**Priority Matrix**
Location 1	1	5	6	0.74
Location 2	1/5	1	2 5/8	0.20
Location 3	1/6	3/8	1	0.10
Consistency Index (CI) = 0.0342				
Consistency Ratio (CR) = 0.0590				

Table 6-21: Pairwise Comparison Matrix of ULSA

Criteria	**Location 1**	**Location 2**	**Location 3**	**Priority Matrix**
Location 1	1	4 1/3	4 1/2	0.68
Location 2	1/4	1	2 5/8	0.22
Location 3	2/9	3/8	1	0.12
Consistency Index (CI) = 0.0486				
Consistency Ratio (CR) = 0.0837				

Table 6-22: Pairwise Comparison Matrix of DF

Criteria	**Location 1**	**Location 2**	**Location 3**	**Priority Matrix**
Location 1	1	4	5	0.66
Location 2	1/4	1	2 5/8	0.22
Location 3	1/5	3/8	1	0.11
Consistency Index (CI) = 0.0302				
Consistency Ratio (CR) = 0.0521				

Table 6-23: Priority Matrix

	RRS	**LRS**	**AFRS**	**RV**	**ULSA**	**DF**
Location 1	0.71	0.69	0.66	0.74	0.68	0.66
Location 2	0.19	0.20	0.23	0.20	0.22	0.22
Location 3	0.11	0.11	0.12	0.10	0.12	0.11

Table 6-24: Location Weightage (AHP Technique)

Proposed Location	Weight
Location 1	0.70
Location 2	0.20
Location 3	0.11

6.7 Results and Discussion

The result indicated that the prototype served the objective of this study effectively, and expert validation confirmed the satisfactory acceptability of the combined spatial-MCDA technique for providing early assessments of feasible locations for future hospital construction. For each case study, the following results will be discussed:

a. Weightage for each criteria according to WSM, AHP, TOPSIS, and VIKOR
b. Ranking of proposed locations
c. Recommended location
d. Validation of location from experts

6.7.1 Results and Discussion: Case Study 1

6.7.1.1 Locations Analysis for Period 2010-2039

The analysis results consistently favour L1 as the top-ranked location among the three proposed locations in all scenarios and methods. There are occasional exceptions where it is ranked second (Rank 2) or NA (Not Acceptable Location), but these instances are infrequent. L2 consistently ranks in the middle, while L3 consistently ranks last in all climate scenarios and ranking techniques.

In terms of the frequency of being ranked first, L1 obtained the highest score for most climate scenarios. The analysis revealed that it received the highest ranking at least 11 times out of 20. In the RCP 2.6 and 4.5 scenarios, it obtained the highest ranking 12 times out of 20. This suggests that L1 is generally the preferred location compared to L2 and L3.

For L2, it consistently ranks second in all climate scenarios and ranking techniques, with an overall frequency of 10 out of 20. While it is not ranked first as frequently as L1, it still outperforms L3 and establishes itself as the second-best location option.

L3 consistently ranks last among the three locations, with a frequency of NA in some cases. Across all four climate scenario models, most ranking methods, and most months, L3 always comes in third position (Rank 3), with very few instances where it manages to rank higher. This suggests that L3 is the least preferred and least feasible location compared to the other proposed locations.

Overall, these location analyses offer valuable insights for decision-makers, consistently positioning L1 and L2 as superior choices compared to L3 across various climate scenarios and ranking techniques. L1, with its highest-ranking frequency, emerges as the strongly recommended choice. However, it's important to note that rankings can vary depending on the decision-making method and climate scenario under consideration. Moreover, for a more comprehensive analysis, additional factors and assumptions beyond the current set of criteria may need to be addressed. The ranking results for L1, L2, and L3 are presented in Table 6-25 to

Table 6-27, with detailed calculations for each location based on various scenarios in Appendix I1 for the period 2010-2039.

Table 6-25: Ranking Analysis for Location 1 (2010-2039)

Proposed Location	**Location 1 (L1)**																				**Ranking Mode**	**Rank 1 (Frequency)**
Period	**2010-2039**																					
Month	**Nov**				**Dec**				**Jan**				**Feb**				**Mar**					
Method	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**		
Scenario																						
RCP 2.6	1	2	1	1	1	2	1	1	1	2	NA	1	1	2	NA	1	1	2	NA	1	1	12
RCP 4.5	1	2	1	1	1	2	NA	1	1	2	NA	1	1	2	1	1	1	2	NA	1	1	12
RCP 6.0	1	2	NA	1	1	2	NA	1	1	2	NA	1	1	2	NA	1	1	2	1	1	1	11
RCP 8.5	1	2	NA	1	1	2	NA	1	1	2	NA	1	1	2	1	1	1	2	NA	1	1	11

Table 6-26: Ranking Analysis for Location 2 (2010-2039)

Proposed Location	**Location 2 (L2)**																				**Ranking Mode**	**Rank 1 (Frequency)**
Period	**2010-2039**																					
Month	**Nov**				**Dec**				**Jan**				**Feb**				**Mar**					
Method	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**		
Scenario																						
RCP 2.6	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	3	1	10
RCP 4.5	2	1	NA	2	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2	9
RCP 6.0	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2	10
RCP 8.5	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2	10

Table 6-27: Ranking Analysis for Location 3 (2010-2039)

Proposed Location	Location 3 (L3)																				Ranking Mode	Rank 1 (Frequency)
Period	2010-2039																					
Month	Nov				Dec				Jan				Feb				Mar					
Method	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM		
Scenario																						
RCP 2.6	3	3	2	3	3	3	2	3	3	3	NA	3	3	3	NA	3	3	3	NA	2	3	0
RCP 4.5	3	3	NA	3	3	3	1	3	3	3	NA	3	3	3	1	3	3	3	NA	3	3	2
RCP 6.0	3	3	NA	3	3	3	1	3	3	3	NA	3	3	3	NA	3	3	3	1	3	3	2
RCP 8.5	3	3	NA	3	3	3	NA	3	3	3	NA	3	3	3	NA	3	3	3	NA	3	3	0

6.7.1.2 Locations Analysis for Period 2040-2069

Both L1 and L2 consistently outperform L3 across all climate scenarios and ranking techniques, with L1 and L2 achieving the highest frequency of Rank 1 compared to L3, which consistently ranked third across all climate scenarios and ranking techniques.

For L1, it achieves the most Rank 1 rankings, with 11 out of 20 being the highest frequency in all climate scenarios. For L2, at least 9 out of 20 were ranked first, with 10 out of 20 being the most common. These findings support the recommendation that both L1 and L2 are suitable options. However, when considering the frequency of Rank 1 rankings, L1 emerges as a more feasible, preferred, and robust location overall compared to L2. L2 occasionally ranks first (Rank 1) but is consistently positioned as the second-best location across all climate scenarios, months, and most ranking techniques, indicating that it is a less viable choice than L1.

In contrast, L3 consistently ranks last in almost all climate scenarios. It achieves the highest number of Rank 1 rankings in all climate scenarios and months, with just one instance. This makes L3 the least recommended location among the three.

Overall, the location analyses show that L1 is the most suitable and practical location, then L2. L1 consistently secures the top rank in most scenarios, while L2 is in the second-best place. Meanwhile, L3 is not a recommended location based on its poor ranking results. These results can help guide decision-making in this study and inform which location might be the best choice for future planning, considering the strengths and weaknesses of each location and the ranking methods used.

The ranking results for L1, L2, and L3 are shown in Table 6-28, Table 6-29 and Table 6-30. Appendix I2 contains details of the calculations for each location based on various scenarios for the period 2040-2069.

Table 6-28: Ranking Analysis for Location 1 (2040-2069)

Proposed Location	**Location 1 (L1)**																				**Ranking Mode**	**Rank 1 (Frequency)**
Period	**2040-2069**																					
Month	**Nov**				**Dec**				**Jan**				**Feb**				**Mar**					
Method	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**		
Scenario																						
RCP 2.6	1	2	NA	1	1	2	NA	1	1	2	NA	1	1	2	NA	1	1	2	NA	1	**1**	**10**
RCP 4.5	1	2	1	1	1	2	NA	1	1	2	NA	1	1	2	NA	1	1	2	NA	1	**1**	**11**
RCP 6.0	1	2	NA	1	1	2	NA	1	1	2	NA	1	1	2	NA	1	1	2	NA	1	**1**	**10**
RCP 8.5	1	2	NA	1	1	2	NA	1	1	2	NA	1	1	2	NA	1	1	2	NA	1	**1**	**10**

Table 6-29: Ranking Analysis for Location 2 (2040-2069)

Proposed Location	**Location 2 (L2)**																				**Ranking Mode**	**Rank 1 (Frequency)**
Period	**2040-2069**																					
Month	**Nov**				**Dec**				**Jan**				**Feb**				**Mar**					
Method	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**		
Scenario																						
RCP 2.6	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	**2**	**10**
RCP 4.5	2	1	NA	2	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	**2**	**9**
RCP 6.0	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	**2**	**10**
RCP 8.5	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	**2**	**10**

Table 6-30: Ranking Analysis for Location 3 (2040-2069)

Proposed Location	**Location 3 (L3)**																				**Ranking Mode**	**Rank 1 Frequency)**
Period	**2040-2069**																					
Month	**Nov**				**Dec**				**Jan**				**Feb**				**Mar**					
Method	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**		
Scenario																						
RCP 2.6	3	3	1	3	3	3	NA	3	3	3	NA	3	3	3	NA	3	3	3	NA	3	**3**	**1**
RCP 4.5	3	3	NA	3	3	3	NA	3	3	3	NA	3	3	3	NA	3	3	3	NA	3	**3**	**0**
RCP 6.0	3	3	NA	3	3	3	NA	3	3	3	NA	3	3	3	NA	3	3	3	NA	3	**3**	**0**
RCP 8.5	3	3	NA	3	3	3	NA	3	3	3	NA	3	3	3	NA	3	3	3	NA	3	**3**	**0**

6.7.1.3 Recommended Location based on period 2010-2039 and 2040-2069

The comprehensive analysis of the location for both time periods and all four climate scenarios provides a clear recommendation. Based on the total sum of the Rank 1 frequencies across scenarios and time periods, L1 emerges as the most recommended location.

The locations are described in Table 6-31 based on the total sum of Rank 1 for each scenario and time period. L1 and L2 are the locations with the highest total rank; the total for L1 is 87 and 78 for L2, while L3 is 5. Therefore, based on this analysis, L1 is the strongly recommended location for selection for both time periods and all four climate scenarios. It demonstrates greater feasibility and robustness compared to L2 and L3.

Table 6-31: Recommended Location

Proposed Location	**Period**	**Scenario**			
		RCP 2.6	**RCP 4.5**	**RCP 6.0**	**RCP 8.5**
L1	2010-2039	12	12	11	11
	2040-2069	10	11	10	10
	Sum Rank 1	**22**	**23**	**21**	**21**
Total Rank1 for L1		**87**			
L2	2010-2039	10	9	10	10
	2040-2069	10	9	10	10
	Sum Rank 1	**20**	**18**	**20**	**20**
Total Rank1 for L2		**78**			
L3	2010-2039	0	2	2	0
	2040-2069	1	0	0	0
	Sum Rank 1	**1**	**2**	**2**	**0**
Total Rank1 for L3		**5**			

Table 6-32 provides additional information about the recommended location of L1. The table revealed that L1 exhibits high rainfall volume values during the months of November and December, ranging between 430mm and 618mm across all scenarios. This indicates that the location is prone to flooding during these months. However, the RRS index for these months is relatively low, suggesting that the location is less vulnerable to the impacts of flooding during this period.

In contrast, the rainfall volume values for the months of January, February, and March are low, indicating that the location is less prone to flooding during these months. Additionally, the RRS values for these months are also relatively low, indicating a lower vulnerability to flooding during this period.

The overall status of L1 indicates that the location experiences either “Wet”, “Normal” or “Dry” conditions, and no “Extreme Wet” conditions have been identified. This supports the recommendation of L1 as the most feasible location.

In summary, the results show that L1 is the feasible location for the specified time period and scenarios. However, further steps should be taken to lessen the effects of flooding, as the location is still likely to flood during certain months. Details of the calculation for locations under different RCPs and for both periods can be found in Appendices I3 to I10.

Table 6-32: Details of recommended location, L1

Proposed Location	**Month**	**Criteria**	**Ranking by Scenario**							
			RCP 2.6	**RCP 4.5**	**RCP 6.0**	**RCP 8.5**	**RCP 2.6**	**RCP 4.5**	**RCP 6.0**	**RCP 8.5**
			2010-2039				**2040-2069**			
L1	**Nov**	RV	616.11	436.67	601.16	450.25	454.97	442.76	454.08	462.79
		RRS	0.23	0.17	0.23	0.02	0.21	0.20	0.21	0.21
		RRS Status	W	N	W	N	N	N	N	N
	Dec	RV	609.75	559.56	617.48	516.6	466.61	470.9	489.56	464.2
		RRS	0.24	0.21	0.24	0.18	0.21	0.22	0.22	0.21
		RRS Status	W	W	W	N	N	N	N	N
	Jan	RV	271	209.61	111.08	120.81	252.19	254.93	292.03	233.26
		RRS	0.11	0.08	0.04	0.05	0.11	0.11	0.1	0.1
		RRS Status	N	N	N	N	N	N	N	N
	Feb	RV	111.36	110.23	59.61	67.57	100.02	107.29	107.98	112.59
		RRS	0.03	0.04	0.02	0.02	0.03	0.03	0.03	0.03
		RRS Status	D	N	D	D	D	D	D	D
	Mar	RV	13.53	44.89	10.25	18.63	60.19	84.76	89.59	77.53
		RRS	0.00	0.02	0.00	0.01	0.01	0.02	0.02	0.02
		RRS Status	D	D	D	D	D	D	D	D

6.7.1.4 Experts’ Validation

The final recommendation location, L1, underwent expert validation using the Content Validity Index (CVI), which involved the evaluation of six CVI items (refer to Table 6-7) by eleven experts. These experts rated each item’s relevance to L1 using a provided scale.

The I-CVI measures the level of agreement among experts regarding the relevance of each item. It is calculated as the proportion of experts who rated the item as relevant. In this case, the I-CVI scores range from 0.82 to 1.00, indicating a generally high degree of agreement among the experts. The S-CVI is 0.89, which surpasses the recommended threshold of 0.78 (Lynn, M.R., 1986). This S-CVI value suggests a good level of agreement among the experts regarding the validity of the content of the scale.

The findings show that more than 80% of experts agreed on the relevance of the items, particularly I2 and I5, which received unanimous support from all experts. Some disagreement was also exhibited, especially for I1, I4, and I6, which received a relatively low I-CVI score of 0.82, indicating that there was less agreement between experts about their relevancy. However, I3 received more than 90% agreement from all experts, with an I-CVI score of 0.91, signifying its high relevance.

As determined by the panel of experts, the results indicate that the items have good content validity for assessing L1. Thus, based on expert validation, L1 demonstrated a high degree of agreement as a recommended location feasible for constructing a new hospital building. Table 6-33 shows the CVI results for L1.

Table 6-33: CVI Result for L1

No	Item ID	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Expert 10	Expert 11	Expert In Agreement	I-CVI
1	I1	1	0	1	1	0	1	1	1	1	1	1	9	0.82
2	I2	1	1	1	1	1	1	1	1	1	1	1	11	1.00
3	I3	1	1	1	1	1	1	1	0	1	1	1	10	0.91
4	I4	1	1	1	1	1	1	0	1	1	0	1	9	0.82
5	I5	1	1	1	1	1	1	1	1	1	1	1	11	1.00
6	I6	1	1	0	1	1	0	1	1	1	1	1	9	0.82
Proportion Relevant		**1.00**	**0.83**	**0.83**	**1.00**	**0.83**	**0.83**	**0.83**	**0.83**	**1.00**	**0.83**	**1.00**	Sum I-CVI	**5.36**
													S-CVI	**0.89**

6.7.2 Result and Discussion: Case Study 2

6.7.2.1 Locations Analysis 2010-2039

In all climate scenarios and ranking techniques, L1 and L3 consistently outperformed the other two locations. The analysis revealed that L1 obtained the highest ranking at least 7 times out of 20, whereas L3 received at least 14 out of 20. In the RCP 2.6 scenario, L1 obtained the highest ranking frequency 9 times out of 20, while L3 received the highest ranking 15 times out of 20 in RCP 4.5 and 8.5. This suggests that L1 and L3 are the most preferred locations compared to L2, but based on the frequency of Rank 1, L3 appears to be a more feasible location compared to L1.

L2 consistently ranked second in all scenarios. The analysis of L2 consistently shows that it was ranked second (Rank 2) across all four climate scenarios and most of the ranking techniques and months. There are no cases where it ranked first (Rank 1). Notably, the VIKOR technique for all RCPs suggested that L2 was not a promising location to be selected, whereas other techniques generally rank it second. This suggests that L2 is less preferred as a location compared to L1 and L3.

Overall, these location analyses give decision-makers useful information to choose a feasible location, considering different climate scenarios and ranking methods. L1 and L3 consistently rank higher than L2 in all climate scenarios and ranking techniques, with L3 having the highest ranking frequency. Therefore, selecting L3 is strongly recommended. It is critical to understand that rankings can change depending on a variety of factors.

The ranking results for L1, L2, and L3 are shown in Table 6-34, Table 6-35, and Table 6-36. Appendix J1 contains details of the calculations for each location based on various scenarios for the period 2010-2039.

Table 6-34: Ranking Analysis Location 1 (2010-2039)

Proposed Location	**Location 1 (L1)**																				**Ranking Mode**	**Rank 1 (Frequency)**
Period	**2010-2039**																					
Month	**Nov**				**Dec**				**Jan**				**Feb**				**Mar**					
Method	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**		
	Scenario																					
RCP 2.6	1	3	NA	3	1	2	1	3	1	3	NA	3	1	3	1	3	1	1	1	3	**1**	**9**
RCP 4.5	1	3	1	3	1	3	NA	3	1	3	NA	3	1	3	NA	3	1	2	1	2	**3**	**7**
RCP 6.0	1	3	NA	3	1	3	NA	3	1	2	1	2	1	2	1	2	1	3	NA	3	**1**	**7**
RCP 8.5	1	3	NA	3	1	2	1	3	1	3	NA	3	1	2	NA	3	1	2	1	3	**1**	**7**

Table 6-35: Ranking Analysis Location 2 (2010-2039)

Proposed Location	Location 2 (L2)																				Ranking Mode	Rank 1 Frequency)
Period	2010-2039																					
Month	Nov				Dec				Jan				Feb				Mar					
Method	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM		
Scenario																						
RCP 2.6	2	2	NA	2	2	3	NA	2	2	2	NA	2	2	2	NA	2	2	3	NA	2	**2**	**0**
RCP 4.5	2	2	NA	2	2	2	NA	2	2	2	NA	2	2	2	NA	2	2	3	NA	3	**2**	**0**
RCP 6.0	2	2	NA	2	2	2	NA	2	2	3	NA	3	2	2	NA	2	2	2	NA	2	**2**	**0**
RCP 8.5	2	2	NA	2	2	3	NA	NA	2	2	NA	2	2	3	NA	2	2	3	NA	2	**2**	**0**

Table 6-36: Ranking Analysis Location 3 (2010-2039)

Proposed Location	Location 3 (L3)																				Ranking Mode	Rank 1 (Frequency)
Period	2010-2039																					
Month	Nov				Dec				Jan				Feb				Mar					
Method	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM		
Scenario																						
RCP 2.6	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	3	2	1	1	**1**	**14**
RCP 4.5	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	**1**	**15**
RCP 6.0	3	1	1	1	3	1	1	1	3	1	3	1	3	1	1	1	3	1	1	1	**1**	**14**
RCP 8.5	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	**1**	**15**

6.7.2.2 Locations Analysis 2040-2069

In summary, the results consistently indicate that L1 and L3, two of the proposed locations, achieved a higher frequency of Rank 1 than L2, which consistently ranked last across all climate scenarios and methods. For L1, the highest Rank 1 frequency is 10 out of 20, while for L3, it is 15 out of 20 across all climate scenarios. Hence, both locations should be considered for recommendations. However, based on the frequency of Rank 1, L3 appears to be a more feasible, preferred, and robust location than L1.

L2 consistently ranked second across all climate scenarios except for the VIKOR technique, which suggested that L2 was not a feasible recommendation in all cases. For some climate scenarios, L2 was ranked third, specifically in December and February, based on the TOPSIS and WSM ranking techniques. This suggests that L2 is not a feasible location when compared to L1 and L3.

Overall, these location analyses highlight the importance of considering different scenarios and ranking techniques when making decisions, as the optimal location can vary depending on these factors. However, there are some consistent patterns, such as L1 and L3 consistently ranking as the top locations. To make an informed decision, it is also important to consider possible trade-offs and unknowns for each location.

In conclusion, L3 is the most feasible location for all months and situations, followed by L1. L2 is not a recommended location based on its poor ranking results. These findings provide valuable guidance for decision-making in this study and can help determine the best location for future planning, considering the strengths and weaknesses of each location and the ranking techniques used.

The ranking results for L1, L2, and L3 are shown in Table 6-37, Table 6-38, and Table 6-39. Appendix J2 contains details of the calculations for each location based on various scenarios for the period 2040-2069.

Table 6-37: Ranking Analysis Location 1 (2040-2069)

Proposed Location	**Location 1 (L1)**																				**Ranking Mode**	**Rank 1 (Frequency)**
Period	**2010-2039**																					
Month	**Nov**				**Dec**				**Jan**				**Feb**				**Mar**					
Method	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**		
Scenario																						
RCP 2.6	1	3	1	3	1	3	1	3	1	2	1	3	1	2	1	2	1	3	1	3	**1**	**10**
RCP 4.5	1	3	NA	3	1	3	NA	3	1	2	1	3	1	3	1	3	1	3	1	3	**3**	**8**
RCP 6.0	1	3	NA	3	1	3	NA	3	1	2	1	2	1	3	NA	3	1	3	NA	3	**3**	**6**
RCP 8.5	1	3	NA	3	1	3	NA	3	1	2	1	3	1	2	1	2	1	3	NA	3	**1**	**7**

Table 6-38: Ranking Analysis Location 2 (2040-2069)

Proposed Location	**Location 2 (L2)**																				**Ranking Mode**	**Rank 1 (Frequency)**
Period	**2040-2069**																					
Month	**Nov**				**Dec**				**Jan**				**Feb**				**Mar**					
Method	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**	**AHP**	**TOPSIS**	**VIKOR**	**WSM**		
Scenario																						
RCP 2.6	2	2	NA	2	2	2	NA	2	2	3	NA	2	2	3	NA	3	2	2	NA	2	**2**	**0**
RCP 4.5	2	2	NA	2	2	2	NA	2	2	3	NA	2	2	2	NA	2	2	2	NA	2	**2**	**0**
RCP 6.0	2	2	NA	2	2	2	NA	2	2	3	NA	2	2	2	NA	2	2	2	NA	2	**2**	**0**
RCP 8.5	2	2	NA	2	2	2	NA	2	2	3	NA	2	2	3	NA	3	2	2	NA	2	**2**	**0**

Table 6-39: Ranking Analysis Location 3 (2040-2069)

Proposed Location	Location 3 (L3)																				Ranking Mode	Rank 1 Frequency)
Period	20140-2069																					
Month	Nov				Dec				Jan				Feb				Mar					
Method	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM	AHP	TOPSIS	VIKOR	WSM		
Scenario																						
RCP 2.6	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	**1**	**15**
RCP 4.5	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	**1**	**15**
RCP 6.0	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	**1**	**15**
RCP 8.5	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	3	1	1	1	**1**	**15**

6.7.2.3 Recommended Location based on period 2010-2039 and 2040-2069

The location analyses for both time periods were further examined to determine the most recommended location that could be chosen. The rankings are determined by the total sum of the Rank 1 frequency for each climate scenario and the period analysis for each location.

Table 6-40 provides information on the locations for each scenario and period based on the total sum of Rank 1. L1 and L3 are the locations with the highest total rank; L1 has a total of 61 and L3 has a total of 118, while L2 has no score. The analysis revealed that L3 is the highest-ranked location for all four climate scenarios and both time periods, with a total score of 29 or 30, depending on the climate scenario. Hence, L3 appears to be the most feasible location in comparison to L1 and L2.

Table 6-41 provides more details on the recommended L3 location. The table shows that the L3 has a high rainfall volume value for the months of November and December for all scenarios between 370 mm and 660 mm, indicating that the location is prone to flooding during these months. However, the RRS index for these months is relatively low, indicating that the location is less vulnerable to the impact of the flooding.

On the other hand, the rainfall volume values for the months of January, February, and March are low, indicating that the location is less prone to flooding during these months. Similarly, the RRS index for these months is also relatively low, indicating that the location is less vulnerable to the impact of the flooding. The overall Status of L3 across all climate scenarios and periods indicates that the RRS status of the location is either Wet, Normal or Dry, and no Extreme Wet was discovered, hence supporting the selection of L3 as a recommended location.

In conclusion, the results suggest that L3 is the most feasible location for the studied period and climate scenarios. Nonetheless, the location is still prone to flooding during certain months, and appropriate measures such as improved drainage systems and flood resilience construction material should be taken to mitigate the impact of flooding during these periods. Details of the calculation for locations in different RCPs and for both periods can be found in Appendices J3 and J10.

Table 6-40: Recommended Location

Proposed Location	**Period**	**Scenario**			
		RCP 2.6	**RCP 4.5**	**RCP 6.0**	**RCP 8.5**
L1	2010-2039	9	7	7	7
	2040-2069	10	8	6	7
	Sum Rank 1	**19**	**15**	**13**	**14**
Total Rank1 for L1		**61**			
L2	2010-2039	0	0	0	0
	2040-2069	0	0	0	0
	Sum Rank 1	**0**	**0**	**0**	**0**
Total Rank1 for L2		**0**			
L3	2010-2039	14	15	14	15
	2040-2069	15	15	15	15
	Sum Rank 1	**29**	**30**	**29**	**30**
Total Rank1 for L3		**118**			

Table 6-41: Details on recommended L3

Proposed Location	**Month**	**Criteria**	**Ranking by Scenario**							
			RCP 2.6	**RCP 4.5**	**RCP 6.0**	**RCP 8.5**	**RCP 2.6**	**RCP 4.5**	**RCP 6.0**	**RCP 8.5**
			2010-2039				**2040-2069**			
L3	Nov	RV	519.37	469.06	476.69	372.04	437.73	433.79	432.15	433.62
		RRS	0.20	0.18	0.18	0.14	0.20	0.02	0.20	0.20
		RRS Status	W	N	N	N	N	N	N	N
	Dec	RV	652.29	498.08	477.69	647.7	491.61	466.5	507.8	458.65

Proposed Location	**Month**	**Criteria**	**Ranking by Scenario**							
			RCP 2.6	**RCP 4.5**	**RCP 6.0**	**RCP 8.5**	**RCP 2.6**	**RCP 4.5**	**RCP 6.0**	**RCP 8.5**
			2010-2039				**2040-2069**			
		RRS	0.25	0.19	0.18	0.25	0.23	0.21	0.24	0.21
		RRS Status	W	N	N	W	N	N	W	N
	Jan	RV	296.54	213.86	121.53	110.14	264.4	274.75	276.79	250.8
		RRS	0.11	0.08	0.05	0.04	0.11	0.12	0.12	0.10
		RRS Status	N	N	N	N	N	N	N	N
	Feb	RV	115.6	82.34	101.24	74.87	97.31	103.29	120.47	120.49
		RRS	0.04	0.03	0.04	0.03	0.03	0.03	0.04	0.04
		RRS Status	N	D	N	D	D	D	D	D
	Mar	RV	15.12	54.53	7.04	23.24	67.02	82.22	88.35	74.49
		RRS	0.01	0.02	0.00	0.01	0.01	0.02	0.02	0.02
		RRS Status	D	D	D	D	D	D	D	D

RV: Rainfall Volume, N: Normal, D: Dry, W: Wet

6.7.2.4 Experts’ Validation

The final recommendation location, L3, underwent expert validation using the CVI. Eleven experts evaluated six CVI items (refer to Table 6-7), rating each item's relevance to L3 using the provided scale.

In this case, the I-CVI scores range from 0.73 to 1.00, showing a high degree of agreement among the experts. The S-CVI is 0.84, which is above the recommended threshold of 0.78 (Lynn, M.R., 1986), further supporting the content validity of the scale, which is generally considered to be a good level of agreement. The findings revealed that more than 80% of experts agree on the relevance of the items, specifically I2, I3, I5, and I6. In addition, items 1 and 4 had a lower I-CVI of 0.73, indicating that the experts had slightly less agreement on their relevance. Overall, the results suggest that the items have good content validity for measuring the L3, as assessed by a panel of experts. Hence, based on experts’ validation, L3 had a high degree of agreement as a recommended location feasible for constructing a new hospital building. The CVI results are shown in Table 6-42.

Table 6-42: CVI Result for L3

No	**Item ID**	**Expert 1**	**Expert 2**	**Expert 3**	**Expert 4**	**Expert 5**	**Expert 6**	**Expert 7**	**Expert 8**	**Expert 9**	**Expert 10**	**Expert 11**	**Expert in Agreement**	**I-CVI**
1	I1	1	1	1	0	0	1	0	1	1	1	1	8	0.73
2	I2	1	1	1	1	1	1	1	1	1	1	1	11	1.00
3	I3	1	1	1	0	1	1	0	1	1	1	1	9	0.82
4	I4	0	1	1	1	1	1	1	0	1	0	1	8	0.73
5	I5	1	1	1	1	1	1	1	0	1	1	1	10	0.91
6	I6	1	1	1	0	1	0	1	1	1	1	1	9	0.82
Proportion Relevant		**0.83**	**1.00**	**0.83**	**0.50**	**0.83**	**0.83**	**0.67**	**0.67**	**1.00**	**0.83**	**1.00**	Sum I-CVI	**5.01**
													S-CVI	**0.84**

6.8 Conclusion

Health and safety (H&S) facility management within flood-prone areas is crucial for strategic disaster planning. Ensuring these facilities are not only accessible but also located in safe zones is essential for continuous service during and after disasters. However, selecting suitable hospital locations can be challenging due to data limitations and the absence of prior assessments. This study developed a spatial decision support system (SDSS) to aid decision-makers in choosing flood-prone locations based on existing data.

The essence of this study is to provide a platform as a supporting toolkit for decision-makers to stimulate the suitability of flood action based on multiple locations proposed by decision-makers for improving FMP. Using a hospital in Kelantan as a case study, the SDSS prototype's key feature is its ability to identify the most suitable location using four MCDA techniques. It allows decision-makers to choose MCDA methods based on their strengths and weaknesses. While this study considered current data from NAHRIM and criteria understanding, it acknowledges that future criteria changes should be incorporated.

Regardless of the MCDA technique used, climate scenarios significantly impact future H&S facility management decisions. In each case study, locations L1 and L3 were found to be the most feasible options for constructing new hospital buildings in the future.

It is important to note that the criteria weights proposed by experts for WSM, TOPSIS, and VIKOR do not align with weights calculated using AHP. This suggests that subjective and objective expert judgements influence the distribution of initial criteria weight values, impacting the output results.

In conclusion, the combined spatial-MCDA approach provides a comprehensive understanding for efficient management and allows for prioritising flood-resistant measures in selected locations (Akay and Baduna Koçyiğit, 2020). This study demonstrates that this approach is a promising decision-support tool for recommending flood-prone locations, which can then be validated by decision-makers. It enables decision-makers to visualise spatial decisions with embedded criteria and performance values in a user-friendly format.

6.8.1 Contribution

The proposed prototype holds great potential for FMP applications, where decision analysis based on specific criteria is essential for planning and preparedness. This study presents a combined spatial-MCDA technique as a DSS, facilitating comprehensive and collective decision-making where each criteria value significantly influences the final decisions. This represents a significant step towards the development of a decision support system that utilises spatial analysis and MCDA techniques as its primary methodologies.

6.8.1.1 Contribution to Practice

The prototype has several potential applications and benefits for NAHRIM specifically, and the Government of Malaysia:

a. Comprehensive Information Platform: The prototype can serve as an analysis platform for NAHRIM, enabling the organisation to gather comprehensive information based on selected criteria for analysis and reporting purposes to the Government of Malaysia.
b. Decision-Making Toolkit: It can be used as a toolkit to facilitate the decision-making process among various stakeholders in the Malaysian government. This tool allows decision-makers to gain a deeper understanding before implementing decisions, fostering more informed discussions and recommendations.
c. Adaptability and Expandability: The prototype is highly adaptable and expandable. It can easily accommodate new criteria or changes in criteria values to meet the requirements of different analyses and strategies. This adaptability is crucial in accommodating changes in criteria selection during the decision-making process.
d. Cross-Disciplinary Applications: The prototype's applicability extends beyond flood management. Different ministries and stakeholders can replicate and adopt the prototype to enhance decision analysis in various domains, including economic activity planning, tourism and hospitality management, and town planning, among others.
    i. Economic Activity Planning

       Example 1: To identify new areas for industrial or agricultural economic activities that are low-risk to flooding.

       Example 2: To identify alternative agricultural economic activities based on rainfall intensity, soil type, and access to roads.
    ii. Tourism and Hospitality Management

       Example 1: To propose alternative flood measures based on current hotels and resorts' locations for reducing flood risk.

       Example 2: To identify potential areas for new hotel and resort development based on demographic and land use criteria.

iii. Town Planning Management

Example 1: To design a disaster-resistant residential area.

The SDSS developed is a forerunner to more complex spatial and MCDA criteria analyses. Future refinements should include the incorporation of additional criteria, both spatial and non-spatial, as well as historical and projection data for validation and ongoing improvement, as detailed in the Recommendation section.

6.8.2 Limitation

This study serves as an initial evaluation of the prototype, focusing on its feasibility based on NAHRIM's requirements and available data. The intention is to pave the way for potential larger-scale implementations in the future. The researcher has duly recognised certain limitations of the prototype, including constraints related to criteria, location selection, expert involvement, and the type of analysis, all of which offer opportunities for enhancement.

The criteria used in this case study were relatively minimal and limited. Future iterations of the prototype could benefit from additional data and information, such as soil type, temperature, population demographics, economic activities, and more robust flood risk modelling. Expanding the criteria would lead to a more comprehensive and evidence-based location selection process.

The prototype's current design involves a fixed number of experts (3 experts). For greater robustness and applicability, it's advisable to have a dynamic number of experts, allowing for more significant input. In FMP decisions, which often require extensive expert involvement, this flexibility would be highly valuable.

The validation of the prototype was focused more on the feasibility of the prototype being adapted within the FMP context than the prototype itself. Future validation efforts should engage experts from the computing domain, soliciting feedback from a system development perspective. This approach, possibly through alpha and beta testing, would ensure that the prototype is not only feasible but also applicable and executable on a larger scale.

While experts selected the criteria employed in this study, there are other relevant criteria, such as land price and the legal aspects of land takeover, that could significantly support location selection. Future recommendations should consider adding these additional criteria as a new layer within the prototype, provided they conform to the prototype's format.

As a conclusion, this study has conscientiously acknowledged the identified limitations of both the developed prototype and the conducted case study. It underscores the potential for further investigation and improvements in future iterations of the prototype. This recognition of limitations, along with proposed solutions, sets the stage for more comprehensive and effective decision support systems in the field of FMP and related domains.

6.8.3 Recommendation

While the prototype is relatively simple, it marks the initial effort by NAHRIM and the Government of Malaysia to employ combined spatial-MCDA techniques with gridded data for Flood Management Preparedness (FMP) analysis. There is room for significant improvement in the criteria, MCDA techniques, analysis, and validation processes.

The first research recommendation is to incorporate a more extensive set of criteria from various domains, as discussed in Chapters 3 and 4. Expanding criteria, such as population density (Mahmoud, S. H. and Gan, T. Y., 2018; Hammami et al., 2019; Karamouz, M. et al., 2019; Khosravi, K. et al., 2019; Moghadas et al., 2019; Banihabib et al., 2020), the number of hospital beds (Levy et al., 2007; de Brito et al., 2018; Kansal et al., 2019; Lin, L. et al., 2019), and early-warning systems (Naubi et al., 2017), would strengthen the analysis and reveal deeper relationships between criteria and outcomes. It's important to consider criteria from the Political and Legal domains, though their accessibility may pose challenges.

Instead of relying solely on the same four MCDA methods used in the prototype, the second research direction suggests exploring different MCDA techniques. Combining single-method and mixed-method approaches to data analysis can offer a more comprehensive perspective. Given the growing interest in mixed-method techniques, exploring this approach could yield valuable insights.

In this study, the analysis was based on the frequency of Rank 1 obtained by each location using MCDA techniques. Future recommendations could explore different analysis methods. For instance, the study could rank locations based on a primary MCDA technique or expand the analysis by using multiple techniques to support or compare results.

The fourth research direction proposes developing computer modelling and simulation methods for prototype validation. This approach complements expert validation and can enhance results accuracy and assessment.

Additionally, conducting in-situ investigations and observations would further validate the recommended locations.

In conclusion, the prototype represents the first step towards a more comprehensive DSS to enhance decision analysis in the FMP. While it focuses on criteria and spatial analysis, it is adaptable to accommodate additional criteria and values, covering as many possible criteria as identified by decision-makers. The knowledge contribution lies in the applied methodology and technique, which benefit NAHRIM, the Government of Malaysia, and the utilisation of data under the Malaysia Public Sector Big Data Analytics Initiative (MAMPU, 2013). The suggested research directions will undoubtedly bolster the prototype's capabilities, allowing for more robust and informed decision-making in the realm of FMP decisions.

6.9 Publication

The study conducted in this chapter has been presented at the 8th International Case Study Conference (30th August -1st September 2023). The presentation is titled "Spatial Decision Support System Utilizing Multi Criteria Decision Analysis and Spatial Information for Flood Management Planning: A Location Analysis for the Construction of a New Hospital Building in Kelantan, Malaysia." The presentation's focus on the innovative SDSS and its integration with MCDA and spatial information emphasises the study's contributions to enhancing flood management planning, specifically through a meticulous location analysis for the proposed new hospital building in Kelantan, Malaysia. The paper is available in e-proceeding: e-ISSN: 2756-8482.

Chapter 7
General Discussion

7.1 Research Summary

The four studies conducted have revealed two areas where MCDA can be used to optimise the FMP decision-making process. Firstly, there is a need to refine the criteria identification and selection process to establish a definitive set of criteria that can be effectively utilised in FMP decisions. The need for this refinement has been demonstrated in the studies conducted in Chapters 3 and 4. Chapter 3 focused on the integrated MCDA-PESTEL approach, while Chapter 4 discussed the criteria analysis process to improve the study in Chapter 3 based on the MCDA-QMA integrated approaches.

Secondly, it has been recognised that integrated spatial-MCDA approaches as a decision support system tool for decision-makers have a significant impact on facilitating decision-makers in FMP decisions. However, the development of such a system requires the formulation of structured guidelines and thorough testing to assess its feasibility and practicality prior to implementation. The framework proposed in Chapter 5 has been utilised in the prototype development of the combined spatial-MCDA decision support system in Chapter 6.

The results of each study are important for the FMP's decisions. This is true for both managerial aspects, like deciding which criteria to use, and operational or technical aspects, like improving flood measures using the MCDA technique. The significance of each study is elaborated as follows:

a. Chapter 3: The framework proposed enhances decision-makers' understanding of flood criteria to be employed by improving the flood criteria identification and selection process. By incorporating the MCDA technique and the PESTEL macro domain analysis framework, it facilitates the decision-makers consideration of wider aspects that influenced the FMP decisions.
b. Chapter 4: The framework proposed in this study would improve the criteria analysis prior to establishing a definitive set of criteria. Experts' engagement, together with the MCDA technique and QMA, empowers decision-makers to critically analyse and reflect on the criteria to improve FMP decisions.
c. Chapter 5: The proposed framework has laid out the significance process in a way that can be used to make combined spatial-MCDA

applications in the future. This framework would serve as a guideline to facilitate researchers and academicians in the implementation process as well as improve the process.

d. Chapter 6: The developed SDSS would serve as a prototype that had demonstrated its practicability to be employed to facilitate decision-makers improved FMP decisions. By integrating spatial data with the MCDA technique, the SDSS would serve as a dashboard platform that provides comprehensive information to support FMP decisions.

By combining these approaches, the studies demonstrated how MCDA applications can be optimised to enhance the overall decision-making process for FMP. This, in turn, contributes to improving DMP for floods, including mitigation, preparedness, response, and recovery, ultimately leading to a reduction in the impact of floods.

7.2 Contribution

The combined contributions of the individual chapters in this study represent a significant advancement in academic literature, particularly within the domain of FMP and related disciplines. In Chapter 3, the innovative utilisation of the PESTEL analysis framework to enhance the criteria identification and selection process for FMP using MCDA addresses critical gaps identified through an extensive literature review. This research not only expands and re-evaluates criteria options, providing decision-makers with a more extensive range of choices, but also contributes to the academic discourse by offering a practical framework adaptable to various water-related disasters and applicable in diverse disciplines.

Chapter 4 makes substantial contributions to methodology and theory by introducing a conceptual framework emphasising criteria reflection in the identification and selection process. This novel approach aligns with existing recommendations and guides decision-makers towards more informed decisions based on robust structural planning, criteria certainty considerations, and trade-off evaluations. The study broadens the decision-making process, reducing errors and optimising resource utilization. The proposed framework's potential application in various domains strengthens its versatility, making it a noteworthy addition to academic literature.

Chapter 5 introduces a comprehensive conceptual framework for a combined spatial-MCDA decision support system tailored to PESTEL macro domain criteria in FMP. This structured framework offers a clear roadmap for researchers and practitioners, contributing not only to FMP decision-making processes but also serving as a potential guideline for similar platforms in multidisciplinary studies. The academic contribution lies in providing clarity and structure to decision support systems within the context of complex environmental decision-making.

In Chapter 6, the proposed prototype for FMP applications stands out as a significant academic contribution. The combined spatial-MCDA technique as a DSS represents an innovative approach that recognises the substantial influence of each criterion value on the final decision. This not only advances FMP decision-making but also contributes to the broader academic discourse surrounding decision support systems by integrating spatial analysis and MCDA methodologies for more effective and informed planning. Collectively, these chapters elevate the academic discourse surrounding FMP and related domains, providing novel perspectives and practical frameworks that contribute significantly to existing literature.

7.3 Limitation

The researcher acknowledges several limitations in the studies conducted. The SLR study in Chapter 2 only considered works published from 2000–2020 to investigate MCDA application trends and patterns, potentially excluding newer data and information. Consequently, in Chapters 3 and 4, the analysis was focused solely on the data and information gathered during that period. Any new data and information from works published after 2020 were not included in the analysis, highlighting the need to consider this aspect in future research.

In Chapter 3, the details of Phase 4 (Flood Measures) in the proposed conceptual framework shown in Figure 3-6 were not discussed extensively. This was due to the researcher’s limited knowledge, technical expertise, and experience in the appropriate flood measures approach, which would require an in-depth study with experts. However, this study did cover the general and commonly used flood measures, such as structured, unstructured, and hybrid.

In Chapter 6, the case study employed only six criteria, which did not encompass all six PESTEL macro domains originally intended for testing. This limitation was due to restricted data accessibility and availability, which hindered the researcher’s ability to obtain criteria from other domains. However, as mentioned in subsection 6.8.3, the recommendation was made to incorporate new criteria from other domains. The prototype has the potential for expansion to incorporate new criteria from other domains, which the researcher should explore in future studies.

7.4 Future Directions

The study's results indicate a promising prospect for further investigation and advancement in this field. Furthermore, recommendations for expanding the scope of the study have been identified. The following recommendations are addressed below:

a. Criteria Selection

Chapter 6 employs the six criteria used in the case study. A future study should investigate the potential advantages of integrating additional new criteria, whether within the same domains or across different domains. Adding new criteria to decision-making is crucial as it enables a comprehensive analysis, contextualises the decision-making process, adapts to changing circumstances, and promotes stakeholder engagement and transparency. This would enable result comparison and lead to improved decision quality and outcomes for FMP decisions.

b. Frameworks Validation

Obtaining validation from experts would practically extend the work of the proposed frameworks in Chapters 3, 4, and 5. The frameworks can be employed in various fields of study, and seeking validation from experts would bring valuable perspectives, expertise, and scrutiny to ensure their relevance, effectiveness, and practical applicability. It contributes to the overall quality and acceptance of the frameworks, enabling their successful implementation in various contexts.

c. Expert Participation

The level of expert participation and the number of experts involved in the MCDA analysis process in Chapter 6 can significantly impact the results. This underscores the importance of considering the backgrounds of experts in determining the final recommendation of locations. Therefore, future studies should aim to include a more diverse cohort of experts from various disciplines. It will ensure a comprehensive and unbiased approach, improve decision quality, reduce individual biases, promote innovation, and lead to more informed and robust outcomes.

d. Case Study Scenario

Based on the discussion in Chapter 6, sub-section Recommendation, it is recommended to assess the evacuation centres and clinics using the developed prototype. This analysis will focus on the same case study setting, considering the current flood incidents in Malaysia. Additionally, it would be valuable to further analyse the current case study by varying the weighting, land use type risk score, and other parameters. This would offer an interesting avenue for investigation. Furthermore, future work should explore potential investigations or analyses for different domains of study, such as tourism, health, and transportation.

7.5 Conclusion

Despite acknowledging limitations and identifying areas for future work, this study has successfully achieved its primary objective of optimising the application of MCDA for improving the FMP decision-making process. Furthermore, these approaches can be extended to address broader aspects and incorporate additional criteria from various domains when needed.

In conclusion, this study introduces three frameworks that offer decision-makers a comprehensive and effective approach to identifying, selecting, and analysing flood criteria. Additionally, the study presents a prototype of a spatial decision support system as a potential solution for enhancing the decision-making process through a combined spatial-MCDA approach.

The integration of the four study outputs has demonstrated a significant synergistic effect on improving decision outcomes in FMP. The practical implementation of these outputs can serve as a valuable guideline and tool, laying the groundwork for enhancing the quality of decision analysis and strategy in FMP.

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Appendix A

Sections for Clustering Extracted Data

Section 1: MCDA technique

Identified type of MCDA technique and categorized into two groups which are:

a. Single method
b. Mixed method

Section 2: Macro domain criteria

Identify the criteria and map them to six PESTEL macro domains (Political, Economic, Social, Technological, Environmental, and Legal).

Section 3: Number of criteria

Count number of criteria used in each study

Section 4: Decision goals

Identify the MCDA decision goal determined for each study

Section 5: Flood Measure and Action

Determined flood action and flood measure type from each study. The type of flood action and measure were determined based on explanation from the literature and researcher understanding, and grouped as follows:

Flood Measure	**Flood Action**
a. Assessment (*to conduct evaluation and measures specific elements to assist decision making)*	a. Assessment – Reduce Risk b. Assessment – Improve Resilience c. Assessment – Hazards d. Assessment – Reduce Vulnerability e. Assessment – Reduce Risk & Improve Resilience
b. Spatial (*to prepare spatial maps or applications to assist decision making)*	a. Spatial – Reduce Risk b. Spatial – Improve Resilience c. Spatial – Hazards d. Spatial – Reduce Vulnerability
c. Assessment & Spatial (*combination of both, where evaluation of specific elements was conducted based on spatial maps or application to assist decision making)*	a. Assessment & Spatial – Reduce Risk b. Assessment & Spatial – Improve Resilience c. Assessment & Spatial – Hazards d. Assessment & Spatial – Reduce Vulnerability e. Assessment & Spatial – Reduce Vulnerability & Improve Resilience f. Assessment & Spatial – Reduce Risk & Reduce Vulnerability

Appendix B

Interview Questions for Criteria Selection & Identification for Project Viability in Flood Management Plan using PESTEL and Multi-criteria Decision Analysis (MCDA)

Section 1

INTERVIEW QUESTIONS

AIM OF INTERVIEW:

To assess the list of criteria used for project viability in flood disaster management.

Q1 What decisions have you faced that relate to the viability of the flood management project?
(E.g.: to select data to be used, to prioritise flood location, to allocate financial budget for flood management project, to choose relevant flood measures activities, to rank best flood measures activities)

Q2 What are the problems and challenges you face to implement the decisions?
(E.g.: exhaustive dataset, too many location, incomplete data & information, understanding the requirements, current conditions of the location, complicated analysis, time-consuming, conflict of interest) •

Q3 What are the main factors/criteria considered to support your decisions?
(E.g.: technology used, political influenced, funding/budget, economy activities, social implication, environmental impacts, legislative implication) •

Q4 How do you assess/measure the factors/criteria mentioned to facilitate your decisions?
(E.g.: modelling, explanation, statistical analysis, spatial analysis, simulation, etc.)

Q5 Do the following domains capture important criteria for viability in flood management projects? Why?

Political	
Economic	
Social	
Technological	
Environmental	
Legal	

Q6 Based on the table provided, please suggest additional sub-criteria that are relevant and give the value? If possible, can you also list examples of data for the newly proposed sub-criteria?

Political	
Economic	
Social	
Technological	
Environmental	
Legal	

Q7, *Do you use any specific technology or software tool that support your decisions?*

Section 2

Score

1 - Not Important	**2** - Slightly Important	**4** – Moderately Important
6 – Strongly Important	**8**- Very Strong Important	**10**- Extremely Important

Criteria	Sub-criteria (abstract)	Importance	Certainty
Political	1. Fair distribution of resources		
	2. Government capacity & capability		
	3. Updated policy according to the recent system development		
	4. Susceptible to changes		

Criteria	Sub-criteria (abstract)	Importance	Certainty
Economic	1. Damage & Loss to Building (Commercial, Residential, Agricultural, Industrial, Religious, heritage and cultural)		
	2. Damage & Loss in Infrastructure (Transportation, Telecommunication, Energy, Water, Tourism, Aesthetic & Recreation)		
	3. Damage & Loss in Economic Activities		
	4. Investment Cost		
	5. Financial Budget		
	6. Economic Density		
	7. Economic Loss		
	8. Incentives to new policy enforcement		

Criteria	Sub-criteria (abstract)	Importance	Certainty
Social	1. Quality of Life & Human Needs (Income, Residential, Food, Water etc.)		
	2. Transportation Access		

Criteria	Sub-criteria (abstract)	Importance	Certainty
	3. Telecommunication Capacity		
	4. Religious, Cultural & Heritage		
	5. Personal Loss		
	6. Town planning		
	7. Health, Safety, Welfare & Lifestyle		
	8. Education & Awareness		

Criteria	Sub-criteria (abstract)	Importance	Certainty
Technological	1. Flood Early Warning System		
	2. Data collection and analyses		
	3. Flood System/Modelling		
	4. Education & Awareness		
	5. Flood Structure & Control		
	6. Communication		
	7. Financial Budget		
	8. Integrated system using latest technology		

Criteria	Sub-criteria (abstract)	Importance	Certainty
Environmental	1. Water Quality		
	2. Land use & Planning		
	3. Hydrology		
	4. Topographic/Physical Data		
	5. Protection of wildlife habit		
	6. Protection & improvement of natural landscape		
	7. Water Supply Quantity		
	8. Flood risk management plan		
	9. Water Structure for Flood Protection		

Criteria	Sub-criteria (abstract)	Importance	Certainty
	10. Damage in land use and land cover		
	11. Flood Mitigation Plan		
	12. Biodiversity		

Criteria	Sub-criteria (abstract)	Importance	Certainty
Legal	1. Land ownership for flood protection		
	2. Government Law & Policy Regulation		
	3. Flood Disaster Institutional		
	4. International Constitutional & Standard, Guidelines		

Appendix C

Interview Plan: Study Chapter 3

No	Chapter	Study Title	Interview Plan		
			Expert	Date	Mode
1	3	Criteria Identification and Selection in Flood Management Planning from Macro-Domain Perspective in Multi-criteria Analysis Application based using PESTEL Analysis Framework	Expert 1	23rd July 2021	Online
			Expert 2	28th July 2021	Online
			Expert 3	30th July 2021	Online
			Expert 4	1st August 2021	Online
			Expert 5	3rd August 2021	Online
			Expert 6	5th August 2021	Online
			Expert 7	5th August 2021	Face-to-Face
			Expert 8	6th August 2021	Online
			Expert 9	7th August 2021	Online
			Expert 10	9th August 2021	Online

***Mode Online**: The interview session was conducted virtually using Google Meet or Microsoft Teams*

***Mode Face-to-Face**: The interview session was conducted physically with expert*

***Mode Hybrid**: The interview session was conducted virtually and physically*

Appendix D

Interview Plan: Study for Chapter 4

<table>
<tr><th rowspan="2">No</th><th rowspan="2">Chapter</th><th rowspan="2">Study Title</th><th colspan="3">Interview Plan</th></tr>
<tr><th>Expert</th><th>Date</th><th>Mode</th></tr>
<tr><td rowspan="10">1</td><td rowspan="10">4</td><td rowspan="10">Experts Review on Criteria Ranking for Flood Management Planning using Analytical Hierarchical Process (AHP)</td><td>Expert 1</td><td rowspan="10">19th May 2022</td><td rowspan="10">Hybrid</td></tr>
<tr><td>Expert 2</td></tr>
<tr><td>Expert 3</td></tr>
<tr><td>Expert 4</td></tr>
<tr><td>Expert 5</td></tr>
<tr><td>Expert 6</td></tr>
<tr><td>Expert 7</td></tr>
<tr><td>Expert 8</td></tr>
<tr><td>Expert 9</td></tr>
<tr><td>Expert 10</td></tr>
</table>

Mode Online*: The interview session was conducted virtually using Google Meet or Microsoft Teams*

Mode Face-to-Face*: The interview session was conducted physically with expert*

Mode Hybrid*: The interview session was conducted virtually and physically*

Appendix E

SURVEY FORM FOR CRITERIA IN FLOOD MANAGEMENT PLANNING BASED ON MACRO DOMAIN CRITERIA

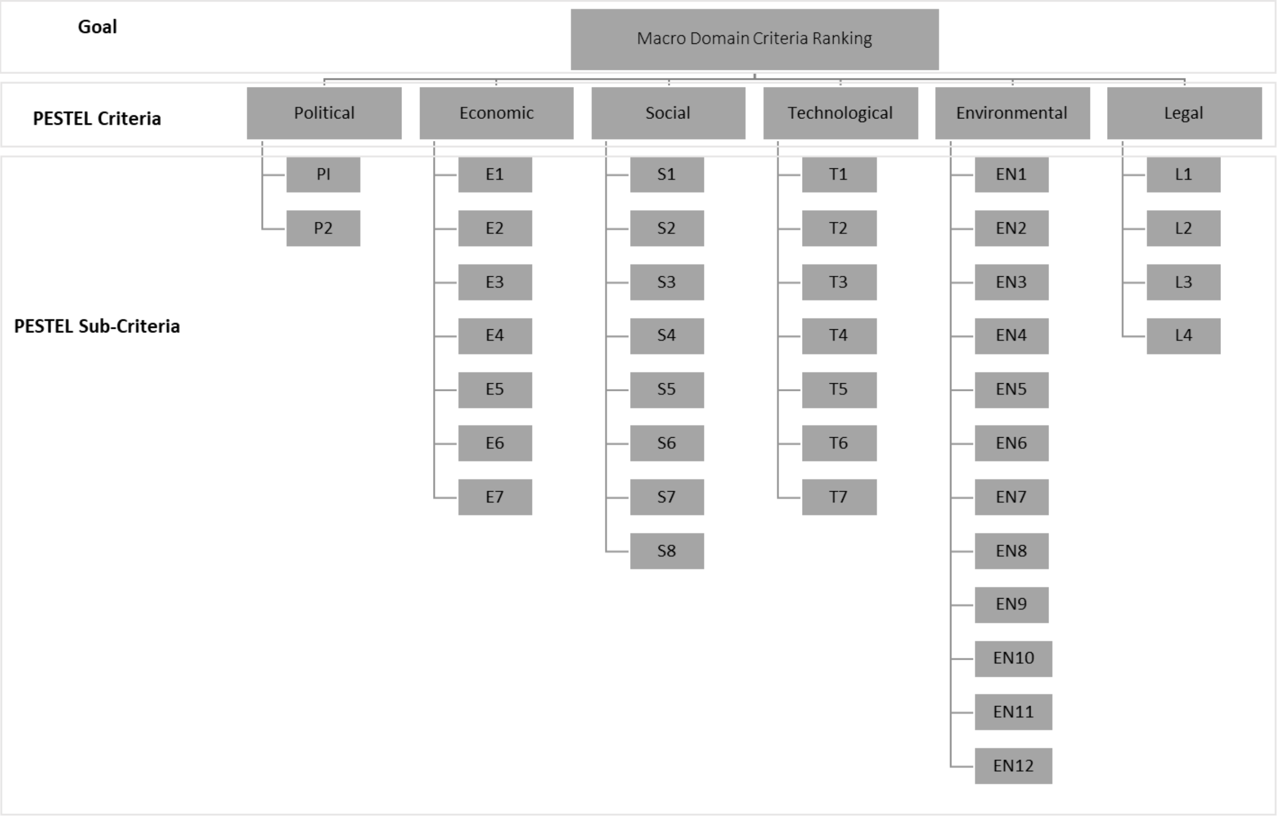
SURVEY FORM FOR CRITERIA IN FLOOD MANAGEMENT PLANNING BASED ON MACRO DOMAIN CRITERIA

The objective of this survey to get input from experts based on the intensity of importance for macro domain criteria based on PESTEL macro domain. The goal is to rank the significance criteria for FMP.

Expected Output: ***Ranking of macro domain criteria based on PESTEL analysis framework (Political, Economic, Social, Technological, Environmental, Legal)***

Expected Outcome:

a. Improve criteria selection in decision making for FMP based on macro domain perspective.
b. Broadening criteria selection for criteria trade-off



Hierarchical Criteria

Scale of Relative Importance (Saaty, 1977)

Intensity of Importance	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance

Intensity of Importance	**Definition**
7	Very Strong Importance
9	Extremely Strong Importance
2,4,6,8	Intermediate Values (for compromise between the above values)

Comparisons among Criteria

Criteria 1	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criteria 2**
Political																		Economic
Political																		Social
Political																		Technological
Political																		Environmental
Political																		Legal
Economic																		Social
Economic																		Technological
Economic																		Environmental
Economic																		Legal
Social																		Technological
Social																		Environmental
Social																		Legal
Technological																		Environmental
Technological																		Legal
Environmental																		Legal

Comparisons among Political Sub-criteria based on “Criteria 1: Political”.

Criteria 1	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criteria 2**
P1																		P2

Comparisons among Economic Sub-criteria based on “Criteria 2: Economic”.

Criteria 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria 2
EC1																		EC2
EC1																		EC3
EC1																		EC4
EC1																		EC5
EC1																		EC6
EC1																		EC7
EC2																		EC3
EC2																		EC4
EC2																		EC5
EC2																		EC6
EC2																		EC7
EC3																		EC4
EC3																		EC5
EC3																		EC6
EC3																		EC7
EC4																		EC5
EC4																		EC6
EC4																		EC7
EC5																		EC6
EC5																		EC7

Comparisons among Social Sub-criteria based on “Criteria 3: Social”.

Criteria 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria 2
S1																		S2
S1																		S3
S1																		S4
S1																		S5

S1																		S6
S1																		S7
S1																		S8
S2																		S3
S2																		S4
S2																		S5
S2																		S6
S2																		S7
S2																		S8
S3																		S4
S3																		S5
S3																		S6
S3																		S7
S3																		S8
S4																		S5
S4																		S6
S4																		S7
S4																		S8
S5																		S6
S5																		S7
S5																		S8
S6																		S7
S6																		S8
S7																		S8

Comparisons among Technological Sub-criteria based on “Criteria 4: Technological”.

Criteria 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria 2
T1																		T2
T1																		T3
T1																		T4
T1																		T5
T1																		T6
T1																		T7
T2																		T3
T2																		T4
T2																		T5
T2																		T6
T2																		T7
T3																		T4
T3																		T5
T3																		T6
T3																		T7
T4																		T5
T4																		T6
T4																		T7
T5																		T6
T5																		T7
T6																		T7

Comparisons among Environmental Sub-criteria based on “Criteria 5: Environmental”.

Criteria 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria 2
EN1																		EN2
EN1																		EN3
EN1																		EN4
EN1																		EN5
EN1																		EN6
EN1																		EN7
EN1																		EN8
EN1																		EN9
EN1																		EN10
EN1																		EN11
EN1																		EN12
E2																		EN3
E2																		EN4
E2																		EN5
E2																		EN6
E2																		EN7
E2																		EN8
E2																		EN9
E2																		EN10
E2																		EN11
E2																		EN12
E3																		EN4
E3																		EN5
E3																		EN6
E3																		EN7

Criteria 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria 2
E3																		EN8
E3																		EN9
E3																		EN10
E3																		EN11
E3																		EN12
E4																		EN5
E4																		EN6
E4																		EN7
E4																		EN8
E4																		EN9
E4																		EN10
E4																		EN11
E4																		EN12
E5																		EN6
E5																		EN7
E5																		EN8
E5																		EN9
E5																		EN10
E5																		EN11
E5																		EN12
E6																		EN7
E6																		EN8
E6																		EN9
E6																		EN10
E6																		EN11
E6																		EN12
E7																		EN8

Criteria 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria 2
E7																		EN9
E7																		EN10
E7																		EN11
E7																		EN12
E8																		EN9
E8																		EN10
E8																		EN11
E8																		EN12
E9																		EN10
E9																		EN11
E9																		EN12
E10																		EN11
E10																		EN12
E11																		EN12

Comparisons among Legal Sub-criteria based on “Criteria 6: Legal”.

Criteria 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria 2
L1																		L2
L1																		L3
L1																		L4
L2																		L3
L2																		L4
L3																		L4

Appendix F

Details on Normalised Pairwise Comparison Matrices, CI and CR

	P	**E**	**S**	**T**	**E**	**L**	**Weights (W)**	**AW**	**lamda**	**CI**	**RI**	**CR**
P	0.24	0.34	0.24	0.26	0.20	0.19	0.24	1.49	6.16	0.02	1.24	0.02
E	0.11	0.15	0.24	0.19	0.18	0.15	0.17	1.04	6.12			
S	0.14	0.09	0.14	0.17	0.19	0.16	0.15	0.91	6.06			
T	0.10	0.09	0.10	0.11	0.13	0.14	0.11	0.69	6.08			
E	0.14	0.10	0.09	0.10	0.12	0.13	0.11	0.69	6.09			
L	0.27	0.23	0.19	0.18	0.19	0.22	0.21	1.29	6.13			
								Average (lamda)	6.11			

	P1	**P2**	**Weights (W)**	**AW**	**lamda**	**CI**	**RI**	**CR**
P1	0.80	0.80	0.80	1.60	2.00	0.00	0.00	0.00
P2	0.20	0.20	0.20	0.40	2.00			
				Average (lamda)	2.00			

	EC1	**EC2**	**EC3**	**EC4**	**EC5**	**EC6**	**EC7**	**Weights (W)**	**AW**	**lamda**	**CI**	**RI**	**CR**
EC1	0.18	0.28	0.24	0.19	0.13	0.16	0.13	0.19	1.35	7.18	0.02	1.32	0.01
EC2	0.08	0.12	0.18	0.14	0.15	0.12	0.14	0.13	0.94	7.10			
EC3	0.09	0.08	0.12	0.15	0.12	0.15	0.13	0.12	0.85	7.07			
EC4	0.10	0.10	0.09	0.11	0.15	0.13	0.12	0.12	0.81	7.09			
EC5	0.18	0.11	0.12	0.10	0.13	0.14	0.13	0.13	0.94	7.13			
EC6	0.14	0.14	0.10	0.12	0.13	0.13	0.15	0.13	0.92	7.12			
EC7	0.24	0.17	0.16	0.18	0.19	0.17	0.19	0.19	1.32	7.13			
									Average (lamda)	7.11			

	S1	S2	S3	S4	S5	S6	S7	S8	Weights (W)	AW	lamda	CI	RI	CR
S1	0.14	0.19	0.17	0.12	0.13	0.09	0.13	0.15	0.14	1.13	8.10	0.01	1.41	0.01
S2	0.09	0.12	0.14	0.12	0.15	0.12	0.13	0.12	0.12	0.99	8.09			
S3	0.10	0.10	0.12	0.13	0.14	0.12	0.14	0.13	0.12	0.98	8.09			
S4	0.15	0.14	0.12	0.13	0.15	0.15	0.16	0.10	0.14	1.11	8.10			
S5	0.10	0.07	0.08	0.08	0.09	0.13	0.10	0.10	0.09	0.75	8.09			
S6	0.17	0.12	0.12	0.10	0.08	0.12	0.11	0.12	0.12	0.94	8.10			
S7	0.11	0.10	0.09	0.09	0.10	0.11	0.11	0.13	0.10	0.84	8.09			
S8	0.15	0.17	0.16	0.22	0.16	0.17	0.14	0.17	0.17	1.35	8.10			
										Average (lamda)	8.10			

	T1	T2	T3	T4	T5	T6	T7	Weights (W)	AW	lamda	CI	RI	CR
T1	0.14	0.14	0.20	0.20	0.16	0.20	0.14	0.17	1.18	7.07	0.01	1.32	0.01
T2	0.12	0.12	0.16	0.18	0.15	0.14	0.13	0.14	1.01	7.09			
T3	0.08	0.09	0.12	0.17	0.16	0.15	0.13	0.13	0.90	6.98			
T4	0.09	0.09	0.09	0.13	0.13	0.15	0.13	0.12	0.81	7.00			
T5	0.08	0.07	0.07	0.10	0.09	0.13	0.12	0.10	0.66	7.00			
T6	0.08	0.10	0.09	0.10	0.08	0.12	0.11	0.10	0.69	7.08			
T7	0.10	0.10	0.10	0.11	0.08	0.10	0.11	0.10	0.70	7.15			
									Average (lamda)	7.05			

	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	Weights (W)	AW	lamda	CI	RI	CR
EN1	0.07	0.11	0.09	0.06	0.08	0.07	0.05	0.06	0.07	0.06	0.06	0.07	0.07	0.85	12.24	0.01	1.48	0.0080
EN2	0.06	0.09	0.14	0.09	0.10	0.11	0.09	0.08	0.09	0.08	0.08	0.08	0.09	1.12	12.40			
EN3	0.06	0.05	0.08	0.10	0.10	0.08	0.11	0.08	0.09	0.08	0.08	0.08	0.08	1.00	12.17			
EN4	0.10	0.08	0.07	0.08	0.10	0.08	0.09	0.07	0.08	0.10	0.10	0.08	0.09	1.05	12.29			
EN5	0.06	0.06	0.05	0.06	0.07	0.06	0.08	0.07	0.08	0.07	0.07	0.08	0.07	0.80	12.06			
EN6	0.07	0.06	0.07	0.07	0.08	0.07	0.07	0.06	0.07	0.07	0.07	0.08	0.07	0.85	12.03			
EN7	0.10	0.07	0.05	0.07	0.06	0.07	0.07	0.08	0.07	0.08	0.08	0.08	0.07	0.88	12.08			
EN8	0.07	0.06	0.07	0.05	0.07	0.08	0.07	0.07	0.07	0.08	0.08	0.08	0.07	0.84	12.01			
EN9	0.10	0.10	0.08	0.12	0.09	0.11	0.08	0.09	0.08	0.09	0.09	0.08	0.09	1.11	12.12			
EN10	0.07	0.07	0.06	0.08	0.06	0.07	0.07	0.08	0.07	0.06	0.06	0.08	0.07	0.84	12.21			
EN11	0.09	0.10	0.08	0.07	0.08	0.08	0.08	0.08	0.09	0.08	0.08	0.07	0.08	0.99	12.02			
EN12	0.14	0.16	0.16	0.16	0.13	0.13	0.13	0.17	0.14	0.16	0.16	0.15	0.15	1.78	11.934			
													Average (lamda)		12.13			

	L1	L2	L3	L4	Weights (W)	AW	lamda	CI	RI	CR
L1	0.34	0.45	0.37	0.25	0.35	1.61	4.60	0.03	0.90	0.04
L2	0.15	0.34	0.24	0.25	0.24	0.96	3.91			
L3	0.20	0.30	0.22	0.28	0.25	0.97	3.96			
L4	0.31	0.31	0.18	0.23	0.26	1.01	3.92			
						Average (lamda)	4.10			

Appendix G

Individual Consistency Index Result

Expert 1

	P	EC	S	T	EN	L	Weights (W)	AW	lamda	CI	RI	CR
P	0.3429	0.4286	0.4091	0.4174	0.1622	0.1875	0.3246	2.1797	6.7153	0.1186	1.2400	0.0956
EC	0.1714	0.2143	0.2727	0.2087	0.2432	0.1875	0.2163	1.4570	6.7356			
S	0.1143	0.1071	0.1364	0.2087	0.1622	0.1875	0.1527	1.0411	6.8183			
T	0.0857	0.1071	0.0682	0.1043	0.3243	0.1875	0.1462	0.9934	6.7947			
EN	0.1714	0.0714	0.0682	0.0261	0.0811	0.1875	0.1010	0.6260	6.2009			
L	0.1143	0.0714	0.0455	0.0348	0.0270	0.0625	0.0592	0.3728	6.2929			
								Average (lamda)	6.5929			

	P1	P2	Weights (W)	AW	lamda	CI	RI	CR
P1	0.8571	0.8571	0.8571	1.7143	2.0000	0.0000	0.0000	0.0000
P2	0.1429	0.1429	0.1429	0.2857	2.0000			
				Average (lamda)	2			

	EC1	EC2	EC3	EC4	EC5	EC6	EC7	Weights (W)	AW	lamda	CI	RI	CR
EC1	0.1500	0.2857	0.3158	0.2432	0.1429	0.0588	0.1250	0.1888	1.4838	7.8600	0.1194	1.3200	0.0905
EC2	0.0750	0.1429	0.2105	0.1622	0.1429	0.2353	0.1250	0.1562	1.2206	7.8123			
EC3	0.0500	0.0714	0.1053	0.1622	0.1429	0.2353	0.1250	0.1274	0.9836	7.7188			
EC4	0.0500	0.0714	0.0526	0.0811	0.2143	0.0588	0.1250	0.0933	0.6871	7.3628			
EC5	0.0750	0.0714	0.0526	0.0270	0.0714	0.0588	0.1250	0.0688	0.5188	7.5452			
EC6	0.3000	0.0714	0.0526	0.1622	0.1429	0.1176	0.1250	0.1388	1.0957	7.8931			
EC7	0.3000	0.2857	0.2105	0.1622	0.1429	0.2353	0.2500	0.2267	1.7733	7.8242			
									Average (lamda)	7.7166			

	S1	S2	S3	S4	S5	S6	S7	S8	Weights (W)	AW	lamda	CI	RI	CR
S1	0.2857	0.3692	0.3711	0.3529	0.1290	0.2143	0.2182	0.1667	0.2634	2.3884	9.0677	0.1233	1.4100	0.0874
S2	0.1429	0.1846	0.2474	0.2647	0.2581	0.1429	0.1636	0.1111	0.1894	1.7740	9.3659			
S3	0.0952	0.0923	0.1237	0.1765	0.2581	0.1429	0.1636	0.1111	0.1454	1.3623	9.3677			
S4	0.0714	0.0615	0.0619	0.0882	0.1935	0.2143	0.1636	0.1667	0.1276	1.1517	9.0224			
S5	0.1429	0.0462	0.0309	0.0294	0.0645	0.1429	0.1091	0.1111	0.0846	0.7216	8.5277			
S6	0.0952	0.0923	0.0619	0.0294	0.0323	0.0714	0.1091	0.1111	0.0753	0.6437	8.5448			
S7	0.0714	0.0615	0.0412	0.0294	0.0323	0.0357	0.0545	0.1667	0.0616	0.5193	8.4299			
S8	0.0952	0.0923	0.0619	0.0294	0.0323	0.0357	0.0182	0.0556	0.0526	0.4508	8.5768			
										Average (lamda)	8.8629			

	T1	T2	T3	T4	T5	T6	T7	Weights (W)	AW	lamda	CI	RI	CR
T1	0.2857	0.5538	0.2474	0.3529	0.1290	0.2143	0.2182	0.2859	2.1932	7.6708	0.1220	1.3200	0.0925
T2	0.0952	0.1846	0.2474	0.2647	0.2581	0.1429	0.1636	0.1938	1.5819	8.1631			
T3	0.1429	0.0923	0.1237	0.3529	0.1290	0.2143	0.1091	0.1663	1.2992	7.8118			
T4	0.0714	0.0615	0.0309	0.0882	0.1935	0.1429	0.1091	0.0997	0.7954	7.9811			
T5	0.1429	0.0462	0.0619	0.0294	0.0645	0.1429	0.1636	0.0930	0.6899	7.4149			
T6	0.0952	0.0923	0.0412	0.0441	0.0323	0.0714	0.1091	0.0694	0.5136	7.4021			
T7	0.0714	0.0615	0.0619	0.0441	0.0215	0.0357	0.0545	0.0501	0.3849	7.6820			
									Average (lamda)	7.7323			

	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	Weights (W)	AW	lamda	CI	RI	CR
EN1	0.0476	0.0256	0.0816	0.0227	0.0714	0.0248	0.0370	0.0484	0.0484	0.0652	0.0652	0.0811	0.0516	0.6276	12.1630	0.1200	1.4800	0.0811
EN2	0.0952	0.0513	0.0816	0.0227	0.0714	0.0248	0.0370	0.0484	0.0484	0.0435	0.0435	0.0811	0.0541	0.7030	12.9986			
EN3	0.0238	0.0256	0.0408	0.0227	0.0714	0.0165	0.0370	0.0484	0.0484	0.0652	0.0652	0.0541	0.0433	0.5208	12.0359			
EN4	0.0952	0.1026	0.0816	0.0455	0.0714	0.0165	0.0247	0.0323	0.0484	0.0652	0.0652	0.0811	0.0608	0.7383	12.1411			
EN5	0.0238	0.0256	0.0204	0.0227	0.0357	0.0248	0.0247	0.0323	0.0484	0.0652	0.0652	0.0541	0.0369	0.4342	11.7647			
EN6	0.0952	0.1026	0.1224	0.1364	0.0714	0.0496	0.0247	0.0323	0.0323	0.0652	0.0652	0.0811	0.0732	0.9353	12.7785			
EN7	0.0952	0.1026	0.0816	0.1364	0.1071	0.1488	0.0741	0.0484	0.0484	0.0652	0.0652	0.0811	0.0878	1.1946	13.6002			
EN8	0.1429	0.1026	0.1224	0.1818	0.1429	0.1983	0.1481	0.0323	0.0484	0.0652	0.0652	0.0811	0.1109	1.5874	14.3092			
EN9	0.0952	0.1026	0.0816	0.1364	0.1071	0.1488	0.1481	0.0968	0.0484	0.0652	0.0652	0.0811	0.0980	1.6088	16.4092			
EN10	0.0952	0.1026	0.0816	0.0909	0.0714	0.1488	0.1481	0.1935	0.0968	0.0435	0.0435	0.0811	0.0998	1.5263	15.3011			
EN11	0.0952	0.1538	0.0816	0.0909	0.0714	0.0992	0.1481	0.1935	0.2903	0.1304	0.1304	0.0811	0.1305	1.7937	13.7434			
EN12	0.0952	0.1026	0.1224	0.0909	0.1071	0.0992	0.1481	0.1935	0.1935	0.2609	0.2609	0.1622	0.1531	1.9271	12.5913			
														Average (lamda)	13.3197			

	L1	L2	L3	L4	Weights (W)	AW	lamda	CI	RI	CR
L1	0.5607	0.6545	0.4800	0.3846	0.5200	2.7209	5.2328	0.0831	0.9000	0.0923
L2	0.1869	0.5607	0.3600	0.3077	0.3538	1.4048	3.9702			
L3	0.1402	0.1869	0.1200	0.2308	0.1695	0.6944	4.0973			
L4	0.1121	0.1402	0.0400	0.0769	0.0923	0.3413	3.6967			
					Average (lamda)		4.2492			

Expert 2

	P	EC	S	T	EN	L	Weights (W)	AW	lamda	CI	RI	CR
P	0.2000	0.2500	0.2143	0.1538	0.2667	0.1579	0.2071	1.3402	6.4707	0.0692	1.2400	0.0558
EC	0.1000	0.1250	0.2143	0.1538	0.0667	0.1579	0.1363	0.8612	6.3189			
S	0.1000	0.0625	0.1071	0.2308	0.0667	0.1579	0.1208	0.7467	6.1797			
T	0.1000	0.0625	0.0357	0.0769	0.0667	0.1053	0.0745	0.4668	6.2650			
EN	0.1000	0.2500	0.2143	0.1538	0.1333	0.1053	0.1595	1.0269	6.4398			
L	0.4000	0.2500	0.2143	0.2308	0.4000	0.3158	0.3018	1.9322	6.4020			
								Average (lamda)	6.3460			

	P1	P2	Weights (W)	AW	lamda	CI	RI	CR
P1	0.8333	0.8333	0.8333	1.6667	2.0000	0.0000	0.0000	0.0000
P2	0.1667	0.1667	0.1667	0.3333	2.0000			
				Average (lamda)	2.0000			

	EC1	EC2	EC3	EC4	EC5	EC6	EC7	Weights (W)	AW	lamda	CI	RI	CR
EC1	0.3158	0.4000	0.3396	0.3478	0.2034	0.2222	0.2353	0.2949	2.2517	7.6362	0.0787	1.3200	0.0596
EC2	0.1579	0.2000	0.3396	0.1739	0.2034	0.2222	0.1765	0.2105	1.6194	7.6928			
EC3	0.1053	0.0667	0.1132	0.2609	0.2034	0.1481	0.1176	0.1450	1.1231	7.7439			
EC4	0.0789	0.1000	0.0377	0.0870	0.2034	0.1481	0.1176	0.1104	0.8161	7.3919			
EC5	0.1579	0.1000	0.0566	0.0435	0.1017	0.1481	0.1765	0.1120	0.8004	7.1436			
EC6	0.1053	0.0667	0.0566	0.0435	0.0508	0.0741	0.1176	0.0735	0.5330	7.2503			
EC7	0.0789	0.0667	0.0566	0.0435	0.0339	0.0370	0.0588	0.0536	0.3993	7.4453			
									Average (lamda)	7.4720			

	S1	S2	S3	S4	S5	S6	S7	S8	Weights (W)	AW	lamda	CI	RI	CR
S1	0.1111	0.2222	0.3429	0.0435	0.1481	0.0556	0.1333	0.0833	0.1425	1.2519	8.7847	0.1156	1.4100	0.0820
S2	0.0556	0.1111	0.0857	0.1739	0.1481	0.2222	0.1333	0.0833	0.1267	1.1118	8.7773			
S3	0.0556	0.2222	0.1714	0.2609	0.1481	0.2222	0.1333	0.3333	0.1934	1.6981	8.7809			
S4	0.2222	0.0556	0.0571	0.0870	0.1481	0.0556	0.1333	0.0833	0.1053	0.9347	8.8781			
S5	0.0556	0.0556	0.0857	0.0435	0.0741	0.0556	0.1333	0.0833	0.0733	0.6272	8.5538			
S6	0.2222	0.0556	0.0857	0.1739	0.1481	0.1111	0.1333	0.0833	0.1267	1.1355	8.9648			
S7	0.0556	0.0556	0.0857	0.0435	0.0370	0.0556	0.0667	0.0833	0.0604	0.5302	8.7834			
S8	0.2222	0.2222	0.0857	0.1739	0.1481	0.2222	0.1333	0.1667	0.1718	1.5381	8.9526			
										Average (lamda)	8.8095			

	T1	T2	T3	T4	T5	T6	T7	Weights (W)	AW	lamda	CI	RI	CR
T1	0.1111	0.0556	0.3429	0.0435	0.0370	0.0370	0.0333	0.0943	0.6099	6.4645	0.1124	1.3200	0.0851
T2	0.2222	0.1111	0.3429	0.1739	0.0370	0.0556	0.0333	0.1394	1.0089	7.2355			
T3	0.0556	0.0556	0.1714	0.0435	0.1481	0.0556	0.0333	0.0804	0.6726	8.3622			
T4	0.2222	0.0556	0.3429	0.0870	0.1481	0.0556	0.0333	0.1349	0.9621	7.1291			
T5	0.2222	0.2222	0.0857	0.0435	0.0741	0.0556	0.0333	0.1052	0.8778	8.3423			
T6	0.3333	0.2222	0.3429	0.1739	0.1481	0.1111	0.0333	0.1950	1.4980	7.6824			
T7	0.2222	0.2222	0.3429	0.1739	0.1481	0.2222	0.0667	0.1998	1.6985	8.5031			
								Average (lamda)	7.6742				

	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	Weights (W)	AW	lamda	CI	RI	CR
EN1	0.0500	0.0889	0.0294	0.0323	0.1026	0.0323	0.0455	0.0435	0.0357	0.0400	0.0400	0.0870	0.0522	0.6872	13.1529	0.1450	1.4800	0.0979
EN2	0.0250	0.0444	0.1176	0.0323	0.0256	0.0323	0.0455	0.0435	0.0357	0.0400	0.0400	0.0580	0.0450	0.6061	13.4723			
EN3	0.1000	0.0222	0.0588	0.0323	0.1026	0.0323	0.1818	0.0435	0.1429	0.0400	0.0400	0.0870	0.0736	0.9800	13.3142			
EN4	0.1000	0.0889	0.1176	0.0645	0.0256	0.0323	0.0455	0.0435	0.0357	0.1600	0.1600	0.0870	0.0800	1.0316	12.8870			
EN5	0.0250	0.0889	0.0294	0.1290	0.0513	0.0323	0.0455	0.1739	0.0357	0.0400	0.0400	0.0580	0.0624	0.8626	13.8219			
EN6	0.1000	0.0889	0.1176	0.1290	0.1026	0.0645	0.0455	0.0435	0.0357	0.0400	0.0400	0.0870	0.0745	1.0072	13.5157			
EN7	0.1000	0.0889	0.0294	0.1290	0.1026	0.1290	0.0909	0.0435	0.1429	0.1600	0.1600	0.0870	0.1053	1.3725	13.0391			
EN8	0.1000	0.0889	0.1176	0.0323	0.1026	0.1290	0.0455	0.0435	0.0357	0.0400	0.0400	0.0580	0.0694	0.9696	13.9673			
EN9	0.1000	0.0889	0.1176	0.1290	0.0256	0.1290	0.1818	0.0870	0.1429	0.1600	0.1600	0.0435	0.1138	1.5112	13.2823			
EN10	0.1000	0.0889	0.0294	0.1290	0.1026	0.1290	0.0455	0.0435	0.0714	0.0400	0.0400	0.0870	0.0755	1.1132	14.7405			

EN11	0.1000	0.0889	0.1176	0.0323	0.1026	0.1290	0.0455	0.0435	0.1429	0.0800	0.0800	0.0870	0.0874	1.2228	13.9861			
EN12	0.1000	0.1333	0.1176	0.1290	0.1538	0.1290	0.1818	0.3478	0.1429	0.1600	0.1600	0.1739	0.1608	2.2436	13.9549			
													Average (lamda)		13.5945			

	L1	L2	L3	L4	Weights (W)	AW	lamda	CI	RI	CR
L1	0.4286	0.5217	0.3810	0.2727	0.4010	1.8588	4.6354	0.0677	0.9000	0.0752
L2	0.2143	0.4286	0.3810	0.2727	0.3241	1.3342	4.1161			
L3	0.2143	0.2143	0.1905	0.3636	0.2457	1.0325	4.2027			
L4	0.1429	0.1429	0.0476	0.0909	0.1061	0.4092	3.8581			
					Average (lamda)		4.2031			

Expert 3

	P	EC	S	T	EN	L	Weights (W)	AW	lamda	CI	RI	CR
P	0.3333	0.5294	0.3288	0.3051	0.1765	0.1875	0.3101	2.0870	6.7303	0.1123	1.2400	0.0906
EC	0.1111	0.1765	0.3288	0.3051	0.1765	0.1875	0.2142	1.4518	6.7768			
S	0.1667	0.0882	0.1644	0.2034	0.2647	0.2500	0.1896	1.2451	6.5682			
T	0.1111	0.0588	0.0822	0.1017	0.2647	0.1250	0.1239	0.8211	6.6258			
EN	0.1667	0.0882	0.0548	0.0339	0.0882	0.1875	0.1032	0.6468	6.2659			
L	0.1111	0.0588	0.0411	0.0508	0.0294	0.0625	0.0590	0.3775	6.4021			
							Average (lamda)	6.5615				

	P1	P2	Weights (W)	AW	lamda	CI	RI	CR
P1	0.8000	0.8000	0.8000	1.6000	2.0000	0.0000	0.0000	0.0000
P2	0.2000	0.2000	0.2000	0.4000	2.0000			
					2.0000			

	EC1	EC2	EC3	EC4	EC5	EC6	EC7	Weights (W)	AW	lamda	CI	RI	CR
EC1	0.1277	0.2857	0.0412	0.1739	0.2353	0.1875	0.1250	0.1680	1.2747	7.5855	0.1220	1.3200	0.0924
EC2	0.0638	0.1429	0.2474	0.1739	0.2353	0.1250	0.1250	0.1590	1.2519	7.8713			
EC3	0.3830	0.0714	0.1237	0.1739	0.0588	0.2500	0.1250	0.1694	1.3492	7.9643			
EC4	0.0638	0.0714	0.0619	0.0870	0.0588	0.1250	0.1250	0.0847	0.6355	7.5031			
EC5	0.0638	0.0714	0.2474	0.1739	0.1176	0.1250	0.1250	0.1320	1.0403	7.8792			
EC6	0.0426	0.0714	0.0309	0.0435	0.0588	0.0625	0.1250	0.0621	0.4607	7.4183			
EC7	0.2553	0.2857	0.2474	0.1739	0.2353	0.1250	0.2500	0.2247	1.7753	7.9021			
								Average (lamda)	7.7320				

	S1	S2	S3	S4	S5	S6	S7	S8	Weights (W)	AW	lamda	CI	RI	CR
S1	0.0952	0.1212	0.1667	0.1667	0.0484	0.1154	0.0682	0.0667	0.1061	0.9480	8.9392	0.1366	1.4100	0.0969
S2	0.0476	0.0606	0.1667	0.0417	0.0323	0.0769	0.0455	0.0667	0.0672	0.6084	9.0494			
S3	0.0476	0.0303	0.0833	0.1667	0.0484	0.1154	0.2727	0.0667	0.1039	0.9326	8.9772			
S4	0.0476	0.1212	0.0417	0.0833	0.1935	0.1154	0.0682	0.0667	0.0922	0.8209	8.9031			

S5	0.1905	0.1818	0.1667	0.0417	0.0968	0.1154	0.0682	0.0667	0.1160	1.0410	8.9774			
S6	0.1905	0.1818	0.1667	0.1667	0.1935	0.2308	0.2727	0.2667	0.2087	1.8586	8.9068			
S7	0.1905	0.1818	0.0417	0.1667	0.1935	0.1154	0.1364	0.2667	0.1616	1.4368	8.8927			
S8	0.1905	0.1212	0.1667	0.1667	0.1935	0.1154	0.0682	0.1333	0.1444	1.3002	9.0021			
									Average (lamda)	8.9560				

	T1	T2	T3	T4	T5	T6	T7	Weights (W)	AW	lamda	CI	RI	CR
T1	0.0952	0.0303	0.1667	0.1667	0.1935	0.4615	0.0682	0.1689	1.1698	6.9267	0.1218	1.3200	0.0923
T2	0.1905	0.0606	0.1667	0.1667	0.1935	0.1154	0.0682	0.1374	1.2253	8.9202			
T3	0.0476	0.0303	0.0833	0.1667	0.1935	0.1154	0.0682	0.1007	0.8026	7.9684			
T4	0.0476	0.0303	0.0417	0.0833	0.0484	0.1154	0.0682	0.0621	0.4994	8.0382			
T5	0.0476	0.0303	0.0417	0.1667	0.0968	0.4615	0.0455	0.1271	0.7706	6.0608			
T6	0.0476	0.1212	0.1667	0.1667	0.0484	0.2308	0.0682	0.1214	0.9793	8.0695			
T7	0.1905	0.1212	0.1667	0.1667	0.2903	0.4615	0.1364	0.2190	1.7814	8.1327			
								Average (lamda)	7.7309				

	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	Weights (W)	AW	lamda	CI	RI	CR
EN1	0.0645	0.2105	0.1333	0.0326	0.0833	0.0323	0.0217	0.1455	0.0462	0.0303	0.0303	0.0857	0.0764	1.1226	14.7029	0.1460	1.4800	0.0987
EN2	0.0323	0.1053	0.1333	0.1304	0.0833	0.1290	0.0870	0.1455	0.1846	0.1212	0.1212	0.0857	0.1132	1.5323	13.5319			
EN3	0.0323	0.0526	0.0667	0.1304	0.0833	0.0323	0.0870	0.1455	0.1846	0.1212	0.1212	0.0571	0.0928	1.1474	12.3581			
EN4	0.1290	0.0526	0.0333	0.0652	0.0833	0.0323	0.1304	0.0364	0.0462	0.1212	0.1212	0.0857	0.0781	1.0265	13.1472			
EN5	0.0323	0.0526	0.0333	0.0326	0.0417	0.0323	0.0217	0.0364	0.0462	0.0303	0.0303	0.0571	0.0372	0.4920	13.2139			
EN6	0.1290	0.0526	0.1333	0.1304	0.0833	0.0645	0.0870	0.0364	0.0462	0.0303	0.0303	0.0857	0.0758	1.0372	13.6916			
EN7	0.1290	0.0526	0.0333	0.0217	0.0833	0.0323	0.0435	0.0364	0.0308	0.0303	0.0303	0.0571	0.0484	0.6375	13.1736			
EN8	0.0323	0.0526	0.1333	0.0326	0.0833	0.1290	0.0870	0.0182	0.0462	0.0303	0.0303	0.0857	0.0634	0.8923	14.0741			
EN9	0.0323	0.0526	0.0333	0.1304	0.0833	0.1290	0.0870	0.0727	0.0462	0.1212	0.1212	0.0857	0.0829	1.2235	14.7560			
EN10	0.1290	0.0526	0.0333	0.1304	0.0833	0.1290	0.1304	0.1455	0.0923	0.1212	0.1212	0.0857	0.1045	1.3948	13.3460			
EN11	0.1290	0.0526	0.0333	0.0326	0.0833	0.1290	0.0870	0.0364	0.0462	0.0606	0.0606	0.0571	0.0673	0.9587	14.2416			
EN12	0.1290	0.2105	0.2000	0.1304	0.1250	0.1290	0.1304	0.1455	0.1846	0.1818	0.1818	0.1714	0.1600	2.0858	13.0391			
													Average (lamda)		13.6063			

	L1	L2	L3	L4	Weights (W)	AW	lamda	CI	RI	CR
L1	0.2609	0.3750	0.3636	0.2000	0.2999	1.5218	5.0748	0.0661	0.9000	0.0734
L2	0.0870	0.2609	0.0909	0.2000	0.1597	0.6148	3.8500			
L3	0.1304	0.5217	0.1818	0.2000	0.2585	0.9537	3.6894			
L4	0.5217	0.5217	0.3636	0.4000	0.4518	1.8879	4.1788			
					Average (lamda)		4.1982			

Expert 4

	P	EC	S	T	EN	L	Weights (W)	AW	lamda	CI	RI	CR
P	0.2182	0.3158	0.3333	0.2857	0.2105	0.1429	0.2511	1.6153	6.4337	0.0623	1.2400	0.0502
EC	0.1091	0.1579	0.2222	0.2143	0.2105	0.1429	0.1761	1.1155	6.3328			
S	0.0727	0.0789	0.1111	0.1429	0.2105	0.1429	0.1265	0.7875	6.2248			
T	0.0545	0.0526	0.0556	0.0714	0.0526	0.1429	0.0716	0.4437	6.1959			
EN	0.1091	0.0789	0.0556	0.1429	0.1053	0.1429	0.1058	0.6603	6.2432			
L	0.4364	0.3158	0.2222	0.1429	0.2105	0.2857	0.2689	1.7311	6.4374			
							Average (lamda)		6.3113			

	P1	P2	Weights (W)	AW	lamda	CI	RI	CR
P1	0.833	0.833	0.833	1.667	2.000	0.000	0.000	0.000
P2	0.167	0.167	0.167	0.333	2.000			
					2.000			

	EC1	EC2	EC3	EC4	EC5	EC6	EC7	Weights (W)	AW	lamda	CI	RI	CR
EC1	0.1277	0.2222	0.1600	0.2500	0.0526	0.1818	0.1111	0.1579	1.2202	7.7264	0.1238	1.3200	0.0938
EC2	0.0426	0.0741	0.0400	0.0625	0.2105	0.0455	0.1111	0.0837	0.6602	7.8835			
EC3	0.0638	0.1481	0.0800	0.0625	0.0526	0.0455	0.1111	0.0805	0.6149	7.6359			
EC4	0.0638	0.1481	0.1600	0.1250	0.2105	0.1818	0.1111	0.1429	1.1102	7.7679			
EC5	0.2553	0.0370	0.1600	0.0625	0.1053	0.1818	0.1111	0.1304	1.0196	7.8165			
EC6	0.0638	0.1481	0.1600	0.0625	0.0526	0.0909	0.1111	0.0984	0.7446	7.5637			
EC7	0.3830	0.2222	0.2400	0.3750	0.3158	0.2727	0.3333	0.3060	2.3880	7.8037			
									Average (lamda)	7.7425			

	S1	S2	S3	S4	S5	S6	S7	S8	Weights (W)	AW	lamda	CI	RI	CR
S1	0.0500	0.0400	0.0455	0.0435	0.0435	0.0357	0.0244	0.1111	0.0492	0.4228	8.5939	0.1275	1.4100	0.0904
S2	0.1000	0.0800	0.0455	0.0435	0.1739	0.0536	0.1951	0.1111	0.1003	0.8874	8.8450			
S3	0.1000	0.1600	0.0909	0.0435	0.1739	0.0536	0.1951	0.1111	0.1160	1.0458	9.0143			
S4	0.2000	0.3200	0.3636	0.1739	0.0870	0.2143	0.1951	0.1111	0.2081	1.9347	9.2957			
S5	0.1000	0.0400	0.0455	0.1739	0.0870	0.1071	0.0488	0.1111	0.0892	0.7808	8.7558			
S6	0.1500	0.1600	0.1818	0.0870	0.0870	0.1071	0.0488	0.1111	0.1166	1.0504	9.0090			
S7	0.2000	0.0400	0.0455	0.0870	0.1739	0.2143	0.0976	0.1111	0.1212	1.0414	8.5956			
S8	0.1000	0.1600	0.1818	0.3478	0.1739	0.2143	0.1951	0.2222	0.1994	1.8006	9.0302			
										Average (lamda)	8.8924			

	T1	T2	T3	T4	T5	T6	T7	Weights (W)	AW	lamda	CI	RI	CR
T1	0.0500	0.1600	0.2727	0.3478	0.0435	0.0536	0.0244	0.1360	0.9663	7.1056	0.0864	1.3200	0.0655

T2	0.0250	0.0800	0.1818	0.3478	0.0435	0.0536	0.0244	0.1080	0.7022	6.5013			
T3	0.0167	0.0400	0.0909	0.3478	0.0435	0.0536	0.0244	0.0881	0.5374	6.0988			
T4	0.0250	0.0400	0.0455	0.1739	0.0435	0.0536	0.0244	0.0580	0.4581	7.9013			
T5	0.1000	0.1600	0.1818	0.3478	0.0870	0.0536	0.0244	0.1364	1.0824	7.9375			
T6	0.1000	0.1600	0.1818	0.3478	0.1739	0.1071	0.0244	0.1564	1.2970	8.2906			
T7	0.2000	0.3200	0.3636	0.6957	0.3478	0.4286	0.0976	0.3505	3.0821	8.7944			
									Average (lamda)	7.5185			

	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	Weights (W)	AW	lamda	CI	RI	CR
EN1	0.0750	0.1463	0.1224	0.0531	0.1026	0.0594	0.0909	0.1277	0.0400	0.0667	0.0667	0.0667	0.0848	1.1679	13.7744	0.0777	1.4800	0.0525
EN2	0.0375	0.0732	0.1224	0.1593	0.1026	0.1188	0.0909	0.0851	0.0400	0.1000	0.1000	0.0667	0.0914	1.2144	13.2911			
EN3	0.0375	0.0366	0.0612	0.1593	0.1026	0.0594	0.0909	0.0851	0.0400	0.0667	0.0667	0.0667	0.0727	0.9411	12.9420			
EN4	0.0750	0.0244	0.0204	0.0531	0.1026	0.0594	0.0909	0.0426	0.0400	0.1000	0.1000	0.0667	0.0646	0.8362	12.9477			
EN5	0.0375	0.0366	0.0306	0.0265	0.0513	0.0594	0.0909	0.0851	0.0400	0.0667	0.0667	0.0667	0.0548	0.6884	12.5561			
EN6	0.0750	0.0366	0.0612	0.0531	0.0513	0.0594	0.0909	0.0426	0.0400	0.1000	0.1000	0.0667	0.0647	0.7859	12.1422			
EN7	0.0375	0.0366	0.0306	0.0265	0.0256	0.0297	0.0455	0.0851	0.0400	0.0667	0.0667	0.0667	0.0464	0.5822	12.5402			
EN8	0.0375	0.0366	0.0612	0.0265	0.0513	0.0594	0.0455	0.0851	0.0400	0.1000	0.1000	0.0667	0.0591	0.7095	11.9946			
EN9	0.0250	0.0366	0.0306	0.0531	0.0256	0.0594	0.0227	0.0426	0.0400	0.0667	0.0667	0.0667	0.0446	0.5353	11.9935			
EN10	0.2250	0.2195	0.1837	0.1593	0.1538	0.1782	0.1364	0.1277	0.1200	0.1000	0.1000	0.0667	0.1475	2.0500	13.8964			
EN11	0.0375	0.0244	0.0306	0.0177	0.0256	0.0198	0.0227	0.0213	0.0400	0.0333	0.0333	0.0667	0.0311	0.3848	12.3793			
EN12	0.3000	0.2927	0.2449	0.2124	0.2051	0.2376	0.1818	0.1702	0.4800	0.1333	0.1333	0.2667	0.2382	3.2855	13.7945			
														Average (lamda)	12.8543			

	L1	L2	L3	L4	Weights (W)	AW	lamda	CI	RI	CR
L1	0.2069	0.4000	0.2500	0.1667	0.2559	1.2009	4.6931	0.0766	0.9000	0.0852
L2	0.0690	0.2069	0.2500	0.1667	0.1731	0.6841	3.9512			
L3	0.1034	0.1034	0.1250	0.1667	0.1246	0.5155	4.1360			
L4	0.6207	0.6207	0.3750	0.5000	0.5291	2.1901	4.1393			
						Average (lamda)	4.2299			

Expert 5

	P	EC	S	T	EN	L	Weights (W)	AW	lamda	CI	RI	CR
P	0.1644	0.3396	0.3478	0.1667	0.1000	0.1429	0.2102	1.4219	6.7639	0.1033	1.2400	0.0833
EC	0.0548	0.1132	0.1739	0.2500	0.1000	0.1429	0.1391	0.8871	6.3759			
S	0.0411	0.0566	0.0870	0.1667	0.1000	0.1429	0.0990	0.6194	6.2542			
T	0.0822	0.0377	0.0435	0.0833	0.1000	0.1429	0.0816	0.5176	6.3433			
EN	0.3288	0.2264	0.1739	0.1667	0.2000	0.1429	0.2064	1.3982	6.7730			
L	0.3288	0.2264	0.1739	0.1667	0.4000	0.2857	0.2636	1.7364	6.5878			
							Average (lamda)		6.5164			

	P1	P2	Weights (W)	AW	lamda	CI	RI	CR
P1	0.8000	0.8000	0.8000	1.6000	2.0000	0.0000	0.0000	0.0000
P2	0.2000	0.2000	0.2000	0.4000	2.0000			
					2.0000			

	EC1	EC2	EC3	EC4	EC5	EC6	EC7	Weights (W)	AW	lamda	CI	RI	CR
EC1	0.1579	0.2857	0.2000	0.1739	0.0645	0.3636	0.1538	0.1999	1.5446	7.7256	0.1074	1.3200	0.0813
EC2	0.0526	0.0952	0.2000	0.1739	0.0645	0.0909	0.1538	0.1187	0.8811	7.4218			
EC3	0.0789	0.0476	0.1000	0.1739	0.0968	0.0909	0.1538	0.1060	0.7865	7.4198			
EC4	0.0789	0.0476	0.0500	0.0870	0.0968	0.0909	0.1538	0.0864	0.6471	7.4861			
EC5	0.4737	0.2857	0.2000	0.1739	0.1935	0.0909	0.1538	0.2245	1.8014	8.0235			
EC6	0.0789	0.1905	0.2000	0.1739	0.3871	0.1818	0.1538	0.1952	1.5049	7.7115			
EC7	0.0789	0.0476	0.0500	0.0435	0.0968	0.0909	0.0769	0.0692	0.5346	7.7217			
								Average (lamda)		7.6443			

	S1	S2	S3	S4	S5	S6	S7	S8	Weights (W)	AW	lamda	CI	RI	CR
S1	0.2308	0.1111	0.1212	0.2553	0.2000	0.1875	0.2308	0.4390	0.2220	1.9518	8.7932	0.0831	1.4100	0.0589
S2	0.1154	0.0556	0.0303	0.0426	0.0500	0.0313	0.0385	0.0732	0.0546	0.4632	8.4851			
S3	0.1154	0.1111	0.0606	0.0638	0.0500	0.0313	0.0385	0.0488	0.0649	0.5446	8.3883			
S4	0.1154	0.1667	0.1212	0.1277	0.1000	0.1875	0.2308	0.0732	0.1403	1.2208	8.7014			
S5	0.1154	0.1111	0.1212	0.1277	0.1000	0.0938	0.0577	0.0732	0.1000	0.8527	8.5271			
S6	0.1154	0.1667	0.1818	0.0638	0.1000	0.0938	0.0577	0.0732	0.1065	0.9021	8.4669			
S7	0.1154	0.1667	0.1818	0.0638	0.2000	0.1875	0.1154	0.0732	0.1380	1.1776	8.5350			
S8	0.0769	0.1111	0.1818	0.2553	0.2000	0.1875	0.2308	0.1463	0.1737	1.5213	8.7569			
									Average (lamda)		8.5817			

	T1	T2	T3	T4	T5	T6	T7	Weights (W)	AW	lamda	CI	RI	CR
T1	0.2308	0.1111	0.1818	0.2553	0.3000	0.1875	0.3462	0.2304	1.9865	8.6227	0.1211	1.3200	0.0917

T2	0.1154	0.0556	0.1212	0.0638	0.0500	0.0469	0.2308	0.0977	0.7890	8.0787			
T3	0.0769	0.0278	0.0606	0.2553	0.0500	0.0469	0.3462	0.1234	0.7859	6.3695			
T4	0.1154	0.1111	0.0303	0.1277	0.0500	0.0469	0.2308	0.1017	0.7524	7.3964			
T5	0.0769	0.1111	0.1212	0.2553	0.1000	0.0234	0.3462	0.1477	1.0822	7.3251			
T6	0.1154	0.1111	0.1212	0.2553	0.4000	0.0938	0.2308	0.1896	1.6511	8.7062			
T7	0.0769	0.0278	0.0202	0.0638	0.0333	0.0469	0.1154	0.0549	0.4166	7.5876			
								Average (lamda)		7.7266			

	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	Weights (W)	AW	lamda	CI	RI	CR
EN1	0.0526	0.0800	0.0769	0.0238	0.0255	0.0303	0.0263	0.1290	0.0536	0.0500	0.0500	0.0769	0.0563	0.8280	14.7184	0.1411	1.4800	0.0953
EN2	0.0263	0.0400	0.0769	0.0238	0.0170	0.0303	0.0197	0.0323	0.0357	0.0500	0.0500	0.0769	0.0399	0.6115	15.3187			
EN3	0.0263	0.0200	0.0385	0.0238	0.0128	0.0303	0.0395	0.0323	0.0536	0.0500	0.0500	0.0769	0.0378	0.4751	12.5602			
EN4	0.1053	0.0800	0.0769	0.0476	0.0255	0.0303	0.0197	0.0323	0.0536	0.0375	0.0375	0.0769	0.0519	0.7770	14.9630			
EN5	0.1053	0.1200	0.1538	0.0952	0.0511	0.0303	0.0263	0.0323	0.0536	0.0375	0.0375	0.0769	0.0683	0.8704	12.7414			
EN6	0.1053	0.0800	0.0769	0.0952	0.1021	0.0606	0.0395	0.0323	0.0536	0.0500	0.0500	0.0769	0.0685	0.8889	12.9700			
EN7	0.1579	0.1600	0.0769	0.1905	0.1532	0.1212	0.0789	0.1290	0.0536	0.0500	0.0500	0.0769	0.1082	1.4305	13.2235			
EN8	0.0263	0.0200	0.0769	0.0238	0.1021	0.1212	0.1579	0.1290	0.0536	0.0750	0.0750	0.0769	0.0782	1.0741	13.7445			
EN9	0.0263	0.0800	0.0769	0.0952	0.1021	0.1212	0.0395	0.0645	0.0536	0.0750	0.0750	0.0769	0.0739	0.9367	12.6824			
EN10	0.1053	0.1200	0.0769	0.0952	0.1021	0.1212	0.1579	0.1290	0.1071	0.0750	0.0750	0.0769	0.1035	1.4661	14.1679			
EN11	0.1579	0.1200	0.1154	0.1905	0.2043	0.1818	0.2368	0.1290	0.2143	0.1500	0.1500	0.0769	0.1606	2.1611	13.4587			
EN12	0.1053	0.0800	0.0769	0.0952	0.1021	0.1212	0.1579	0.1290	0.2143	0.3000	0.3000	0.1538	0.1530	1.8470	12.0732			
													Average (lamda)		13.5518			

	L1	L2	L3	L4	Weights (W)	AW	lamda	CI	RI	CR
L1	0.4615	0.5455	0.4091	0.3000	0.4290	2.0276	4.7262	0.0805	0.9000	0.0894
L2	0.2308	0.4615	0.4091	0.3000	0.3503	1.4628	4.1751			
L3	0.1538	0.1538	0.1364	0.3000	0.1860	0.7857	4.2237			
L4	0.1538	0.1538	0.0455	0.1000	0.1133	0.4351	3.8405			
					Average (lamda)		4.2414			

Expert 6

	P	EC	S	T	EN	L	Weights (W)	AW	lamda	CI	RI	CR
P	0.1538	0.2105	0.1818	0.2500	0.1000	0.1429	0.1732	1.0947	6.3212	0.0544	1.2400	0.0439
EC	0.0769	0.1053	0.1818	0.0625	0.1000	0.1429	0.1116	0.6872	6.1602			
S	0.0769	0.0526	0.0909	0.0625	0.1000	0.1429	0.0876	0.5438	6.2054			
T	0.0769	0.2105	0.1818	0.1250	0.1000	0.1429	0.1395	0.8686	6.2253			
EN	0.3077	0.2105	0.1818	0.2500	0.2000	0.1429	0.2155	1.3756	6.3837			
L	0.3077	0.2105	0.1818	0.2500	0.4000	0.2857	0.2726	1.7274	6.3361			

Average (lamda) 6.2720

	P1	P2	Weights (W)	AW	lamda	CI	RI	CR
P1	0.8000	0.8000	0.8000	1.6000	2.0000	0.0000	0.0000	0.0000
P2	0.2000	0.2000	0.2000	0.4000	2.0000			

2.0000

	EC1	EC2	EC3	EC4	EC5	EC6	EC7	Weights (W)	AW	lamda	CI	RI	CR
EC1	0.1277	0.2222	0.1600	0.2500	0.0526	0.1818	0.1111	0.1579	1.2202	7.7264	0.1238	1.3200	0.0938
EC2	0.0426	0.0741	0.0400	0.0625	0.2105	0.0455	0.1111	0.0837	0.6602	7.8835			
EC3	0.0638	0.1481	0.0800	0.0625	0.0526	0.0455	0.1111	0.0805	0.6149	7.6359			
EC4	0.0638	0.1481	0.1600	0.1250	0.2105	0.1818	0.1111	0.1429	1.1102	7.7679			
EC5	0.2553	0.0370	0.1600	0.0625	0.1053	0.1818	0.1111	0.1304	1.0196	7.8165			
EC6	0.0638	0.1481	0.1600	0.0625	0.0526	0.0909	0.1111	0.0984	0.7446	7.5637			
EC7	0.3830	0.2222	0.2400	0.3750	0.3158	0.2727	0.3333	0.3060	2.3880	7.8037			

Average (lamda) 7.7425

	S1	S2	S3	S4	S5	S6	S7	S8	Weights (W)	AW	lamda	CI	RI	CR
S1	0.0909	0.2222	0.1905	0.0323	0.1481	0.0571	0.1111	0.1333	0.1232	1.0716	8.6977	0.1052	1.4100	0.0746
S2	0.0455	0.1111	0.1905	0.1935	0.1481	0.0857	0.1111	0.1333	0.1274	1.1108	8.7215			
S3	0.0455	0.0556	0.0952	0.1935	0.1481	0.0857	0.1111	0.1333	0.1085	0.9386	8.6496			
S4	0.2727	0.0556	0.0476	0.0968	0.1481	0.0857	0.1111	0.1333	0.1189	1.0735	9.0303			
S5	0.0455	0.0556	0.0476	0.0484	0.0741	0.0857	0.1111	0.1333	0.0752	0.6309	8.3941			
S6	0.2727	0.2222	0.1905	0.1935	0.1481	0.1714	0.1111	0.1333	0.1804	1.6363	9.0719			
S7	0.1818	0.2222	0.1905	0.1935	0.1481	0.3429	0.2222	0.1333	0.2043	1.7957	8.7882			
S8	0.0455	0.0556	0.0476	0.0484	0.0370	0.0857	0.1111	0.0667	0.0622	0.5311	8.5395			

Average (lamda) 8.7366

	T1	T2	T3	T4	T5	T6	T7	Weights (W)	AW	lamda	CI	RI	CR
T1	0.0909	0.2222	0.0476	0.0484	0.1481	0.3429	0.8889	0.2556	2.0252	7.9239	0.0945	1.3200	0.0716

T2	0.0455	0.1111	0.0476	0.0484	0.1481	0.3429	0.8889	0.2332	1.6642	7.1359			
T3	0.1818	0.2222	0.0952	0.0484	0.1481	0.3429	0.8889	0.2754	2.4184	8.7826			
T4	0.1818	0.2222	0.1905	0.0968	0.1481	0.3429	0.8889	0.2959	2.8417	9.6042			
T5	0.0455	0.0556	0.0476	0.0484	0.0741	0.3429	0.8889	0.2147	1.3329	6.2083			
T6	0.0455	0.0556	0.0476	0.0484	0.0370	0.1714	0.8889	0.1849	1.0406	5.6277			
T7	0.0227	0.0278	0.0238	0.0242	0.0185	0.0429	0.2222	0.0546	0.4195	7.6850			
								Average (lamda)		7.5668			

	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	Weights (W)	AW	lamda	CI	RI	CR
EN1	0.0535	0.0529	0.0440	0.1070	0.0291	0.1070	0.0267	0.0420	0.0901	0.0877	0.0877	0.0893	0.0681	0.8499	12.4847	0.1139	1.4800	0.0770
EN2	0.1070	0.1058	0.1760	0.2139	0.1744	0.1604	0.1070	0.0560	0.0901	0.0877	0.0877	0.0893	0.1213	1.7250	14.2241			
EN3	0.1070	0.0529	0.0880	0.1604	0.1163	0.1070	0.1070	0.0560	0.0901	0.0877	0.0877	0.0893	0.0958	1.3690	14.2940			
EN4	0.0267	0.0265	0.0293	0.0535	0.1163	0.1070	0.1070	0.0420	0.0901	0.0877	0.0877	0.0893	0.0719	0.9613	13.3673			
EN5	0.1070	0.0353	0.0440	0.0267	0.0581	0.0535	0.1070	0.0560	0.0901	0.0585	0.0585	0.0893	0.0653	0.9141	13.9941			
EN6	0.0267	0.0353	0.0440	0.0267	0.0581	0.0535	0.1070	0.0420	0.0901	0.0877	0.0877	0.0893	0.0623	0.8238	13.2134			
EN7	0.1070	0.0529	0.0440	0.0267	0.0291	0.0267	0.0535	0.0560	0.0901	0.0585	0.0585	0.0893	0.0577	0.8128	14.0906			
EN8	0.1070	0.0353	0.0293	0.0267	0.0291	0.0267	0.0267	0.0560	0.0901	0.0585	0.0585	0.0893	0.0528	0.6950	13.1722			
EN9	0.2139	0.3175	0.2639	0.2139	0.1744	0.2139	0.1604	0.1681	0.1351	0.0877	0.0877	0.0893	0.1772	2.4875	14.0412			
EN10	0.0267	0.0529	0.0440	0.0267	0.0291	0.0267	0.0267	0.0560	0.0450	0.0877	0.0877	0.0893	0.0499	0.5794	11.6120			
EN11	0.1070	0.2116	0.1760	0.1070	0.1744	0.1070	0.1604	0.3361	0.0901	0.1754	0.1754	0.0893	0.1591	2.0726	13.0237			
EN12	0.0107	0.0212	0.0176	0.0107	0.0116	0.0107	0.0107	0.0336	0.0090	0.0351	0.0351	0.0179	0.0187	0.2149	11.5228			
													Average (lamda)		13.2533			

	L1	L2	L3	L4	Weights (W)	AW	lamda	CI	RI	CR
L1	0.4615	0.5581	0.4091	0.2727	0.4254	1.9997	4.7010	0.0765	0.9000	0.0849
L2	0.2308	0.4615	0.4091	0.3636	0.3663	1.5221	4.1559			
L3	0.1538	0.1538	0.1364	0.2727	0.1792	0.7473	4.1701			
L4	0.1538	0.1154	0.0455	0.0909	0.1014	0.3945	3.8905			
					Average (lamda)		4.2294			

Expert 7

	P	EC	S	T	EN	L	Weights (W)	AW	lamda	CI	RI	CR
P	0.1017	0.1622	0.0600	0.0638	0.1667	0.1190	0.1122	0.6963	6.2040	0.0678	1.2400	0.0547
EC	0.0508	0.0811	0.0600	0.0638	0.1667	0.0952	0.0863	0.5315	6.1607			
S	0.2034	0.1622	0.1200	0.0638	0.1667	0.1190	0.1392	0.8781	6.3091			
T	0.2034	0.1622	0.2400	0.1277	0.1667	0.0952	0.1659	1.0779	6.4989			
EN	0.0339	0.0270	0.0400	0.0426	0.0556	0.0952	0.0490	0.3064	6.2468			
L	0.4068	0.4054	0.4800	0.6383	0.2778	0.4762	0.4474	2.9589	6.6135			
							Average (lamda)		6.3388			

	P1	P2	Weights (W)	AW	lamda	CI	RI	CR
P1	0.8000	0.8000	0.8000	1.6000	2.0000	0.0000	0.0000	0.0000
P2	0.2000	0.2000	0.2000	0.4000	2.0000			
			Average (lamda)		2.0000			

	EC1	EC2	EC3	EC4	EC5	EC6	EC7	Weights (W)	AW	lamda	CI	RI	CR
EC1	0.0857	0.2222	0.2000	0.0476	0.0435	0.0769	0.1111	0.1124	0.8242	7.3304	0.1043	1.3200	0.0790
EC2	0.0286	0.0741	0.1333	0.0476	0.0652	0.0769	0.1111	0.0767	0.5612	7.3175			
EC3	0.0286	0.0370	0.0667	0.0476	0.0652	0.0769	0.1111	0.0619	0.4610	7.4498			
EC4	0.1714	0.1481	0.1333	0.0952	0.0435	0.0769	0.1111	0.1114	0.8538	7.6654			
EC5	0.2571	0.1481	0.1333	0.2857	0.1304	0.0769	0.1111	0.1633	1.2978	7.9494			
EC6	0.1714	0.1481	0.1333	0.1905	0.2609	0.1538	0.1111	0.1670	1.3208	7.9073			
EC7	0.2571	0.2222	0.2000	0.2857	0.3913	0.4615	0.3333	0.3073	2.3854	7.7617			
								Average (lamda)		7.6260			

	S1	S2	S3	S4	S5	S6	S7	S8	Weights (W)	AW	lamda	CI	RI	CR
S1	0.0526	0.0333	0.0370	0.0303	0.0370	0.0323	0.0526	0.1304	0.0507	0.4345	8.5692	0.1203	1.4100	0.0853
S2	0.1053	0.0667	0.0370	0.0303	0.1481	0.0484	0.0789	0.0870	0.0752	0.6450	8.5761			
S3	0.1053	0.1333	0.0741	0.0303	0.1481	0.0484	0.0526	0.1304	0.0903	0.7749	8.5790			
S4	0.2105	0.2667	0.2963	0.1212	0.0741	0.1935	0.0789	0.0870	0.1660	1.4969	9.0162			
S5	0.1053	0.0333	0.0370	0.1212	0.0741	0.0968	0.0526	0.0870	0.0759	0.6779	8.9301			
S6	0.1579	0.1333	0.1481	0.0606	0.0741	0.0968	0.0526	0.1304	0.1067	0.9349	8.7586			
S7	0.1579	0.1333	0.2222	0.2424	0.2222	0.2903	0.1579	0.0870	0.1892	1.7246	9.1175			
S8	0.1053	0.2000	0.1481	0.3636	0.2222	0.1935	0.4737	0.2609	0.2459	2.2604	9.1915			
									Average (lamda)		8.8423			

	T1	T2	T3	T4	T5	T6	T7	Weights (W)	AW	lamda	CI	RI	CR
T1	0.0526	0.0333	0.2222	0.0606	0.1481	0.1935	0.0316	0.1060	0.7853	7.4077	0.1285	1.3200	0.0973

T2	0.1053	0.0667	0.1481	0.0404	0.2222	0.1935	0.0395	0.1165	0.9155	7.8561			
T3	0.0175	0.0333	0.0741	0.0303	0.2222	0.1935	0.0316	0.0861	0.5649	6.5618			
T4	0.1053	0.2000	0.2963	0.1212	0.1481	0.1935	0.0395	0.1577	1.3640	8.6490			
T5	0.0263	0.0222	0.0247	0.0606	0.0741	0.1935	0.0316	0.0619	0.4214	6.8125			
T6	0.0263	0.0333	0.0370	0.0606	0.0370	0.0968	0.0395	0.0472	0.3935	8.3320			
T7	0.2632	0.2667	0.3704	0.4848	0.3704	0.3871	0.1579	0.3286	2.8843	8.7767			
								Average (lamda)		7.7708			

	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	Weights (W)	AW	lamda	CI	RI	CR
EN1	0.0458	0.0836	0.0224	0.0328	0.0854	0.0663	0.0769	0.0141	0.0833	0.0323	0.0323	0.0551	0.0525	0.7144	13.6012	0.1748	1.4800	0.1181
EN2	0.0229	0.0418	0.0224	0.0219	0.0854	0.0994	0.0769	0.0141	0.1111	0.0242	0.0242	0.0661	0.0509	0.7153	14.0613			
EN3	0.0916	0.0836	0.0448	0.0164	0.0854	0.0663	0.0769	0.0176	0.0556	0.0242	0.0242	0.0551	0.0535	0.7781	14.5509			
EN4	0.0916	0.1254	0.1791	0.0656	0.0854	0.0994	0.0769	0.0235	0.0833	0.0484	0.0484	0.0551	0.0819	1.1197	13.6803			
EN5	0.0229	0.0209	0.0224	0.0328	0.0427	0.0994	0.0769	0.0141	0.1111	0.0323	0.0323	0.0661	0.0478	0.6668	13.9434			
EN6	0.0229	0.0139	0.0224	0.0219	0.0142	0.0331	0.0769	0.0141	0.0833	0.0242	0.0242	0.0551	0.0339	0.4988	14.7318			
EN7	0.0229	0.0209	0.0224	0.0328	0.0214	0.0166	0.0385	0.0176	0.0556	0.0323	0.0323	0.0661	0.0316	0.4507	14.2634			
EN8	0.0229	0.0139	0.0149	0.0328	0.0142	0.0110	0.0192	0.0141	0.0833	0.0484	0.0484	0.0826	0.0338	0.4263	12.6020			
EN9	0.2290	0.2091	0.1791	0.1967	0.2135	0.1657	0.1538	0.0706	0.0833	0.0242	0.0242	0.0472	0.1330	1.9662	14.7785			
EN10	0.0153	0.0105	0.0224	0.0219	0.0107	0.0110	0.0192	0.0235	0.0278	0.0323	0.0323	0.0661	0.0244	0.3125	12.8056			
EN11	0.1374	0.1672	0.1791	0.1311	0.1281	0.1326	0.1154	0.2824	0.0833	0.0968	0.0968	0.0551	0.1338	1.9730	14.7485			
EN12	0.2748	0.2091	0.2687	0.3934	0.2135	0.1989	0.1923	0.4941	0.1389	0.5806	0.5806	0.3304	0.3230	4.2959	13.3020			
													Average (lamda)		13.9224			

	L1	L2	L3	L4	Weights (W)	AW	lamda	CI	RI	CR
L1	0.1071	0.2500	0.0588	0.1212	0.1343	0.5765	4.2931	0.0859	0.9000	0.0955
L2	0.0357	0.1071	0.0588	0.1212	0.0807	0.3256	4.0330			
L3	0.3214	0.3214	0.1765	0.1515	0.2427	1.0367	4.2714			
L4	0.5357	0.5357	0.7059	0.6061	0.5958	2.6418	4.4337			
					Average (lamda)		4.2578			

Expert 8

	P	EC	S	T	EN	L	Weights (W)	AW	lamda	CI	RI	CR
P	0.1519	0.2243	0.1702	0.2093	0.2000	0.1190	0.1791	1.2278	6.8546	0.1131	1.2400	0.0912
EC	0.0759	0.1121	0.2553	0.2791	0.1500	0.0952	0.1613	1.0934	6.7789			
S	0.0759	0.0374	0.0851	0.1395	0.2000	0.0952	0.1055	0.6656	6.3069			
T	0.0506	0.0280	0.0426	0.0698	0.1500	0.1190	0.0767	0.4703	6.1343			
EN	0.0380	0.0374	0.0213	0.0233	0.0500	0.0952	0.0442	0.2813	6.3662			
L	0.6076	0.5607	0.4255	0.2791	0.2500	0.4762	0.4332	3.0114	6.9518			
							Average (lamda)		6.5654			

	P1	P2	Weights (W)	AW	lamda	CI	RI	CR
P1	0.8000	0.8000	0.8000	1.6000	2.0000	0.0000	0.0000	0.0000
P2	0.2000	0.2000	0.2000	0.4000	2.0000			
					2.0000			

	EC1	EC2	EC3	EC4	EC5	EC6	EC7	Weights (W)	AW	lamda	CI	RI	CR
EC1	0.2727	0.4286	0.3529	0.1967	0.1690	0.2093	0.1111	0.2486	1.9870	7.9919	0.1316	1.3200	0.0997
EC2	0.1364	0.2143	0.3529	0.2951	0.2535	0.2093	0.1667	0.2326	1.9132	8.2257			
EC3	0.0909	0.0714	0.1176	0.2951	0.1690	0.2093	0.1667	0.1600	1.2981	8.1130			
EC4	0.1364	0.0714	0.0392	0.0984	0.2535	0.1395	0.1667	0.1293	0.9973	7.7129			
EC5	0.1364	0.0714	0.0588	0.0328	0.0845	0.1395	0.1667	0.0986	0.7406	7.5117			
EC6	0.0909	0.0714	0.0392	0.0492	0.0423	0.0698	0.1667	0.0756	0.5691	7.5243			
EC7	0.1364	0.0714	0.0392	0.0328	0.0282	0.0233	0.0556	0.0553	0.4116	7.4494			
								Average (lamda)		7.7899			

	S1	S2	S3	S4	S5	S6	S7	S8	Weights (W)	AW	lamda	CI	RI	CR
S1	0.1111	0.2927	0.1548	0.0769	0.1121	0.1395	0.1429	0.0847	0.1394	1.3049	9.3640	0.1224	1.4100	0.0868
S2	0.0370	0.0976	0.2323	0.0769	0.1682	0.1860	0.1429	0.1130	0.1317	1.1933	9.0585			
S3	0.0556	0.0325	0.0774	0.0769	0.1682	0.1860	0.1429	0.0847	0.1030	0.8971	8.7064			
S4	0.2222	0.1951	0.1548	0.1538	0.1682	0.1395	0.1429	0.1130	0.1612	1.4842	9.2071			
S5	0.0556	0.0325	0.0258	0.0513	0.0561	0.1395	0.0952	0.0678	0.0655	0.5632	8.6020			
S6	0.0370	0.0244	0.0194	0.0513	0.0187	0.0465	0.0952	0.1130	0.0507	0.4164	8.2145			
S7	0.0370	0.0325	0.0258	0.0513	0.0280	0.0233	0.0476	0.0847	0.0413	0.3546	8.5889			
S8	0.4444	0.2927	0.3097	0.4615	0.2804	0.1395	0.1905	0.3390	0.3072	2.8002	9.1148			
									Average (lamda)		8.8570			

	T1	T2	T3	T4	T5	T6	T7	Weights (W)	AW	lamda	CI	RI	CR
T1	0.1111	0.0488	0.0194	0.3077	0.1121	0.1395	0.1429	0.1259	0.8686	6.8979	0.1141	1.3200	0.0864
T2	0.2222	0.0976	0.0194	0.4615	0.1682	0.1395	0.1905	0.1856	1.2864	6.9327			
T3	0.4444	0.3902	0.0774	0.4615	0.2243	0.1860	0.1429	0.2753	2.3909	8.6858			
T4	0.0556	0.0325	0.0258	0.1538	0.1121	0.1395	0.1905	0.1014	0.7259	7.1579			
T5	0.0556	0.0325	0.0194	0.0769	0.0561	0.0930	0.1429	0.0680	0.5035	7.3994			
T6	0.0370	0.0325	0.0194	0.0513	0.0280	0.0465	0.1429	0.0511	0.3805	7.4480			
T7	0.0370	0.0244	0.0258	0.0385	0.0187	0.0155	0.0476	0.0296	0.2748	9.2708			
								Average (lamda)		7.6847			

	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	Weights (W)	AW	lamda	CI	RI	CR
EN1	0.0333	0.0577	0.0370	0.0274	0.0306	0.0225	0.0275	0.0144	0.0192	0.0182	0.0182	0.0391	0.0288	0.3978	13.8302	0.1421	1.4800	0.0960
EN2	0.0667	0.1154	0.3333	0.1644	0.1224	0.1348	0.1101	0.1295	0.0769	0.0727	0.0727	0.0651	0.1220	1.7773	14.5661			
EN3	0.1000	0.0385	0.1111	0.2466	0.1837	0.2022	0.1651	0.1295	0.1154	0.1091	0.1091	0.0977	0.1340	1.9682	14.6882			
EN4	0.1000	0.0577	0.0370	0.0822	0.1837	0.2022	0.1101	0.0863	0.1154	0.1091	0.1091	0.0651	0.1048	1.4757	14.0766			
EN5	0.0667	0.0577	0.0370	0.0274	0.0612	0.0225	0.1651	0.1295	0.1154	0.1091	0.1091	0.0977	0.0832	1.1264	13.5387			
EN6	0.1000	0.0577	0.0370	0.0274	0.1837	0.0674	0.1651	0.0863	0.1154	0.0727	0.0727	0.0651	0.0876	1.2571	14.3577			
EN7	0.0667	0.0577	0.0370	0.0411	0.0204	0.0225	0.0550	0.1295	0.0769	0.0727	0.0727	0.0977	0.0625	0.9484	15.1740			
EN8	0.0667	0.0577	0.0370	0.0411	0.0306	0.0337	0.0183	0.1295	0.0769	0.1091	0.1091	0.0651	0.0646	0.8129	12.5878			
EN9	0.1000	0.0385	0.0370	0.0411	0.0204	0.0337	0.0183	0.0432	0.1154	0.0727	0.0727	0.0977	0.0576	0.6860	11.9162			
EN10	0.0667	0.0577	0.0370	0.0274	0.0204	0.0225	0.0275	0.0144	0.0385	0.0727	0.0727	0.0651	0.0436	0.5119	11.7541			
EN11	0.0667	0.0577	0.0370	0.0274	0.0204	0.0337	0.0275	0.0216	0.0192	0.0364	0.0364	0.0489	0.0361	0.4529	12.5563			
EN12	0.1667	0.3462	0.2222	0.2466	0.1224	0.2022	0.1101	0.0863	0.1154	0.1455	0.1455	0.1954	0.1754	2.4056	13.7170			
													Average (lamda)		13.5636			

	L1	L2	L3	L4	Weights (W)	AW	lamda	CI	RI	CR
L1	0.2500	0.2857	0.3636	0.2000	0.2748	1.3317	4.8452	0.0533	0.9000	0.0592
L2	0.1250	0.2500	0.0909	0.2000	0.1665	0.6502	3.9057			
L3	0.1250	0.5000	0.1818	0.2000	0.2517	0.9425	3.7446			
L4	0.5000	0.5000	0.3636	0.4000	0.4409	1.8269	4.1436			
					Average (lamda)		4.1598			

Expert 9

	P	EC	S	T	EN	L	Weights (W)	AW	lamda	CI	RI	CR
P	0.3333	0.4091	0.2500	0.2308	0.2105	0.5000	0.3223	2.1142	6.5600	0.0702	1.2400	0.0566
EC	0.1111	0.1364	0.2500	0.2308	0.2105	0.0833	0.1704	1.0733	6.3004			
S	0.1667	0.0682	0.1250	0.1538	0.2105	0.0833	0.1346	0.8352	6.2056			
T	0.1111	0.0455	0.0625	0.0769	0.0526	0.0833	0.0720	0.4539	6.3047			
EN	0.1667	0.0682	0.0625	0.1538	0.1053	0.0833	0.1066	0.6613	6.2018			
L	0.1111	0.2727	0.2500	0.1538	0.2105	0.1667	0.1941	1.2687	6.5348			
							Average (lamda)		6.3512			

	P1	P2	Weights (W)	AW	lamda	CI	RI	CR
P1	0.8333	0.8333	0.8333	1.6667	2.0000	0.0000	0.0000	0.0000
P2	0.1667	0.1667	0.1667	0.3333	2.0000			
					2.0000			

	EC1	EC2	EC3	EC4	EC5	EC6	EC7	Weights (W)	AW	lamda	CI	RI	CR
EC1	0.0984	0.2143	0.1739	0.2000	0.0435	0.0769	0.1304	0.1339	1.0175	7.5980	0.1026	1.3200	0.0777
EC2	0.0328	0.0714	0.1739	0.1333	0.0435	0.0769	0.0870	0.0884	0.6464	7.3122			
EC3	0.0492	0.0357	0.0870	0.1333	0.0652	0.1154	0.1304	0.0880	0.6407	7.2781			
EC4	0.0328	0.0357	0.0435	0.0667	0.0652	0.0769	0.1304	0.0645	0.4737	7.3489			
EC5	0.2951	0.2143	0.1739	0.1333	0.1304	0.0769	0.1304	0.1649	1.3308	8.0695			
EC6	0.2951	0.2143	0.1739	0.2000	0.3913	0.1154	0.1304	0.2172	1.7613	8.1090			
EC7	0.1967	0.2143	0.1739	0.1333	0.2609	0.4615	0.2609	0.2431	1.8453	7.5916			
								Average (lamda)		7.6153			

	S1	S2	S3	S4	S5	S6	S7	S8	Weights (W)	AW	lamda	CI	RI	CR
S1	0.2667	0.5217	0.3214	0.2308	0.1558	0.1538	0.1250	0.3000	0.2594	2.4150	9.3095	0.1287	1.4100	0.0913
S2	0.0667	0.1304	0.3214	0.1538	0.1558	0.1538	0.1875	0.2000	0.1712	1.5704	9.1733			
S3	0.0889	0.0435	0.1071	0.1538	0.2338	0.1538	0.1250	0.2000	0.1382	1.2386	8.9596			
S4	0.0889	0.0652	0.0536	0.0769	0.1558	0.0385	0.1250	0.0500	0.0817	0.7255	8.8757			
S5	0.1333	0.0652	0.0357	0.0385	0.0779	0.2308	0.1250	0.0500	0.0946	0.8240	8.7144			
S6	0.1333	0.0652	0.0536	0.1538	0.0260	0.0769	0.1250	0.0500	0.0855	0.7356	8.6053			
S7	0.1333	0.0435	0.0536	0.0385	0.0390	0.0385	0.0625	0.0500	0.0573	0.5001	8.7215			
S8	0.0889	0.0652	0.0536	0.1538	0.1558	0.1538	0.1250	0.1000	0.1120	0.9915	8.8502			
									Average (lamda)		8.9012			

	T1	T2	T3	T4	T5	T6	T7	Weights (W)	AW	lamda	CI	RI	CR
T1	0.2667	0.3913	0.3214	0.2308	0.2338	0.2308	0.2500	0.2750	2.2239	8.0881	0.1008	1.3200	0.0764

T2	0.0889	0.1304	0.2143	0.1538	0.2338	0.1538	0.1875	0.1661	1.3202	7.9491			
T3	0.0889	0.0652	0.1071	0.1538	0.1558	0.1538	0.1250	0.1214	0.9903	8.1573			
T4	0.0889	0.0652	0.0536	0.0769	0.3117	0.2308	0.1875	0.1449	1.0671	7.3624			
T5	0.0889	0.0435	0.0536	0.0192	0.0779	0.1538	0.1250	0.0803	0.5680	7.0753			
T6	0.0889	0.0652	0.0536	0.0256	0.0390	0.0769	0.1875	0.0767	0.5361	6.9927			
T7	0.0667	0.0435	0.0536	0.0256	0.0390	0.0256	0.0625	0.0452	0.3440	7.6095			
								Average (lamda)		7.6049			

	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	Weights (W)	AW	lamda	CI	RI	CR
EN1	0.0706	0.2857	0.1690	0.1905	0.0556	0.1552	0.0227	0.0189	0.1176	0.0784	0.0784	0.0816	0.1104	1.4258	12.9204	0.1629	1.4800	0.1101
EN2	0.0353	0.1429	0.2535	0.1905	0.2222	0.1552	0.2045	0.1132	0.1176	0.1176	0.1176	0.1224	0.1494	2.0458	13.6943			
EN3	0.0353	0.0476	0.0845	0.1905	0.0556	0.1034	0.1364	0.1132	0.0784	0.0784	0.0784	0.0816	0.0903	1.4120	15.6397			
EN4	0.0353	0.0714	0.0423	0.0952	0.2222	0.1034	0.1364	0.1698	0.1176	0.1176	0.1176	0.0816	0.1092	1.5146	13.8679			
EN5	0.1412	0.0714	0.1690	0.0476	0.1111	0.1552	0.1364	0.1132	0.1176	0.0784	0.0784	0.1224	0.1118	1.6434	14.6943			
EN6	0.0235	0.0476	0.0423	0.0476	0.0370	0.0517	0.0227	0.1132	0.0784	0.1176	0.1176	0.0816	0.0651	0.9085	13.9574			
EN7	0.2118	0.0476	0.0423	0.0476	0.0556	0.1552	0.0682	0.1132	0.0784	0.0784	0.0784	0.0816	0.0882	1.2444	14.1103			
EN8	0.1412	0.0714	0.0282	0.0476	0.0556	0.0259	0.1364	0.1132	0.0784	0.1176	0.1176	0.0816	0.0846	1.1508	13.6087			
EN9	0.2118	0.0714	0.0423	0.0317	0.0556	0.0259	0.0341	0.0566	0.0784	0.0784	0.0784	0.1224	0.0739	1.0125	13.6975			
EN10	0.0235	0.0476	0.0423	0.0317	0.0370	0.0259	0.0341	0.0283	0.0392	0.0196	0.0196	0.0816	0.0359	0.5010	13.9663			
EN11	0.0353	0.0476	0.0423	0.0317	0.0556	0.0172	0.0341	0.0283	0.0784	0.0392	0.0392	0.0204	0.0391	0.5053	12.9192			
EN12	0.0353	0.0476	0.0423	0.0476	0.0370	0.0259	0.0341	0.0189	0.0196	0.0784	0.0784	0.0408	0.0422	0.5239	12.4261			
													Average (lamda)		13.7918			

	L1	L2	L3	L4	Weights (W)	AW	lamda	CI	RI	CR
L1	0.2609	0.4000	0.2308	0.2500	0.2854	1.3866	4.8584	0.0585	0.9000	0.0650
L2	0.0870	0.2609	0.1538	0.2500	0.1879	0.7313	3.8917			
L3	0.5217	0.7826	0.4615	0.3750	0.5352	2.0746	3.8761			
L4	0.1304	0.1304	0.1538	0.1250	0.1349	0.5500	4.0762			
					Average (lamda)		4.1756			

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	P	EC	S	T	EN	L	Weights (W)	AW	lamda	CI	RI	CR
P	0.3529	0.3214	0.3288	0.4235	0.2222	0.2143	0.3105	2.1781	7.0141	0.1514	1.2400	0.1221
EC	0.1176	0.1071	0.0411	0.2824	0.1481	0.2143	0.1518	1.0444	6.8808			
S	0.1765	0.4286	0.1644	0.0706	0.2222	0.1429	0.2008	1.4287	7.1132			
T	0.1176	0.0536	0.3288	0.1412	0.2963	0.2143	0.1920	1.2874	6.7068			
EN	0.1176	0.0536	0.0548	0.0353	0.0741	0.1429	0.0797	0.5044	6.3283			
L	0.1176	0.0357	0.0822	0.0471	0.0370	0.0714	0.0652	0.4235	6.4981			
							Average (lamda)		6.7569			

	P1	P2	Weights (W)	AW	lamda	CI	RI	CR
P1	0.8333	0.8333	0.8333	1.6667	2.0000	0.0000	0.0000	0.0000
P2	0.1667	0.1667	0.1667	0.3333	2.0000			
					2.0000			

	EC1	EC2	EC3	EC4	EC5	EC6	EC7	Weights (W)	AW	lamda	CI	RI	CR
EC1	0.1550	0.3429	0.2500	0.3396	0.1818	0.2609	0.0857	0.2308	1.9327	8.3724	0.1619	1.3200	0.1227
EC2	0.0310	0.0686	0.1875	0.0377	0.2424	0.0435	0.1143	0.1036	0.7803	7.5336			
EC3	0.0388	0.0229	0.0625	0.0566	0.0303	0.0435	0.1714	0.0608	0.4555	7.4851			
EC4	0.0517	0.2057	0.1250	0.1132	0.1212	0.1739	0.1143	0.1293	1.0601	8.1997			
EC5	0.0517	0.0171	0.1250	0.0566	0.0606	0.0435	0.0857	0.0629	0.4789	7.6155			
EC6	0.0517	0.1371	0.1250	0.0566	0.1212	0.0870	0.0857	0.0949	0.7705	8.1192			
EC7	0.6202	0.2057	0.1250	0.3396	0.2424	0.3478	0.3429	0.3177	2.6925	8.4760			
								Average (lamda)		7.9717			

	S1	S2	S3	S4	S5	S6	S7	S8	Weights (W)	AW	lamda	CI	RI	CR
S1	0.1176	0.0469	0.3673	0.2143	0.0429	0.1446	0.1579	0.1304	0.1527	1.3963	9.1416	0.2030	1.4100	0.1440
S2	0.2353	0.0938	0.0612	0.1429	0.2571	0.0241	0.1579	0.0870	0.1324	1.2823	9.6851			
S3	0.0392	0.1875	0.1224	0.1429	0.2571	0.2169	0.1053	0.1304	0.1502	1.4773	9.8343			
S4	0.0392	0.0469	0.0612	0.0714	0.0429	0.1446	0.1053	0.0870	0.0748	0.6854	9.1636			
S5	0.2353	0.0313	0.0408	0.1429	0.0857	0.2169	0.1579	0.0870	0.1247	1.1707	9.3873			
S6	0.0588	0.2813	0.0408	0.0357	0.0286	0.0723	0.1053	0.1304	0.0941	0.9020	9.5804			
S7	0.0392	0.0313	0.0612	0.0357	0.0286	0.0361	0.0526	0.0870	0.0465	0.4175	8.9856			
S8	0.2353	0.2813	0.2449	0.2143	0.2571	0.1446	0.1579	0.2609	0.2245	2.1538	9.5928			
									Average (lamda)		9.4213			

	T1	T2	T3	T4	T5	T6	T7	Weights (W)	AW	lamda	CI	RI	CR
T1	0.1176	0.1875	0.4898	0.1429	0.3429	0.2892	0.1053	0.2393	1.8893	7.8950	0.1145	1.3200	0.0867

T2	0.0588	0.0938	0.2449	0.1429	0.2571	0.2169	0.1579	0.1675	1.2866	7.6827			
T3	0.0294	0.0469	0.1224	0.1429	0.1714	0.1446	0.1053	0.1090	0.8545	7.8412			
T4	0.0588	0.0469	0.0612	0.0714	0.2571	0.1446	0.2105	0.1215	0.9068	7.4626			
T5	0.0294	0.0313	0.0612	0.0238	0.0857	0.2169	0.1579	0.0866	0.5759	6.6505			
T6	0.0294	0.0313	0.0612	0.0357	0.0286	0.0723	0.1053	0.0520	0.3936	7.5745			
T7	0.0588	0.0313	0.0612	0.0179	0.0286	0.0361	0.0526	0.0409	0.3561	8.7007			
								Average (lamda)		7.6867			

	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	Weights (W)	AW	lamda	CI	RI	CR
EN1	0.0822	0.1463	0.1827	0.1644	0.1682	0.0221	0.0896	0.1277	0.0682	0.0645	0.0645	0.0609	0.1034	1.5119	14.6166	0.1466	1.4800	0.0991
EN2	0.0411	0.0732	0.1218	0.0411	0.1121	0.0882	0.0896	0.0851	0.1023	0.0968	0.0968	0.0609	0.0841	1.2114	14.4071			
EN3	0.0274	0.0366	0.0609	0.0411	0.1682	0.1324	0.0896	0.0851	0.1364	0.0645	0.0645	0.0761	0.0819	1.1123	13.5814			
EN4	0.0411	0.1463	0.1218	0.0822	0.1121	0.1324	0.0896	0.0851	0.0682	0.0968	0.0968	0.0609	0.0944	1.3679	14.4850			
EN5	0.0274	0.0366	0.0203	0.0411	0.0561	0.1324	0.0896	0.0851	0.0682	0.0645	0.0645	0.0761	0.0635	0.9584	15.0964			
EN6	0.1644	0.0366	0.0203	0.0274	0.0187	0.0441	0.0896	0.0213	0.1023	0.0968	0.0968	0.0609	0.0649	0.8240	12.6918			
EN7	0.0411	0.0366	0.0305	0.0411	0.0280	0.0221	0.0448	0.0851	0.1023	0.0645	0.0645	0.0508	0.0509	0.6548	12.8538			
EN8	0.0274	0.0366	0.1218	0.0411	0.0280	0.0882	0.0896	0.0851	0.0682	0.0968	0.0968	0.0761	0.0713	0.9592	13.4517			
EN9	0.0274	0.0366	0.0305	0.0411	0.0280	0.0882	0.0224	0.0426	0.0682	0.0645	0.0645	0.0508	0.0471	0.6227	13.2329			
EN10	0.0274	0.0244	0.0152	0.0411	0.0280	0.0147	0.0149	0.0213	0.0341	0.0968	0.0968	0.0609	0.0396	0.4496	11.3435			
EN11	0.0822	0.0244	0.0305	0.0274	0.0280	0.0147	0.0224	0.0213	0.0114	0.0323	0.0323	0.0609	0.0323	0.4289	13.2761			
EN12	0.4110	0.3659	0.2437	0.4110	0.2243	0.2206	0.2687	0.2553	0.1705	0.1613	0.1613	0.3046	0.2665	3.8153	14.3170			
													Average (lamda)		13.6128			

	L1	L2	L3	L4	Weights (W)	AW	lamda	CI	RI	CR
L1	0.2727	0.4615	0.3750	0.2000	0.3273	1.5694	4.7946	0.0779	0.9000	0.0865
L2	0.0909	0.2727	0.2500	0.2000	0.2034	0.8063	3.9638			
L3	0.0909	0.1364	0.1250	0.2000	0.1381	0.5665	4.1030			
L4	0.5455	0.5455	0.2500	0.4000	0.4352	1.7728	4.0733			
							4.2337			

Appendix H

Content Validity Index Form

EXPERTS VALIDATION ON PROPOSED HEALTH & SAFETY LOCATION FOR NEW FACILITY CONSTRUCTION OR RELOCATION

Title of Project: Spatial Decision Support System (SDSS) based on MCDA for flood management planning: Case Study of Health and Safety Facility in Kelantan.

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Objective: To validate the proposed location for the new construction of a health and safety facility (hospital, clinic & evacuation center) as a preparedness measure in FMP. The proposed location was recommended based on analysis of **4** Multi-criteria Analysis (WSM, AHP, TOPSIS and VIKOR).

Instructions for validation: There are 6 items that need to be validated based on the relevance of each item (how important the item is). Kindly review and validate the items based on your expertise and provide feedback and recommendation to improve the project.

Relevant Scale:

1= Not Agree 2=Somewhat Agree 3= Quite Agree 4= Strongly Agree

No	Item	Relevant Scale			
		Not Agree	Somewhat Agree	Quite Agree	Strongly Agree
1	The criteria of projected rainfall used to propose the location is acceptable				
2	The criteria of rainfall risk score for the proposed location is acceptable				
3	The criteria of landuse risk score for the proposed location is acceptable				

4	The criteria of the urban size area for the proposed location are acceptable				
5	The criteria risk score of the proposed location to access the nearest health and safety facilities is acceptable				
6	The criteria of distance for the proposed location from the nearest health and safety facility is acceptable				

Signature:

Name:

Date:

Recommendation & Feedback

No	Measure	Recommendation
1	Data	
2	Criteria Selection	
3	MCDA Technique	
4	Result and Analysis	
5	System Visualisation	

Potential adaptation area of the system in flood management planning?

Further comment

Appendix I1

Case Study 1- Details Results Analysis for RCPs (2010-2039)

Weightage and Ranking for RCP 2.6, November- March, 2010-2039

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L1	Nov.	0.691	1	0.640	2	0.429	1	0.471	1
L2		0.200	2	0.974	1	0.000	1	0.277	2
L3		0.108	3	0.285	3	1.000	NA	0.252	3
L1	Dec.	0.691	1	0.639	2	0.449	1	0.468	1
L2		0.200	2	0.978	1	0.500	1	0.275	2
L3		0.108	3	0.285	3	1.000	NA	0.275	3
L1	Jan.	0.691	1	0.637	2	0.925	NA	0.464	1
L2		0.200	2	0.992	1	0.000	1	0.285	2
L3		0.108	3	0.284	3	1.000	NA	0.251	3
L1	Feb.	0.691	1	0.621	2	0.987	NA	0.455	1
L2		0.200	2	0.992	1	0.000	1	0.301	2
L3		0.108	3	0.281	3	1.000	NA	0.245	3
L1	Mar.	0.691	1	0.729	2	0.658	NA	0.402	1
L2		0.200	2	0.994	1	0.000	1	0.219	3
L3		0.108	3	0.221	3	1.000	NA	0.379	2

Wt.: Weightage; Rk: Rank

Weightage and Ranking for RCP 4.5, November- March, 2010-2039

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L1	Nov.	0.691	1	0.640	2	0.001	1	0.473	1
L2		0.200	2	0.954	1	0.500	NA	0.274	2
L3		0.108	3	0.285	3	1.000	NA	0.253	3

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L1	Dec.	0.691	1	0.638	2	0.500	NA	0.464	1
L2		0.200	2	0.967	1	0.000	1	0.275	2
L3		0.108	3	0.286	3	0.078	1	0.261	3
L1	Jan.	0.691	1	0.633	2	1.000	NA	0.455	1
L2		0.200	2	0.992	1	0.000	1	0.284	2
L3		0.108	3	0.291	3	0.789	NA	0.261	3
L1	Feb.	0.691	1	0.640	2	0.500	1	0.468	1
L2		0.200	2	0.931	1	0.500	1	0.272	2
L3		0.108	3	0.289	3	0.965	1	0.260	3
L1	Mar.	0.691	1	0.588	2	1.000	NA	0.443	1
L2		0.200	2	0.992	1	0.000	1	0.320	2
L3		0.108	3	0.275	3	0.983	NA	0.237	3

Wt.: Weightage; Rk: Rank

Weightage and Ranking for RCP 6.0, November- March, 2010-2039

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L1	Nov.	0.691	1	0.634	2	1.000	NA	0.460	1
L2		0.200	2	0.932	1	0.000	1	0.274	2
L3		0.108	3	0.292	3	0.611	NA	0.267	3
L1	Dec.	0.691	1	0.638	2	0.500	NA	0.464	1
L2		0.200	2	0.963	1	0.000	1	0.275	2
L3		0.108	3	0.286	3	0.017	1	0.261	3
L1	Jan.	0.691	1	0.644	2	0.602	NA	0.477	1
L2		0.200	2	0.986	1	0.000	1	0.285	2
L3		0.108	3	0.282	3	1.000	NA	0.238	3
L1	Feb.	0.691	1	0.653	2	0.624	NA	0.482	1

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L2		0.200	2	0.992	1	0.000	1	0.293	2
L3		0.108	3	0.276	3	1.000	NA	0.225	3
L1	Mar.	0.691	1	0.639	2	0.500	1	0.400	1
L2		0.200	2	0.941	1	0.500	1	0.206	2
L3		0.108	3	0.288	3	0.875	1	0.194	3

Wt.: Weightage; Rk: Rank

Weightage and Ranking for RCP 8.5, November- March, 2010-2039

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L1	Nov.	0.691	1	0.635	2	1.000	NA	0.459	1
L2		0.200	2	0.960	1	0.000	1	0.277	2
L3		0.108	3	0.290	3	0.680	NA	0.264	3
L1	Dec.	0.691	1	0.641	2	0.640	NA	0.472	1
L2		0.200	2	0.992	1	0.000	1	0.284	2
L3		0.108	3	0.284	3	1.000	NA	0.244	3
L1	Jan.	0.691	1	0.631	2	0.967	NA	0.460	1
L2		0.200	2	0.992	1	0.000	1	0.292	2
L3		0.108	3	0.283	3	1.000	NA	0.249	3
L1	Feb.	0.691	1	0.649	2	0.102	1	0.493	1
L2		0.200	2	0.836	1	0.500	1	0.268	2
L3		0.108	3	0.279	3	1.000	NA	0.239	3
L1	Mar.	0.691	1	0.637	2	1.000	NA	0.462	1
L2		0.200	2	0.992	1	0.000	1	0.281	2
L3		0.108	3	0.286	3	0.925	NA	0.257	3

Wt.: Weightage; Rk: Rank

Appendix I2

Case Study 1- Details Results Analysis for RCPs (2040-2069)

Weightage and Ranking for RCP 2.6, November- March, 2040-2069

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L1	Nov.	0.691	1	0.639	2	0.5	NA	0.465	1
L2		0.200	2	0.974	1	0	1	0.276	2
L3		0.108	3	0.285	3	0.124	1	0.259	3
L1	Dec.	0.691	1	0.639	2	0.650	NA	0.468	1
L2		0.200	2	0.992	1	0.000	1	0.279	2
L3		0.108	3	0.285	3	1.000	NA	0.252	3
L1	Jan.	0.691	1	0.638	2	0.924	NA	0.464	1
L2		0.200	2	0.992	1	0.000	1	0.285	2
L3		0.108	3	0.284	3	1.000	NA	0.251	3
L1	Feb.	0.691	1	0.639	2	0.797	NA	0.466	1
L2		0.200	2	0.992	1	0.000	1	0.279	2
L3		0.108	3	0.285	3	1.000	NA	0.254	3
L1	Mar.	0.691	1	0.639	2	0.710	NA	0.468	1

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L2		0.200	2	0.992	1	0.000	1	0.279	2
L3		0.108	3	0.285	3	1.000	NA	0.253	3

Wt.: Weightage; Rk: Rank

Weightage and Ranking for RCP 4.5, November- March, 2040-2069

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L1	Nov.	0.691	1	0.639	2	0.000	1	0.468	1
L2		0.200	2	0.973	1	0.634	NA	0.274	2
L3		0.108	3	0.285	3	1.000	NA	0.258	3
L1	Dec.	0.691	1	0.639	2	0.642	NA	0.468	1
L2		0.200	2	0.992	1	0.000	1	0.279	2
L3		0.108	3	0.285	3	1.000	NA	0.253	3
L1	Jan.	0.691	1	0.639	2	0.720	NA	0.467	1
L2		0.200	2	0.992	1	0.000	1	0.286	2
L3		0.108	3	0.284	3	1.000	NA	0.247	3
L1	Feb.	0.691	1	0.639	2	0.814	NA	0.466	1

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L2		0.200	2	0.992	1	0.000	1	0.278	2
L3		0.108	3	0.285	3	1.000	NA	0.255	3
L1	Mar.	0.691	1	0.639	2	0.990	NA	0.466	1
L2		0.200	2	0.992	1	0.000	1	0.278	2
L3		0.108	3	0.285	3	1.000	NA	0.256	3

Wt.: Weightage; Rk: Rank

Weightage and Ranking for RCP 6.0, November- March, 2040-2069

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L1	Nov.	0.691	1	0.639	2	0.524	NA	0.467	1
L2		0.200	2	0.992	1	0.000	1	0.277	2
L3		0.108	3	0.285	3	1.000	NA	0.256	3
L1	Dec.	0.691	1	0.639	2	0.703	NA	0.468	1
L2		0.200	2	0.992	1	0.000	1	0.282	2
L3		0.108	3	0.285	3	1.000	NA	0.251	3
L1	Jan.	0.691	1	0.638	2	0.743	NA	0.466	1

Location	**Month**	**AHP**		**TOPSIS**		**VIKOR**		**WSM**	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L2		0.200	2	0.992	1	0.000	1	0.288	2
L3		0.108	3	0.283	3	1.000	NA	0.245	3
L1	Feb.	0.691	1	0.644	2	0.604	NA	0.476	1
L2		0.200	2	0.990	1	0.000	1	0.285	2
L3		0.108	3	0.282	3	1.000	NA	0.239	3
L1	Mar.	0.691	1	0.648	2	0.684	NA	0.475	1
L2		0.200	2	0.992	1	0.000	1	0.288	2
L3		0.108	3	0.279	3	1.000	NA	0.237	3

Wt.: Weightage; Rk: Rank

Weightage and Ranking for RCP 8.5, November- March, 2040-2069

Location	**Month**	**AHP**		**TOPSIS**		**VIKOR**		**WSM**	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L1	Nov.	0.691	1	0.639	2	0.666	NA	0.467	1
L2		0.200	2	0.992	1	0.000	1	0.277	2
L3		0.108	3	0.285	3	1.000	NA	0.256	3
L1	Dec.	0.691	1	0.639	2	0.717	NA	0.467	1

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L2		0.200	2	0.992	1	0.000	1	0.279	2
L3		0.108	3	0.285	3	1.000	NA	0.253	3
L1	Jan.	0.691	1	0.640	2	0.651	NA	0.470	1
L2		0.200	2	0.992	1	0.000	1	0.282	2
L3		0.108	3	0.284	3	1.000	NA	0.248	3
L1	Feb.	0.691	1	0.644	2	0.643	NA	0.475	1
L2		0.200	2	0.992	1	0.000	1	0.286	2
L3		0.108	3	0.282	3	1.000	NA	0.239	3
L1	Mar.	0.691	1	0.639	2	0.700	NA	0.468	1
L2		0.200	2	0.992	1	0.000	1	0.278	2
L3		0.108	3	0.285	3	1.000	NA	0.255	3

Wt.: Weightage; Rk: Rank

Appendix I3

Case Study 1: Details Calculation for RCP 2.6 2010-2039

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.4935	5.82483	11	Wet	612.64	0.23	2.9521	0.3704	11.452	0.10971	0.691	1	0.640	2	0.429	1	0.471	1
L2	102.4394	5.87865	11	Wet	629.17	0.24	0.5751	0.2319	7.669	0.106	0.200	2	0.974	1	0.000	1	0.277	2
L3	102.3312	5.87865	11	Wet	627.38	0.25	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.252	3
L1	102.4935	5.82483	12	Wet	614.67	0.24	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.449	1	0.468	1
L2	102.4394	5.87865	12	Wet	638.89	0.24	0.5751	0.2319	7.669	0.106	0.200	2	0.978	1	0.500	1	0.275	2
L3	102.3312	5.87865	12	Wet	613.63	0.24	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.275	3
L1	102.4935	5.82483	1	Normal	278.6	0.11	2.9521	0.3704	11.452	0.10971	0.691	1	0.637	2	0.925	NA	0.464	1
L2	102.4394	5.87865	1	Normal	261.57	0.1	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.285	2
L3	102.3312	5.87865	1	Normal	292.97	0.11	0.5187	0.4099	8.039	0.12378	0.108	3	0.284	3	1.000	NA	0.251	3
L1	102.4935	5.82483	2	Normal	108.53	0.04	2.9521	0.3704	11.452	0.10971	0.691	1	0.621	2	0.987	NA	0.455	1
L2	102.4394	5.87865	2	Dry	85.9	0.03	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.301	2
L3	102.3312	5.87865	2	Normal	107.5	0.04	0.5187	0.4099	8.039	0.12378	0.108	3	0.281	3	1.000	NA	0.245	3
L1	102.4935	5.82483	3	Dry	13.52	0.00	2.9521	0.3704	11.452	0.10971	0.691	1	0.729	2	0.658	NA	0.402	1
L2	102.4394	5.87865	3	Dry	12.25	0.00	0.5751	0.2319	7.669	0.106	0.200	2	0.994	1	0.000	1	0.219	3
L3	102.3312	5.87865	3	Dry	16.67	0.01	0.5187	0.4099	8.039	0.12378	0.108	3	0.221	3	1.000	NA	0.379	2

Appendix I4

Case Study 1: Details Calculation for RCP 4.5 2010-2039

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.4935	5.82483	11	Normal	435.55	0.17	2.9521	0.3704	11.452	0.10971	0.691	1	0.640	2	0.001	1	0.473	1
L2	102.4394	5.87865	11	Normal	468.52	0.18	0.5751	0.2319	7.669	0.106	0.200	2	0.954	1	0.500	NA	0.274	2
L3	102.3312	5.87865	11	Normal	472.72	0.18	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.253	3
L1	102.4935	5.82483	12	Wet	558.41	0.21	2.9521	0.3704	11.452	0.10971	0.691	1	0.638	2	0.500	NA	0.464	1
L2	102.4394	5.87865	12	Wet	548.67	0.21	0.5751	0.2319	7.669	0.106	0.200	2	0.967	1	0.000	1	0.275	2
L3	102.3312	5.87865	12	Wet	526.51	0.2	0.5187	0.4099	8.039	0.12378	0.108	3	0.286	3	0.078	1	0.261	3
L1	102.4935	5.82483	1	Normal	210.24	0.08	2.9521	0.3704	11.452	0.10971	0.691	1	0.633	2	1.000	NA	0.455	1
L2	102.4394	5.87865	1	Normal	181.83	0.07	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.284	2
L3	102.3312	5.87865	1	Normal	187.8	0.07	0.5187	0.4099	8.039	0.12378	0.108	3	0.291	3	0.789	NA	0.261	3
L1	102.4935	5.82483	2	Normal	105.97	0.04	2.9521	0.3704	11.452	0.10971	0.691	1	0.640	2	0.500	1	0.468	1
L2	102.4394	5.87865	2	Normal	117.92	0.04	0.5751	0.2319	7.669	0.106	0.200	2	0.931	1	0.500	1	0.272	2
L3	102.3312	5.87865	2	Normal	102.54	0.04	0.5187	0.4099	8.039	0.12378	0.108	3	0.289	3	0.965	1	0.260	3
L1	102.4935	5.82483	3	Dry	47.32	0.02	2.9521	0.3704	11.452	0.10971	0.691	1	0.588	2	1.000	NA	0.443	1
L2	102.4394	5.87865	3	Dry	36.95	0.01	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.320	2
L3	102.3312	5.87865	3	Dry	44.4	0.02	0.5187	0.4099	8.039	0.12378	0.108	3	0.275	3	0.983	NA	0.237	3

Appendix I5

Case Study 1: Details Calculation for RCP 6.0 2010-2039

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.4935	5.82483	11	Wet	616.81	0.24	2.9521	0.3704	11.452	0.10971	0.691	1	0.634	2	1.000	NA	0.460	1
L2	102.4394	5.87865	11	Wet	604.86	0.23	0.5751	0.2319	7.669	0.106	0.200	2	0.932	1	0.000	1	0.274	2
L3	102.3312	5.87865	11	Wet	541.31	0.21	0.5187	0.4099	8.039	0.12378	0.108	3	0.292	3	0.611	NA	0.267	3
L1	102.4935	5.82483	12	Wet	633.81	0.24	2.9521	0.3704	11.452	0.10971	0.691	1	0.638	2	0.500	NA	0.464	1
L2	102.4394	5.87865	12	Wet	632.79	0.24	0.5751	0.2319	7.669	0.106	0.200	2	0.963	1	0.000	1	0.275	2
L3	102.3312	5.87865	12	Wet	569.74	0.23	0.5187	0.4099	8.039	0.12378	0.108	3	0.286	3	0.017	1	0.261	3
L1	102.4935	5.82483	1	Normal	108.38	0.04	2.9521	0.3704	11.452	0.10971	0.691	1	0.644	2	0.602	NA	0.477	1
L2	102.4394	5.87865	1	Normal	111.13	0.04	0.5751	0.2319	7.669	0.106	0.200	2	0.986	1	0.000	1	0.285	2
L3	102.3312	5.87865	1	Normal	133.2	0.05	0.5187	0.4099	8.039	0.12378	0.108	3	0.282	3	1.000	NA	0.238	3
L1	102.4935	5.82483	2	Dry	56.59	0.02	2.9521	0.3704	11.452	0.10971	0.691	1	0.653	2	0.624	NA	0.482	1
L2	102.4394	5.87865	2	Dry	56.18	0.02	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.293	2
L3	102.3312	5.87865	2	Dry	79.21	0.03	0.5187	0.4099	8.039	0.12378	0.108	3	0.276	3	1.000	NA	0.225	3
L1	102.4935	5.82483	3	Dry	9.86	0.00	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.500	1	0.400	1
L2	102.4394	5.87865	3	Dry	10.46	0.00	0.5751	0.2319	7.669	0.106	0.200	2	0.941	1	0.500	1	0.206	2
L3	102.3312	5.87865	3	Dry	9.27	0.00	0.5187	0.4099	8.039	0.12378	0.108	3	0.288	3	0.875	1	0.194	3

Appendix I6

Case Study 1: Details Calculation for RCP 8.5 2010-2039

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.4935	5.82483	11	Normal	462.58	0.18	2.9521	0.3704	11.452	0.10971	0.691	1	0.635	2	1.000	NA	0.459	1
L2	102.4394	5.87865	11	Normal	438.42	0.17	0.5751	0.2319	7.669	0.106	0.200	2	0.960	1	0.000	1	0.277	2
L3	102.3312	5.87865	11	Normal	414.93	0.16	0.5187	0.4099	8.039	0.12378	0.108	3	0.290	3	0.680	NA	0.264	3
L1	102.4935	5.82483	12	Normal	499.26	0.19	2.9521	0.3704	11.452	0.10971	0.691	1	0.641	2	0.640	NA	0.472	1
L2	102.4394	5.87865	12	Normal	488.45	0.19	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.284	2
L3	102.3312	5.87865	12	Wet	562.88	0.22	0.5187	0.4099	8.039	0.12378	0.108	3	0.284	3	1.000	NA	0.244	3
L1	102.4935	5.82483	1	Normal	124.9	0.05	2.9521	0.3704	11.452	0.10971	0.691	1	0.631	2	0.967	NA	0.460	1
L2	102.4394	5.87865	1	Normal	113.94	0.04	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.292	2
L3	102.3312	5.87865	1	Normal	126.36	0.05	0.5187	0.4099	8.039	0.12378	0.108	3	0.283	3	1.000	NA	0.249	3
L1	102.4935	5.82483	2	Dry	63.2	0.02	2.9521	0.3704	11.452	0.10971	0.691	1	0.649	2	0.102	1	0.493	1
L2	102.4394	5.87865	2	Dry	68.97	0.03	0.5751	0.2319	7.669	0.106	0.200	2	0.836	1	0.500	1	0.268	2
L3	102.3312	5.87865	2	Dry	79.95	0.03	0.5187	0.4099	8.039	0.12378	0.108	3	0.279	3	1.000	NA	0.239	3
L1	102.4935	5.82483	3	Dry	19.06	0.01	2.9521	0.3704	11.452	0.10971	0.691	1	0.637	2	1.000	NA	0.462	1
L2	102.4394	5.87865	3	Dry	16.75	0.01	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.281	2
L3	102.3312	5.87865	3	Dry	17.72	0.01	0.5187	0.4099	8.039	0.12378	0.108	3	0.286	3	0.925	NA	0.257	3

Appendix I7

Case Study 1: Details Calculation for RCP 2.6 2040-2069

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.4935	5.82483	11	Normal	454.62	0.21	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.5	NA	0.465	1
L2	102.4394	5.87865	11	Normal	448.59	0.21	0.5751	0.2319	7.669	0.106	0.200	2	0.974	1	0	1	0.276	2
L3	102.3312	5.87865	11	Normal	444.06	0.2	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	0.124	1	0.259	3
L1	102.4935	5.82483	12	Normal	464.65	0.21	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.650	NA	0.468	1
L2	102.4394	5.87865	12	Normal	458.67	0.21	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.279	2
L3	102.3312	5.87865	12	Normal	485.2	0.22	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.252	3
L1	102.4935	5.82483	1	Normal	252	0.11	2.9521	0.3704	11.452	0.10971	0.691	1	0.638	2	0.924	NA	0.464	1
L2	102.4394	5.87865	1	Normal	237.68	0.1	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.285	2
L3	102.3312	5.87865	1	Normal	264.72	0.11	0.5187	0.4099	8.039	0.12378	0.108	3	0.284	3	1.000	NA	0.251	3
L1	102.4935	5.82483	2	Dry	98.94	0.03	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.797	NA	0.466	1
L2	102.4394	5.87865	2	Dry	94.71	0.03	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.279	2
L3	102.3312	5.87865	2	Dry	101.65	0.03	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.254	3
L1	102.4935	5.82483	3	Dry	60.16	0.01	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.710	NA	0.468	1
L2	102.4394	5.87865	3	Dry	59.87	0.01	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.279	2
L3	102.3312	5.87865	3	Dry	64.15	0.01	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.253	3

Appendix I8

Case Study 1: Details Calculation for RCP 4.5 2040-2069

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.4935	5.82483	11	Normal	443.14	0.2	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.000	1	0.468	1
L2	102.4394	5.87865	11	Normal	448.97	0.21	0.5751	0.2319	7.669	0.106	0.200	2	0.973	1	0.634	NA	0.274	2
L3	102.3312	5.87865	11	Normal	442.52	0.20	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.258	3
L1	102.4935	5.82483	12	Normal	466.94	0.21	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.642	NA	0.468	1
L2	102.4394	5.87865	12	Normal	464.33	0.21	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.279	2
L3	102.3312	5.87865	12	Normal	480.69	0.22	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.253	3
L1	102.4935	5.82483	1	Normal	252.86	0.11	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.720	NA	0.467	1
L2	102.4394	5.87865	1	Normal	245.28	0.1	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.286	2
L3	102.3312	5.87865	1	Normal	271.09	0.12	0.5187	0.4099	8.039	0.12378	0.108	3	0.284	3	1.000	NA	0.247	3
L1	102.4935	5.82483	2	Dry	106.04	0.03	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.814	NA	0.466	1
L2	102.4394	5.87865	2	Dry	102.98	0.03	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.278	2
L3	102.3312	5.87865	2	Dry	107.36	0.03	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.255	3
L1	102.4935	5.82483	3	Dry	85.62	0.02	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.990	NA	0.466	1
L2	102.4394	5.87865	3	Dry	83.04	0.02	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.278	2
L3	102.3312	5.87865	3	Dry	85.4	0.02	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.256	3

Appendix I9

Case Study 1: Details Calculation for RCP 6.0 2040-2069

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.4935	5.82483	11	Normal	455.37	0.21	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.524	NA	0.467	1
L2	102.4394	5.87865	11	Normal	457.03	0.21	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.277	2
L3	102.3312	5.87865	11	Normal	458.39	0.21	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.256	3
L1	102.4935	5.82483	12	Normal	488.51	0.23	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.703	NA	0.468	1
L2	102.4394	5.87865	12	Normal	483.45	0.22	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.282	2
L3	102.3312	5.87865	12	Wet	515.79	0.24	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.251	3
L1	102.4935	5.82483	1	Normal	241.71	0.1	2.9521	0.3704	11.452	0.10971	0.691	1	0.638	2	0.743	NA	0.466	1
L2	102.4394	5.87865	1	Normal	225.84	0.09	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.288	2
L3	102.3312	5.87865	1	Normal	259.25	0.11	0.5187	0.4099	8.039	0.12378	0.108	3	0.283	3	1.000	NA	0.245	3
L1	102.4935	5.82483	2	Dry	105.62	0.03	2.9521	0.3704	11.452	0.10971	0.691	1	0.644	2	0.604	NA	0.476	1
L2	102.4394	5.87865	2	Dry	107.06	0.03	0.5751	0.2319	7.669	0.106	0.200	2	0.990	1	0.000	1	0.285	2
L3	102.3312	5.87865	2	Dry	120.11	0.04	0.5187	0.4099	8.039	0.12378	0.108	3	0.282	3	1.000	NA	0.239	3
L1	102.4935	5.82483	3	Dry	89.12	0.02	2.9521	0.3704	11.452	0.10971	0.691	1	0.648	2	0.684	NA	0.475	1
L2	102.4394	5.87865	3	Dry	85.23	0.02	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.288	2
L3	102.3312	5.87865	3	Dry	93.07	0.03	0.5187	0.4099	8.039	0.12378	0.108	3	0.279	3	1.000	NA	0.237	3

Appendix I10

Case Study 1: Details Calculation for RCP 8.5 2040-2069

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.4935	5.82483	11	Normal	460.59	0.21	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.666	NA	0.467	1
L2	102.4394	5.87865	11	Normal	461.46	0.21	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.277	2
L3	102.3312	5.87865	11	Normal	465.61	0.21	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.256	3
L1	102.4935	5.82483	12	Normal	465.41	0.21	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.717	NA	0.467	1
L2	102.4394	5.87865	12	Normal	454.34	0.21	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.279	2
L3	102.3312	5.87865	12	Normal	468.78	0.22	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.253	3
L1	102.4935	5.82483	1	Normal	229.65	0.09	2.9521	0.3704	11.452	0.10971	0.691	1	0.640	2	0.651	NA	0.470	1
L2	102.4394	5.87865	1	Normal	224.32	0.09	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.282	2
L3	102.3312	5.87865	1	Normal	247.4	0.1	0.5187	0.4099	8.039	0.12378	0.108	3	0.284	3	1.000	NA	0.248	3
L1	102.4935	5.82483	2	Dry	110.4	0.03	2.9521	0.3704	11.452	0.10971	0.691	1	0.644	2	0.643	NA	0.475	1
L2	102.4394	5.87865	2	Dry	107.92	0.03	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.286	2
L3	102.3312	5.87865	2	Dry	122.41	0.04	0.5187	0.4099	8.039	0.12378	0.108	3	0.282	3	1.000	NA	0.239	3
L1	102.4935	5.82483	3	Dry	77.3	0.02	2.9521	0.3704	11.452	0.10971	0.691	1	0.639	2	0.700	NA	0.468	1
L2	102.4394	5.87865	3	Dry	77.28	0.02	0.5751	0.2319	7.669	0.106	0.200	2	0.992	1	0.000	1	0.278	2
L3	102.3312	5.87865	3	Dry	80.07	0.02	0.5187	0.4099	8.039	0.12378	0.108	3	0.285	3	1.000	NA	0.255	3

Appendix J1

Case Study 2- Details Results Analysis for RCPs (2010-2039)

a. Weightage and Ranking for RCP 2.6, November- March, 2010-2039

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L1	**Nov.**	0.691	1	0.134	3	0.788	2	NA	0.303
L2		0.200	2	0.146	2	1.000	3	NA	0.311
L3		0.108	3	1.000	1	0.000	1	1	0.386
L1	**Dec.**	0.691	1	0.156	2	0.101	1	1	0.309
L2		0.200	2	0.146	3	1.000	3	NA	0.312
L3		0.108	3	0.899	1	0.500	2	1	0.379
L1	**Jan.**	0.691	1	0.139	3	0.664	2	NA	0.305
L2		0.200	2	0.146	2	1.000	3	NA	0.313
L3		0.108	3	0.937	1	0.000	1	1	0.381
L1	**Feb.**	0.691	1	0.144	3	0.325	1	1	0.305
L2		0.200	2	0.149	2	1.000	3	NA	0.315
L3		0.108	3	0.921	1	0.500	2	1	0.380
L1	**Mar.**	0.691	1	0.573	1	0.102	1	1	0.245

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L2		0.200	2	0.095	3	1.000	3	NA	0.434
L3		0.108	3	0.448	2	0.500	2	1	0.412

Wt.: Weightage; Rk: Rank

Weightage and Ranking for RCP 4.5, November- March, 2010-2039

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L1	**Nov.**	0.108	3	0.913	1	0.500	2	1	0.378
L2		0.691	1	0.119	3	1.000	3	NA	0.290
L3		0.200	2	0.174	2	0.923	2	NA	0.314
L1	**Dec.**	0.108	3	1.000	1	0.000	1	1	0.396
L2		0.691	1	0.126	3	0.772	2	NA	0.303
L3		0.200	2	0.146	2	1.000	3	NA	0.314
L1	**Jan.**	0.108	3	0.980	1	0.000	1	1	0.383
L2		0.691	1	0.117	3	1.000	3	NA	0.286
L3		0.200	2	0.262	2	0.871	2	NA	0.321
L1	**Feb.**	0.108	3	1.000	1	0.000	1	1	0.393

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L2		0.691	1	0.419	2	0.106	1	1	0.349
L3		0.200	2	0.140	3	1.000	3	NA	0.294
L1	**Mar.**	0.108	3	0.605	1	0.050	2	1	0.357
L2		0.108	3	0.913	1	0.500	2	1	0.378
L3		0.691	1	0.119	3	1.000	3	NA	0.290

Wt.: Weightage; Rk: Rank

Weightage and Ranking for RCP 6.0, November- March, 2010-2039

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L1	**Nov.**	0.691	1	0.122	3	1.000	3	NA	0.297
L2		0.200	2	0.163	2	0.793	2	NA	0.318
L3		0.108	3	0.982	1	0.000	1	1	0.385
L1	**Dec.**	0.691	1	0.118	3	1.000	3	NA	0.291
L2		0.200	2	0.159	2	0.958	2	NA	0.311
L3		0.108	3	1.000	1	0.000	1	1	0.398
L1	**Jan.**	0.691	1	0.217	2	0.102	1	1	0.315

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L2		0.200	2	0.144	3	1.000	3	NA	0.309
L3		0.108	3	0.819	1	0.500	2	NA	0.376
L1	**Feb.**	0.691	1	0.265	2	0.113	1	1	0.321
L2		0.200	2	0.150	3	1.000	3	NA	0.308
L3		0.108	3	0.765	1	0.500	2	1	0.372
L1	**Mar.**	0.691	1	0.120	3	0.974	2	NA	0.230
L2		0.200	2	0.144	2	1.000	3	NA	0.244
L3		0.108	3	1.000	1	0.000	1	1	0.326

Wt.: Weightage; Rk: Rank

Weightage and Ranking for RCP 8.5, November- March, 2010-2039

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L1	**Nov.**	0.691	1	0.122	3	1.000	3	NA	0.298
L2		0.200	2	0.159	2	0.821	2	NA	0.317
L3		0.108	3	1.000	1	0.000	1	1	0.385
L1	**Dec.**	0.691	1	0.160	2	0.157	1	1	0.308

Location	**Month**	**AHP**		**TOPSIS**		**VIKOR**		**WSM**	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L2		0.200	2	0.156	3	1.000	3	NA	0.315
L3		0.108	3	0.893	1	0.500	2	1	0.377
L1	**Jan.**	0.691	1	0.124	3	0.943	2	NA	0.296
L2		0.200	2	0.143	2	1.000	3	NA	0.306
L3		0.108	3	1.000	1	0.000	1	1	0.398
L1	**Feb.**	0.691	1	0.163	2	0.808	2	NA	0.305
L2		0.200	2	0.145	3	1.000	3	NA	0.310
L3		0.108	3	0.972	1	0.000	1	1	0.384
L1	**Mar.**	0.691	1	0.199	2	0.285	1	1	0.311
L2		0.200	2	0.145	3	1.000	3	NA	0.311
L3		0.108	3	0.841	1	0.500	2	1	0.378

Wt.: Weightage; Rk: Rank

Appendix J2

Case Study 2 – Details Results Analysis for RCPs (2040-2069)

b. Weightage and Ranking for RCP 2.6, November- March, 2040-2069

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L1	**Nov.**	0.691	1	0.132	3	0.132	1	0.305	3
L2		0.200	2	0.146	2	0.146	NA	0.314	2
L3		0.108	3	0.947	1	0.947	1	0.381	1
L1	**Dec.**	0.691	1	0.133	3	0.123	1	0.305	3
L2		0.200	2	0.146	2	1.000	NA	0.313	2
L3		0.108	3	0.950	1	0.500	1	0.381	1
L1	**Jan.**	0.691	1	0.159	2	0.105	1	0.309	3
L2		0.200	2	0.146	3	1.000	NA	0.312	2
L3		0.108	3	0.894	1	0.500	1	0.379	1
L1	**Feb.**	0.691	1	0.299	2	0.108	1	0.324	2
L2		0.200	2	0.138	3	1.000	NA	0.304	3
L3		0.108	3	0.730	1	0.500	1	0.372	1
L1	**Mar.**	0.691	1	0.130	3	0.336	1	0.304	3

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L2		0.200	2	0.148	2	1.000	NA	0.315	2
L3		0.108	3	0.954	1	0.500	1	0.381	1

Wt.: Weightage; Rk: Rank

Weightage and Ranking for RCP 4.5, November- March, 2040-2069

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L1	**Nov.**	0.691	1	0.127	3	0.815	NA	0.303	3
L2		0.200	2	0.146	2	1.000	NA	0.314	2
L3		0.108	3	0.996	1	0.000	1	0.383	1
L1	**Dec.**	0.691	1	0.131	3	0.751	NA	0.304	3
L2		0.200	2	0.146	2	1.000	NA	0.312	2
L3		0.108	3	0.999	1	0.000	1	0.384	1
L1	**Jan.**	0.691	1	0.154	2	0.103	1	0.309	3
L2		0.200	2	0.146	3	1.000	NA	0.312	2
L3		0.108	3	0.903	1	0.500	1	0.379	1
L1	**Feb.**	0.691	1	0.127	3	0.284	1	0.304	3

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L2		0.200	2	0.146	2	1.000	NA	0.314	2
L3		0.108	3	0.963	1	0.500	1	0.382	1
L1	**Mar.**	0.691	1	0.133	3	0.297	1	0.304	3
L2		0.200	2	0.147	2	1.000	NA	0.314	2
L3		0.108	3	0.945	1	0.500	1	0.381	1

Wt.: Weightage; Rk: Rank

Weightage and Ranking for RCP 6.0, November- March, 2040-2069

Location	Month	AHP		TOPSIS		VIKOR		WSM	
		Wt.	Rk.	Wt.	Rk.	Wt.	Rk.	Wt.	Rk.
L1	**Nov.**	0.691	1	0.123	3	0.976	NA	0.301	3
L2		0.200	2	0.146	2	1	NA	0.315	2
L3		0.108	3	1	1	0	1	0.384	1
L1	**Dec.**	0.691	1	0.125	3	0.854	NA	0.302	3
L2		0.200	2	0.146	2	1.000	NA	0.314	2
L3		0.108	3	1.000	1	0.000	1	0.384	1
L1	**Jan.**	0.691	1	0.224	2	0.131	1	0.314	2

Location	**Month**	**AHP**		**TOPSIS**		**VIKOR**		**WSM**	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L2		0.200	2	0.165	3	1.000	NA	0.313	3
L3		0.108	3	0.810	1	0.500	1	0.373	1
L1	**Feb.**	0.691	1	0.134	3	0.520	NA	0.305	3
L2		0.200	2	0.146	2	1.000	NA	0.314	2
L3		0.108	3	0.944	1	0.000	1	0.382	1
L1	**Mar.**	0.691	1	0.127	3	0.815	NA	0.303	3
L2		0.200	2	0.146	2	1.000	NA	0.314	2
L3		0.108	3	0.995	1	0.000	1	0.383	1

Wt.: Weightage; Rk: Rank

Weightage and Ranking for RCP 8.5, November- March, 2040-2069

Location	**Month**	**AHP**		**TOPSIS**		**VIKOR**		**WSM**	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L1	**Nov.**	0.691	1	0.122	3	0.979	NA	0.300	3
L2		0.200	2	0.146	2	1.000	NA	0.313	2
L3		0.108	3	1.000	1	0.000	1	0.387	1
L1	**Dec.**	0.691	1	0.124	3	0.783	NA	0.303	3

Location	**Month**	**AHP**		**TOPSIS**		**VIKOR**		**WSM**	
		Wt.	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**	**Wt.**	**Rk.**
L2		0.200	2	0.146	2	1.000	NA	0.315	2
L3		0.108	3	0.991	1	0.000	1	0.383	1
L1	**Jan.**	0.691	1	0.166	2	0.109	1	0.310	3
L2		0.200	2	0.147	3	1.000	NA	0.312	2
L3		0.108	3	0.884	1	0.500	1	0.378	1
L1	**Feb.**	0.691	1	0.249	2	0.101	1	0.318	2
L2		0.200	2	0.142	3	1.000	NA	0.307	3
L3		0.108	3	0.782	1	0.500	1	0.374	1
L1	**Mar.**	0.691	1	0.127	3	0.834	NA	0.303	3
L2		0.200	2	0.146	2	1.000	NA	0.314	2
L3		0.108	3	1.000	1	0.000	1	0.384	1

Wt.: Weightage; Rk: Rank

Appendix J3

Case Study 2: Details Calculation for RCP 2.6 2010-2039

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.2229	5.93247	11	Wet	529.69	0.2	2.5986	0.4569	14.643	0.14615	0.691	1	0.134	3	0.788	NA	0.303	3
L2	102.2229	5.87865	11	Wet	549.6	0.21	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.311	2
L3	102.2229	5.82483	11	Wet	519.37	0.2	0.762	0.418	6.844	0.07982	0.108	3	1.000	1	0.000	1	0.386	1
L1	102.2229	5.93247	12	Wet	603.42	0.23	2.5986	0.4569	14.643	0.14615	0.691	1	0.156	2	0.101	1	0.309	3
L2	102.2229	5.87865	12	Wet	644.92	0.25	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	3	1.000	NA	0.312	2
L3	102.2229	5.82483	12	Wet	652.29	0.25	0.762	0.418	6.844	0.07982	0.108	3	0.899	1	0.500	1	0.379	1
L1	102.2229	5.93247	1	Normal	276.93	0.11	2.5986	0.4569	14.643	0.14615	0.691	1	0.139	3	0.664	NA	0.305	3
L2	102.2229	5.87865	1	Normal	298.98	0.11	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.313	2
L3	102.2229	5.82483	1	Normal	296.54	0.11	0.762	0.418	6.844	0.07982	0.108	3	0.937	1	0.000	1	0.381	1
L1	102.2229	5.93247	2	Normal	106.15	0.04	2.5986	0.4569	14.643	0.14615	0.691	1	0.144	3	0.325	1	0.305	3
L2	102.2229	5.87865	2	Normal	111.82	0.04	3.1843	0.4757	10.921	0.12059	0.200	2	0.149	2	1.000	NA	0.315	2
L3	102.2229	5.82483	2	Normal	115.76	0.04	0.762	0.418	6.844	0.07982	0.108	3	0.921	1	0.500	1	0.380	1
L1	102.2229	5.93247	3	Dry	12.27	0.00	2.5986	0.4569	14.643	0.14615	0.691	1	0.573	1	0.102	1	0.245	3
L2	102.2229	5.87865	3	Dry	15.27	0.01	3.1843	0.4757	10.921	0.12059	0.200	2	0.095	3	1.000	NA	0.434	2
L3	102.2229	5.82483	3	Dry	15.12	0.01	0.762	0.418	6.844	0.07982	0.108	3	0.448	2	0.500	1	0.412	1

Appendix J4

Case Study 2: Details Calculation for RCP 4.5 2010-2039

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.2229	5.93247	11	Normal	434.39	0.17	2.5986	0.4569	14.643	0.14615	0.691	1	0.148	3	0.193	1	0.306	3
L2	102.2229	5.87865	11	Normal	455.27	0.17	3.1843	0.4757	10.921	0.12059	0.200	2	0.156	2	1.000	NA	0.316	2
L3	102.2229	5.82483	11	Normal	469.06	0.18	0.762	0.418	6.844	0.07982	0.108	3	0.913	1	0.500	1	0.378	1
L1	102.2229	5.93247	12	Wet	592.26	0.23	2.5986	0.4569	14.643	0.14615	0.691	1	0.119	3	1.000	NA	0.290	3
L2	102.2229	5.87865	12	Wet	551.39	0.21	3.1843	0.4757	10.921	0.12059	0.200	2	0.174	2	0.923	NA	0.314	2
L3	102.2229	5.82483	12	Normal	498.08	0.19	0.762	0.418	6.844	0.07982	0.108	3	1.000	1	0.000	1	0.396	1
L1	102.2229	5.93247	1	Normal	209.42	0.08	2.5986	0.4569	14.643	0.14615	0.691	1	0.126	3	0.772	NA	0.303	3
L2	102.2229	5.87865	1	Normal	216.92	0.08	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.314	2
L3	102.2229	5.82483	1	Normal	213.86	0.08	0.762	0.418	6.844	0.07982	0.108	3	0.980	1	0.000	1	0.383	1
L1	102.2229	5.93247	2	Normal	93.32	0.04	2.5986	0.4569	14.643	0.14615	0.691	1	0.117	3	1.000	NA	0.286	3
L2	102.2229	5.87865	2	Normal	88.92	0.03	3.1843	0.4757	10.921	0.12059	0.200	2	0.262	2	0.871	NA	0.321	2
L3	102.2229	5.82483	2	Dry	82.34	0.03	0.762	0.418	6.844	0.07982	0.108	3	1.000	1	0.000	1	0.393	1
L1	102.2229	5.93247	3	Dry	39.15	0.01	2.5986	0.4569	14.643	0.14615	0.691	1	0.419	2	0.106	1	0.349	2
L2	102.2229	5.87865	3	Dry	50.33	0.02	3.1843	0.4757	10.921	0.12059	0.200	2	0.140	3	1.000	NA	0.294	3
L3	102.2229	5.82483	3	Dry	54.53	0.02	0.762	0.418	6.844	0.07982	0.108	3	0.605	1	0.050	1	0.357	1

Appendix J5

Case Study 2: Details Calculation for RCP 6.0 2010-2039

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.2229	5.93247	11	Normal	497.95	0.19	2.5986	0.4569	14.643	0.14615	0.691	1	0.122	3	1.000	NA	0.297	3
L2	102.2229	5.87865	11	Normal	464.95	0.18	3.1843	0.4757	10.921	0.12059	0.200	2	0.163	2	0.793	NA	0.318	2
L3	102.2229	5.82483	11	Normal	473.69	0.18	0.762	0.418	6.844	0.07982	0.108	3	0.982	1	0.000	1	0.385	1
L1	102.2229	5.93247	12	Wet	576.8	0.22	2.5986	0.4569	14.643	0.14615	0.691	1	0.118	3	1.000	NA	0.291	3
L2	102.2229	5.87865	12	Wet	540.47	0.21	3.1843	0.4757	10.921	0.12059	0.200	2	0.159	2	0.958	NA	0.311	2
L3	102.2229	5.82483	12	Normal	477.69	0.18	0.762	0.418	6.844	0.07982	0.108	3	1.000	1	0.000	1	0.398	1
L1	102.2229	5.93247	1	Normal	113.86	0.04	2.5986	0.4569	14.643	0.14615	0.691	1	0.217	2	0.102	1	0.315	2
L2	102.2229	5.87865	1	Normal	120.2	0.05	3.1843	0.4757	10.921	0.12059	0.200	2	0.144	3	1.000	NA	0.309	3
L3	102.2229	5.82483	1	Normal	121.53	0.05	0.762	0.418	6.844	0.07982	0.108	3	0.819	1	0.500	3	0.376	1
L1	102.2229	5.93247	2	Dry	87.06	0.03	2.5986	0.4569	14.643	0.14615	0.691	1	0.265	2	0.113	1	0.321	2
L2	102.2229	5.87865	2	Normal	95.3	0.04	3.1843	0.4757	10.921	0.12059	0.200	2	0.150	3	1.000	NA	0.308	3
L3	102.2229	5.82483	2	Normal	101.24	0.04	0.762	0.418	6.844	0.07982	0.108	3	0.765	1	0.500	1	0.372	1
L1	102.2229	5.93247	3	Dry	8.76	0.00	2.5986	0.4569	14.643	0.14615	0.691	1	0.120	3	0.974	NA	0.230	3
L2	102.2229	5.87865	3	Dry	8.69	0.00	3.1843	0.4757	10.921	0.12059	0.200	2	0.144	2	1.000	NA	0.244	2
L3	102.2229	5.82483	3	Dry	7.04	0.00	0.762	0.418	6.844	0.07982	0.108	3	1.000	1	0.000	1	0.326	1

Appendix J6

Case Study 2: Details Calculation for RCP 8.5 2010-2039

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.2229	5.93247	11	Normal	384.53	0.15	2.5986	0.4569	14.643	0.14615	0.691	1	0.122	3	1.000	NA	0.298	3
L2	102.2229	5.87865	11	Normal	373.82	0.14	3.1843	0.4757	10.921	0.12059	0.200	2	0.159	2	0.821	NA	0.317	2
L3	102.2229	5.82483	11	Normal	372.04	0.14	0.762	0.418	6.844	0.07982	0.108	3	1.000	1	0.000	1	0.385	1
L1	102.2229	5.93247	12	Wet	593.48	0.23	2.5986	0.4569	14.643	0.14615	0.691	1	0.160	2	0.157	1	0.308	3
L2	102.2229	5.87865	12	Wet	616.03	0.24	3.1843	0.4757	10.921	0.12059	0.200	2	0.156	3	1.000	NA	0.315	2
L3	102.2229	5.82483	12	Wet	647.7	0.25	0.762	0.418	6.844	0.07982	0.108	3	0.893	1	0.500	1	0.377	1
L1	102.2229	5.93247	1	Normal	120.32	0.05	2.5986	0.4569	14.643	0.14615	0.691	1	0.124	3	0.943	NA	0.296	3
L2	102.2229	5.87865	1	Normal	124.85	0.05	3.1843	0.4757	10.921	0.12059	0.200	2	0.143	2	1.000	NA	0.306	2
L3	102.2229	5.82483	1	Normal	110.14	0.04	0.762	0.418	6.844	0.07982	0.108	3	1.000	1	0.000	1	0.398	1
L1	102.2229	5.93247	2	Dry	72.67	0.03	2.5986	0.4569	14.643	0.14615	0.691	1	0.163	2	0.808	NA	0.305	3
L2	102.2229	5.87865	2	Dry	82.41	0.03	3.1843	0.4757	10.921	0.12059	0.200	2	0.145	3	1.000	NA	0.310	2
L3	102.2229	5.82483	2	Dry	74.87	0.03	0.762	0.418	6.844	0.07982	0.108	3	0.972	1	0.000	1	0.384	1
L1	102.2229	5.93247	3	Dry	19.08	0.01	2.5986	0.4569	14.643	0.14615	0.691	1	0.199	2	0.285	1	0.311	3
L2	102.2229	5.87865	3	Dry	22.9	0.01	3.1843	0.4757	10.921	0.12059	0.200	2	0.145	3	1.000	NA	0.311	2
L3	102.2229	5.82483	3	Dry	23.24	0.01	0.762	0.418	6.844	0.07982	0.108	3	0.841	1	0.500	1	0.378	1

Appendix J7

Case Study 2: Details Calculation for RCP 2.6 2040-2069

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.2229	5.93247	11	Normal	427.17	0.19	2.5986	0.4569	14.643	0.14615	0.691	1	0.132	3	0.132	1	0.305	3
L2	102.2229	5.87865	11	Normal	437.76	0.2	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	0.146	NA	0.314	2
L3	102.2229	5.82483	11	Normal	437.73	0.2	0.762	0.418	6.844	0.07982	0.108	3	0.947	1	0.947	1	0.381	1
L1	102.2229	5.93247	12	Normal	477.05	0.22	2.5986	0.4569	14.643	0.14615	0.691	1	0.133	3	0.123	1	0.305	3
L2	102.2229	5.87865	12	Normal	495.34	0.23	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.313	2
L3	102.2229	5.82483	12	Normal	491.61	0.23	0.762	0.418	6.844	0.07982	0.108	3	0.950	1	0.500	1	0.381	1
L1	102.2229	5.93247	1	Normal	245.43	0.1	2.5986	0.4569	14.643	0.14615	0.691	1	0.159	2	0.105	1	0.309	3
L2	102.2229	5.87865	1	Normal	259.82	0.11	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	3	1.000	NA	0.312	2
L3	102.2229	5.82483	1	Normal	264.4	0.11	0.762	0.418	6.844	0.07982	0.108	3	0.894	1	0.500	1	0.379	1
L1	102.2229	5.93247	2	Dry	91.98	0.02	2.5986	0.4569	14.643	0.14615	0.691	1	0.299	2	0.108	1	0.324	2
L2	102.2229	5.87865	2	Dry	97.84	0.03	3.1843	0.4757	10.921	0.12059	0.200	2	0.138	3	1.000	NA	0.304	3
L3	102.2229	5.82483	2	Dry	97.31	0.03	0.762	0.418	6.844	0.07982	0.108	3	0.730	1	0.500	1	0.372	1
L1	102.2229	5.93247	3	Dry	63.82	0.01	2.5986	0.4569	14.643	0.14615	0.691	1	0.130	3	0.336	1	0.304	3
L2	102.2229	5.87865	3	Dry	65.45	0.01	3.1843	0.4757	10.921	0.12059	0.200	2	0.148	2	1.000	NA	0.315	2
L3	102.2229	5.82483	3	Dry	67.02	0.01	0.762	0.418	6.844	0.07982	0.108	3	0.954	1	0.500	1	0.381	1

Appendix J8

Case Study 2: Details Calculation for RCP 4.5 2040-2069

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.2229	5.93247	11	Normal	431.87	0.2	2.5986	0.4569	14.643	0.14615	0.691	1	0.127	3	0.815	NA	0.303	3
L2	102.2229	5.87865	11	Normal	447.41	0.02	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.314	2
L3	102.2229	5.82483	11	Normal	433.79	0.02	0.762	0.418	6.844	0.07982	0.108	3	0.996	1	0.000	1	0.383	1
L1	102.2229	5.93247	12	Normal	466.24	0.21	2.5986	0.4569	14.643	0.14615	0.691	1	0.131	3	0.751	NA	0.304	3
L2	102.2229	5.87865	12	Normal	477.53	0.22	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.312	2
L3	102.2229	5.82483	12	Normal	466.5	0.21	0.762	0.418	6.844	0.07982	0.108	3	0.999	1	0.000	1	0.384	1
L1	102.2229	5.93247	1	Normal	257.27	0.11	2.5986	0.4569	14.643	0.14615	0.691	1	0.154	2	0.103	1	0.309	3
L2	102.2229	5.87865	1	Normal	271.34	0.12	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	3	1.000	NA	0.312	2
L3	102.2229	5.82483	1	Normal	274.75	0.12	0.762	0.418	6.844	0.07982	0.108	3	0.903	1	0.500	1	0.379	1
L1	102.2229	5.93247	2	Dry	99.37	0.03	2.5986	0.4569	14.643	0.14615	0.691	1	0.127	3	0.284	1	0.304	3
L2	102.2229	5.87865	2	Dry	103.02	0.03	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.314	2
L3	102.2229	5.82483	2	Dry	103.29	0.03	0.762	0.418	6.844	0.07982	0.108	3	0.963	1	0.500	1	0.382	1
L1	102.2229	5.93247	3	Dry	77.49	0.02	2.5986	0.4569	14.643	0.14615	0.691	1	0.133	3	0.297	1	0.304	3
L2	102.2229	5.87865	3	Dry	81.34	0.02	3.1843	0.4757	10.921	0.12059	0.200	2	0.147	2	1.000	NA	0.314	2
L3	102.2229	5.82483	3	Dry	82.22	0.02	0.762	0.418	6.844	0.07982	0.108	3	0.945	1	0.500	1	0.381	1

Appendix J9

Case Study 2: Details Calculation for RCP 6.0 2040-2069

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.2229	5.93247	11	Normal	442.84	0.2	2.5986	0.4569	14.643	0.14615	0.691	1	0.123	3	0.976	NA	0.301	3
L2	102.2229	5.87865	11	Normal	442.24	0.2	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1	NA	0.315	2
L3	102.2229	5.82483	11	Normal	432.15	0.2	0.762	0.418	6.844	0.07982	0.108	3	1	1	0	1	0.384	1
L1	102.2229	5.93247	12	Wet	511.8	0.24	2.5986	0.4569	14.643	0.14615	0.691	1	0.125	3	0.854	NA	0.302	3
L2	102.2229	5.87865	12	Wet	524.9	0.24	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.314	2
L3	102.2229	5.82483	12	Wet	507.8	0.24	0.762	0.418	6.844	0.07982	0.108	3	1.000	1	0.000	1	0.384	1
L1	102.2229	5.93247	1	Normal	237.48	0.1	2.5986	0.4569	14.643	0.14615	0.691	1	0.224	2	0.131	1	0.314	2
L2	102.2229	5.87865	1	Normal	267.27	0.11	3.1843	0.4757	10.921	0.12059	0.200	2	0.165	3	1.000	NA	0.313	3
L3	102.2229	5.82483	1	Normal	276.79	0.12	0.762	0.418	6.844	0.07982	0.108	3	0.810	1	0.500	1	0.373	1
L1	102.2229	5.93247	2	Dry	113.8	0.04	2.5986	0.4569	14.643	0.14615	0.691	1	0.134	3	0.520	NA	0.305	3
L2	102.2229	5.87865	2	Dry	120.85	0.04	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.314	2
L3	102.2229	5.82483	2	Dry	120.47	0.04	0.762	0.418	6.844	0.07982	0.108	3	0.944	1	0.000	1	0.382	1
L1	102.2229	5.93247	3	Dry	87.93	0.02	2.5986	0.4569	14.643	0.14615	0.691	1	0.127	3	0.815	NA	0.303	3
L2	102.2229	5.87865	3	Dry	91.17	0.02	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.314	2
L3	102.2229	5.82483	3	Dry	88.35	0.02	0.762	0.418	6.844	0.07982	0.108	3	0.995	1	0.000	1	0.383	1

Appendix J10

Case Study 2: Details Calculation for RCP 8.5 2040-2069

GRID ID	LONGITUDE	LATITUDE	MONTH	RVI STATUS	RAINFALL VOLUME	RAINFALL RISK SCORE	AREA SIZE (URBAN)	LANDUSE RISK SCORE	DISTANCE TO HOSPITAL	ACCESS TO FACILITY RISK SCORE	AHP WEIGHTAGE	AHP RANK	TOPSIS WEIGHTAGE	TOPSIS RANK	VIKOR WEIGHTAGE	VIKOR RANK	WSM WEIGHTAGE	WSM RANK
L1	102.2229	5.93247	11	Normal	455.46	0.21	2.5986	0.4569	14.643	0.14615	0.691	1	0.122	3	0.979	NA	0.300	3
L2	102.2229	5.87865	11	Normal	454.71	0.21	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.313	2
L3	102.2229	5.82483	11	Normal	433.62	0.2	0.762	0.418	6.844	0.07982	0.108	3	1.000	1	0.000	1	0.387	1
L1	102.2229	5.93247	12	Normal	454.59	0.21	2.5986	0.4569	14.643	0.14615	0.691	1	0.124	3	0.783	NA	0.303	3
L2	102.2229	5.87865	12	Normal	462.64	0.21	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.315	2
L3	102.2229	5.82483	12	Normal	458.65	0.21	0.762	0.418	6.844	0.07982	0.108	3	0.991	1	0.000	1	0.383	1
L1	102.2229	5.93247	1	Normal	231.06	0.09	2.5986	0.4569	14.643	0.14615	0.691	1	0.166	2	0.109	1	0.310	3
L2	102.2229	5.87865	1	Normal	244.11	0.1	3.1843	0.4757	10.921	0.12059	0.200	2	0.147	3	1.000	NA	0.312	2
L3	102.2229	5.82483	1	Normal	250.8	0.1	0.762	0.418	6.844	0.07982	0.108	3	0.884	1	0.500	1	0.378	1
L1	102.2229	5.93247	2	Dry	111.72	0.03	2.5986	0.4569	14.643	0.14615	0.691	1	0.249	2	0.101	1	0.318	2
L2	102.2229	5.87865	2	Dry	119.28	0.04	3.1843	0.4757	10.921	0.12059	0.200	2	0.142	3	1.000	NA	0.307	3
L3	102.2229	5.82483	2	Dry	120.49	0.04	0.762	0.418	6.844	0.07982	0.108	3	0.782	1	0.500	1	0.374	1
L1	102.2229	5.93247	3	Dry	74.74	0.02	2.5986	0.4569	14.643	0.14615	0.691	1	0.127	3	0.834	NA	0.303	3
L2	102.2229	5.87865	3	Dry	77.48	0.02	3.1843	0.4757	10.921	0.12059	0.200	2	0.146	2	1.000	NA	0.314	2
L3	102.2229	5.82483	3	Dry	74.49	0.02	0.762	0.418	6.844	0.07982	0.108	3	1.000	1	0.000	1	0.384	1