FLOOD RISK MAPPING USING AHP METHOD: A CASE STUDY FOR MERU, KLANG

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ABSTRAK

Malaysia lazimnya disertai dengan banjir tahunan yang disebabkan oleh monsun bermusim, mengakibatkan kerugian yang besar. Risiko banjir, pendedahan dan kerosakan banjir semakin meningkat, meningkatkan kemiskinan dan kelemahan. Kejadian bahaya banjir tahunan telah memaksa penduduk untuk merancang lebih awal untuk kembali ke kehidupan normal mereka secepat mungkin. Kajian ini tertumpu kepada kejadian banjir di Meru yang berlaku pada bulan Disember 2021, di mana jalan di Meru telah ditenggelami air akibat taburan hujan tanpa henti sekitar 15 jam, menyebabkan banyak kawasan di Klang ditenggelami air setinggi pinggang. Risiko banjir dibangunkan di peringkat wilayah dan pentadbiran menggunakan analisis membuat keputusan berbilang kriteria (MCDM) - proses hierarki analisis (AHP). Kriteria tersebut mencirikan pertimbangan yang relevan di Meru, Klang, termasuk kecerunan, ketinggian, dan aspek, penampan dari sungai, jalan, dan hutan, dan jenis guna tanah. Kajian ini bertujuan untuk menentukan kriteria risiko banjir di Meru, Klang, Selangor dan menganalisis MCDM-AHP berdasarkan kriteria kritikal yang ditentukan daripada literatur. Penyeragaman, kerja pakar, pemberat, analisis ringkasan, pengagregatan dan pengesahan semua kriteria membuat keputusan yang perlu dipertimbangkan adalah sebahagian daripada fasa ini. Guna tanah kediaman dan perindustrian, penampan dari jalan raya, dan penampan dari sungai semuanya memainkan peranan penting dalam kejadian banjir di kawasan kajian, dengan nilai berat faktor terpilih masing-masing 0.367, 0.090, dan 0.081. Penemuan kajian semasa akan menyokong perancang dalam membangunkan strategi tebatan banjir dan akan menjadi asas untuk penyelidikan masa depan di kawasan kajian sebagai sebahagian daripada persediaan banjir.

ABSTRACT

Malaysia is typically accompanied by annual flooding caused by the seasonal monsoon, resulting in significant losses. Flood risk, exposure, and flood damage are rising, increasing poverty and vulnerability. The annual occurrence of the flood hazard has compelled residents to plan ahead of time in order to return to their normal lives as quickly as possible. This study focused on the flood event in Meru that occur during December 2021, where the road on Meru has become inundated as a result of around 15 hours of nonstop rainfall, leading many areas of Klang to become inundated with waist-high water. Flood risk is developed at the regional and administrative levels using a multi-criteria decision-making analysis (MCDM) - analytical hierarchy process (AHP). The criteria characterize the relevant considerations of Meru, Klang, including slope, elevation, and aspect, buffer from river, road, and forest, and type of land use. This study aimed to determine the criteria of flood risk in Meru, Klang, Selangor and to analyze of MCDM-AHP based on critical criteria determined from literature. Standardization, expert work, weighting, summary analysis, aggregation, and validation of all decision-making criteria to be considered are all part of this phase. Residential and industrial land uses, buffers from roads, and buffers from rivers all played a significant role in flood incidence in the study area, with selected factor weight values of 0.367, 0.090, and 0.081, respectively. The current study's findings will support planners in developing flood mitigation strategies and will serve as a foundation for future research in the study area as part of flood preparedness.

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LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
ANP	Analytical Network Analysis
CI	Consistency Index
CR	Consistency Ratio
DEM	Digital Elevation Model
FVI	Flood Vulnerability Index
GHG	Greenhouse Gas
GISs	Geographic Information Systems
LiDAR	Light Detection and Ranging
MAUT	Multi-Attribute Utility Theory
MAVT	Multi-Attribute Value Theory
MCDM	Multiple-Criteria Decision-Making
MPK	Klang Municipal Council’s
PFF	Pluvial Flash Flood
RI	Random Index
STRM	Shuttle Radar Topography Mission
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
USGS	United States Geological Survey

CHAPTER 1

INTRODUCTION

1.1 Background

Floods have impacted negatively on several parts of Malaysia during the last 50 years. Floods are one of the most common natural disasters that devastate this country, occurring practically every year, especially during the monsoon season. Aside from the monsoon season, Malaysia has been subjected to a variety of extreme meteorological and climatic events over the course of the last several decades. These natural catastrophes resulted in a considerable amount of damage to our country, including a large number of fatalities, significant amounts of property damage, and other intangible losses (Weng Chan, 2012). It is also causing extensive damage and devastation to property, public infrastructure, and the environment, resulting in substantial financial losses for governments. In addition to damage expenses, flooding results in lost productivity, and fewer working hours as a result of the need to divert resources away from daily operations and onto recovery efforts. The stress of overcoming these losses can be tremendous and have long-term psychological consequences. Flooding has extensive and significant health consequences, both in the short and long term, ranging from drowning and injuries to infectious diseases and mental-health issues, among other things (Ardian Xinxo, 2013).

Common primary causes of flooding are high rainfall caused by tropical weather disturbances, deforestation, poor design of drainages and infrastructure, and lack of maintenance of drainages that were clogged by flood-borne debris (Super User, 2022). Drainage systems, rivers, and streams are all subject to flooding, which is a natural occurrence. Extreme weather conditions cause drainage channels to become overflowing, and rivers and streams become unable to handle the additional water generated as a result of these conditions. As an outcome, the drainage canals overflow their natural or man-made banks, causing floods in the adjacent fields. The risk of floods can also increase due to human actions that harm the environment, such as sand mining, deforestation, improper rubbish disposal, etc. The topography of a location can also increases the risk of flooding. The risk of flood events is especially high in urban and riverine areas.

According to Zurich (2022), there are several types of flooding that can give a significant impact which are fluvial floods (river floods), pluvial floods (flash floods and surface water), and coastal flood (storm surge). Hydrologically, fluvial floods or river floods are defined by a river's water level or discharge. Fluvial flood hazard is characterized by the likelihood and intensity of rapid river flows and ensuing flooding, and it is influenced by the physical mechanisms underlying flood formation. (Merz *et al.*, 2010). Fluvial flood risk mitigation has focused on river training, embankment construction, and reservoir retention. As the overflow of a river affects smaller rivers downstream, it can cause dams and dikes to fail and inundate neighboring areas, causing extensive damage. The topography profile and duration and intensity (volume) of rainfall in the river's catchment area determine the severity of a river flood. Other considerations include soil water saturation and the effects of climate change on the duration and intensity of rainfall. In low-lying locations, floodwaters rise more slowly and are typically shallower, yet they frequently persist for days. In hilly or mountainous regions, flooding can start within minutes of a heavy rain, drain rapidly, and inflict damage owing to debris flow (Zurich, 2022).

Pluvial flash flood (PFF) is one of the most frequent and destructive natural hazards. It can cause substantial direct losses such as personal injury and damage to property and rising indirect impacts such as disruption of public infrastructure and financial activities), particularly in the urbanized regions of the world (Yin *et al.*, 2016). Jamali et.al (2018) mention urban pluvial flooding is typically caused by inadequate drainage capacity. This occurs during high-intensity rains, when the subsurface drainage network becomes pressured and the water level increases above-ground, causing overflow in manholes or sewer inlets. The surcharged flow spreads throughout the surface flow network, also known as "major systems," which typically consists of highways, walkways, ground depressions, and minor water courses.

Coastal flooding is the submersion of coastal land areas by seawater. The most common causes of coastal flooding are intense windstorms that coincide with high tide (storm surge) and tsunamis. This is the major cause of coastal flooding and the greatest threat linked with a hurricane or typhoon, as storm surge is produced when high winds from a heavy storm force water onshore. The effects increase as the tide rises; windstorms that occur during high tide can cause catastrophic storm surge flooding (Zurich, 2022). More than 1.2 billion people live within 100 kilometers of the coast and less than 100 meters above sea level, an area that will be impacted by global sea level rise. It is estimated that 5 million people and 2 million properties are at risk of flooding in England and Wales alone, the majority of which are located in coastal floodplains (Purvis, Bates, and Hayes, 2008).

Geographic information systems (GISs) has become an essential tool in hydrological modeling studies. ArcGIS is one of leading GIS software’s that use to analyses data, produce maps and to share the data to other and act as cloud-based mapping and analysis software. It been widely use in other country as well as Malaysia. Most of the studies involved identification of flood-prone area using digital terrain modelling and terrain-derived geomorphological and hydrological attributes. Numerous methods primarily consider a spatial multi-criteria decision analysis framework (MCDM). Thus, in this study, Analytical Hierarchy Process (AHP) was chosen to complete this analysis. AHP is a measurement technique based on pairwise comparisons and expert opinions to produce priority scales. It has been one of the most extensively utilized methods for making multiple criteria decisions and because of a simple and powerful tool, it is employed by decision makers and researchers (Russo & Camanho, 2015). The MCDM method is applicable for flood analysis and mapping in data-deficient locations and could be utilized by local flood mitigation planners. Therefore, flood susceptibility study is a crucial responsibility for early warning systems and emergency services in the development of management strategies for preventing and mitigating future flood events (Samanta, Pal and Palsamanta, 2018).

1.2 Problem Statement

Malaysians are alarmed about the sudden flooding in Meru, Klang, which resulted in huge losses for all people and resulted from ineffective flood management. To address the issue, a flood risk map will be prepared that would enable locals of Meru, Klang to better plan for flood management.

Meru is a town in Klang district of Selangor. Meru is the home for Top Glove, the nation's largest latex glove production as well as various small to medium industrial complexes (Propsocial, 2014). In December 2021, Jalan Meru was flooded due to non-stop rain that begin since December 17, where many parts of Klang become flooded with waist-high waters in some of their areas (The Star Online, 2021).

On 18 December 2021, Meru experienced a non-stop rain event for about 15 hours that has caused the road to become flooded. The rain started on 17 December which causing many parts of Klang to become flooded with waist-high waters in some areas. The Star newspaper said over 1000 people were effected due to the prolonged rain and flooding while 1011 people had to be evacuated because of the floods. In the news, some of the residents say the last time Klang was this badly flooded was nearly 50 years ago, when water overflowed into residential neighborhoods from rivers, drains, and retention ponds. At all entry points into Klang, which were also flooded, there was heavy traffic and stalled vehicles. Several areas experienced a power outage due the heavy downpour.

1.3 Objectives

The objectives of this study are stated below:

I. To determine the criteria of flood risk in Meru, Klang, Selangor.

II. To analyze of MCDM based on critical criteria determined from literature.

III. To analyze GIS and establish a flood risk map of Meru, Klang, Selangor.

1.4 Scope of Works

In this project, an analysis was run to obtain the most critical criteria that caused the flood in specific area which located in Meru, Klang. The DEM data were be obtained from the USGS website. The interview to experts were conducted to obtain the result of critical criteria. Several questions were asked during the interview to get precise result to be discussed.

The outcome of the interview then being analyzes in the MCDM software to determine the criteria weights. From the criteria weights, rating of classified thematic layers was produced. The study can be used to help locals to prepared before worsening conditions occurred. A detailed map of flood inundation would require additional study and research on this topic.

1.5 Expected Outcomes

The expected outcome of this study is to determine and analyze the critical criteria of flood risk in Meru, Klang, Selangor. The critical criteria can be utilized to assist decision-makers in establishing and prioritizing the necessary management to improved local preparedness.

1.6 Dissertation

This dissertation consists of five chapter. Chapter 1 is an introduction that includes the background of study, problem statements, objectives, scope of works and expected outcomes.

Chapter 2 is devoted to literature, in which author's papers are used to provide additional information on the research.

The research methodology of Chapter 3 outlines the techniques that were used in the study to achieve the objectives, and a flow chart was created to make it easier to comprehend.

The results and discussion are presented in Chapter 4. This chapter contains the study's findings, as well as discussion and recommendations regarding the study.

Finally, in Chapter 5, the research will be ended, and all of the topics mentioned in the preceding chapters will be summarized, as well as conclusions drawn from the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, there is an involvement of various flood-related aspects. The chapter elaborate the software used and the analysis needed for these studies. The chapter includes explanation of the Geographic Information System (GIS), Multiple-Choice Decision-Making Analysis (MCDM), urban flood management, and the flood management in Malaysia. Geographic information systems (GIS) have become an important and valuable tool in hydrology and hydrologists. Climate change and increased demands on water supplies necessitate a more educated approach to one of our most critical resources. By combining GIS technology with hydrologic data, it is feasible to elucidate the effects of land-use and land-cover changes at the watershed scale. Multi-criteria decision-making analysis (MCDM) has been recognized as an important tool for analyzing complex decision problems. MCDM methods could be employed to integrate technical, environmental, and socio-economic objectives to achieve an optimal decision. The main advantage of using the GIS-based AHP by the pairwise comparison method was the possibility of obtaining a reliable hazard map that was more flexible and easier to update.

2.2 Geographic Information System (GIS)

Roger Tomlinson's work in Canada in the 1960s led to the development of the Geographic Information System (GIS), which has since been utilized extensively around the globe. GIS is regarded as an indispensable tool for spatial analysis and has been widely applied to natural hazard risk assessment. In numerous local-scale studies conducted in recent years, flood risk assessment and GIS have been integrated. Spatial flood risk assessments are valuable instruments for identifying.

The implementation of geographic information system (GIS) in flood risk mapping and in-depth research of pre-disaster conditions is widely regarded as the most essential method for conducting risk assessments and comprehending flood mitigation measures for cultural assets (Kittipongvises et al., 2020). According to Naidu D. (2015), geographic information systems (GISs) have become an important and valuable tool in hydrology and hydrologists in the scientific research and management of water resources. Climate change and increased demands on water supplies necessitate a more educated approach to one of our most critical resources. Previously, the geospatial representation of hydrologic features in GIS systems was essentially static but these days, GIS platforms are becoming more dynamic, closing the gap between historical data and present hydrologic realities. Other hydrologic data (such as evapotranspiration, infiltration, and groundwater) can be treated similarly to precipitation data using GIS.

Precipitation is a spatial event that is measured using point locations. The challenging aspect of using point data is extending point readings to areas. Thiessen polygons, which evaluate the distance and geometry of points on a plane and identify typical areas for which to give precipitation values, are a valuable technique for extrapolating data. GIS applications such as ArcGIS are able to generate Thiessen polygons, and other techniques for estimating area precipitation are also possible with GIS. By combining GIS technology with hydrologic data, it is becoming feasible to elucidate the effects of land-use and land-cover changes at the watershed scale (Naidu, 2015).

2.3 Multiple-Choice Decision-Making Analysis

Multi-criteria decision-making analysis (MCDM) has been recognized as an important tool for analyzing complex decision problems, which often involve incommensurable data or criteria (Malczewski 2006). MCDM methods could be employed to integrate technical, environmental, and socio-economic objectives to achieve an optimal decision (Ghanbarpour et al. 2013). The use of MCDM techniques may be dictated by the problem's aim and complexity. MCDM technique selection should consider factors such as the type of problem, decision goal, data volume, number of criteria, convenience of use, consistency, and type of analysis (Abdullah, Siraj and Hodgett, 2021). MCDM is a non-linear recursive procedure with four steps: organizing the decision problem, expressing, and modelling preferences, aggregating alternative assessments (preferences), and providing recommendations (Guitouni and Martel, 1997). A few MCDM methods can be used to make an analysis: Analytical Hierarchy Analysis, Multi-Attribute Utility Theory (MAUT), Analytical Network Analysis, and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). Figure 2.1 shown the MCDM Taxonomy adapted from Riberio et al. (2011) (Harputlugil, 2018) showing the method available to be used for any MCDM models.

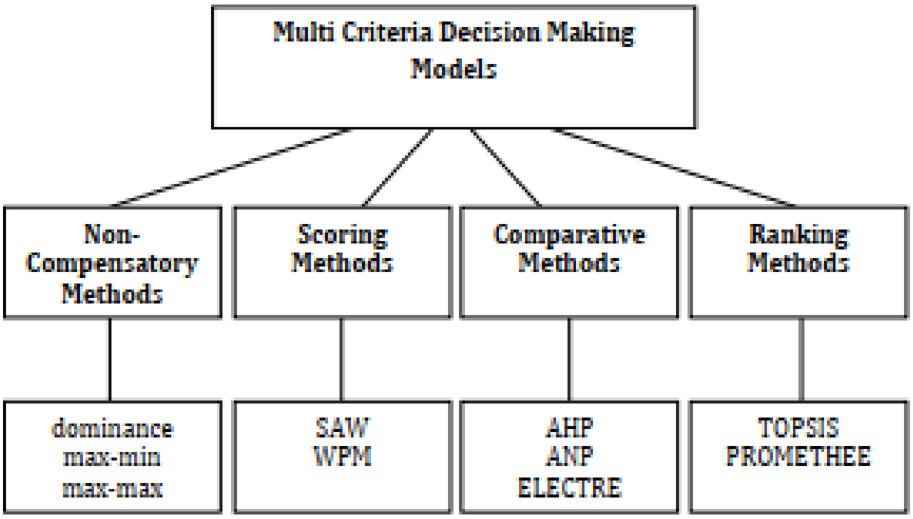


Figure 2.1: MCDM Taxonomy adapted from Riberio et al. (2011) (Harputlugil, 2018)

2.3.1 Analytical Hierarchy Process Analysis

The Analytic Hierarchy Process (AHP) is a method of “measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales”. (Russo and Camanho, 2015). The main advantage of using the GIS-based AHP by the pairwise comparison method was the possibility of obtaining a reliable hazard map that was more flexible and that was easier to update (Kittipongvises et al., 2020). Thomas L. Saaty created this strategy in order to provide a systematic way to describe priorities and facilitate complex decision making. Figure 2.2 shows the methodology flowchart for the AHP. In fact, the AHP methodology's hierarchical structure is capable of measuring and synthetizing a variety of factors of a complicated decision-making process in a hierarchical manner, making it simple to assemble the parts in a whole (Russo and Camanho, 2015).

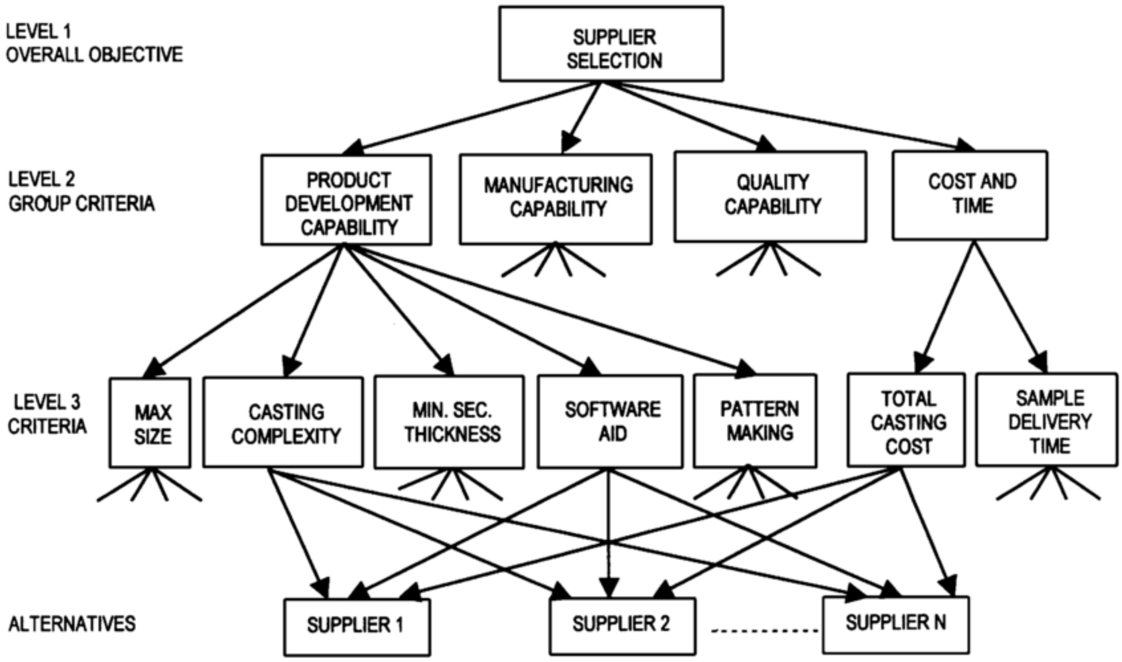


Figure 2.2*:* Analytical Hierarchy Process (AHP) flow chart example (INFORMS, 2011)

2.3.2 Multi-Attribute Utility Theory (MAUT)

MAUT is an extended version of Multi-Attribute Value Theory (MAVT) which is more rigorous methodology for incorporating risk preferences and uncertainty into multi-criteria decision support methods". MAUT was employed due to its widespread application in natural resource management issues. Their strategy centered on societal risk preferences, and they employed a survey to collect and analyze desirable characteristics. MAUT has been applied extensively to economic, financial, actuarial, water distribution, power management, and agricultural issues. All of these types of problems contain substantial amounts of uncertainty and sufficient data to make MAUT an appropriate decision-making technique. MAUT is an expected utility theory that can find the optimal solution to a problem by attributing a utility to each possible consequence and calculating the highest possible utility and their primary advantage of MAUT is that it accounts for uncertainty (Velasquez and Hester, 2013).

2.3.3 Analytical Network Analysis (ANP)

ANP is an extension of the analytic hierarchy process (AHP) that can handle interdependencies among different criteria, making it more realistic in situations where criteria are internally dependent (Hashemi, Karimi and Tavana, 2015). Modeling technique (hierarchical or network structure) and pairwise comparisons to establish relationships within the structure (Abdullah, Siraj and Hodgett, 2021).

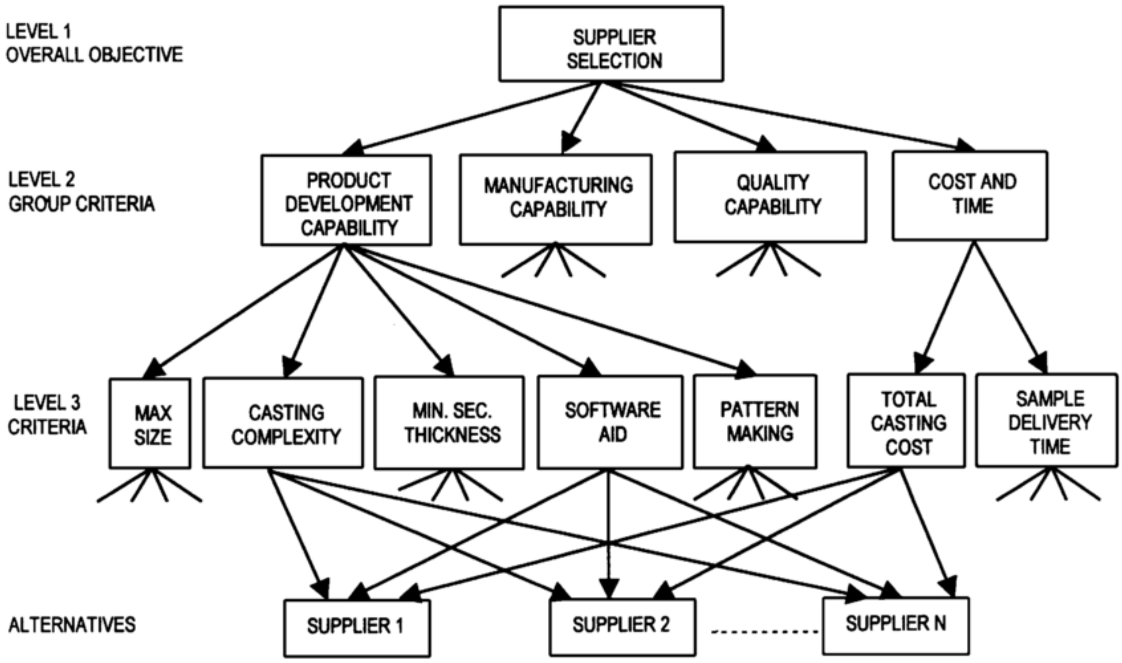


Figure 2.3*:* Analytical Network Process (ANP) method flowchart (INFORMS, 2011)

2.3.4 Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).

TOPSIS is an alternative that is closest to an ideal solution and farthest away from a negative ideal solution. Distances are typically measured in terms of Euclidean distance, but other distances are possible (Abdullah, Siraj and Hodgett, 2021). It offers numerous benefits. It has an easy procedure. It is user-friendly and programmable. The use of Euclidean Distance disregards the correlation of attributes, which is a drawback. It is challenging to weigh attributes and maintain consistency of judgement, especially when there are multiple attributes (Velasquez and Hester, 2013).

2.4 Urban Flood Management

Every year, floods affect the lives of countless of people in ways ranging from minor irritation to serious disruption. During the last decade of the 20th century, it is estimated that this natural disaster claimed approximately 100,000 lives and affected 1.4 billion people worldwide (Romali and Yusop, 2021). Flood is a regular natural disaster that has significant effects on people, infrastructures, and assets, as well as indirect effects on the nation's economy.

Urban flood, which happens around low-lying urban areas due to inadequate drainage of inner water, excessive sewer network capacity, and it is one cause of such severe damage. Urban floods are unpredictable and unavoidable natural calamities. This problem mainly caused by a lack of sewer drainage network information and monitoring facilities for sewer discharge (Kim and Cho, 2019). In Romali et.al (2018) paper, he mentioned that the traditional method of flood management, which centered on the implementation of structural flood mitigation measures, has been replaced by the risk-based flood mitigation concept. Both flood hazard and flood vulnerability are components that contribute to the overall risk of flooding. The possibility of a flood event occurring is known as the flood hazard, and flood vulnerability refers to the potential for flooding to have an adverse effect on a community and its assets where it typically related with the evaluation of property damages. Flooding in urban areas is frequently linked to problems associated with global climate change. This is because the majority of urban areas are the primary contributors to greenhouse gas (GHG) emissions, which eventually lead to global warming. The sustainable development of an urban area degrades as a result of factors such as an excessively concentrated population, expanding infrastructure, and an expanding economy. The creation of a development plan that satisfies the need for urbanization while minimizing the consumption of natural resources has become an increasingly difficult task for both the government and developers over the course of recent history (Safiah Yusmah *et al.*, 2020).

2.4.1 Flood management in Malaysia

Floods are a regular occurrence in Malaysia due to its location in the equatorial region, which receives substantial monsoon season precipitation. Equatorial climate is very hot and extremely humid throughout the year, with an average annual precipitation of 250 cm. Peninsular Malaysia and East Malaysia have different climates, with the climate in West Malaysia being directly impacted by monsoon winds from the northeast and southwest, while the climate in East Malaysia is mostly influenced by maritime weather. The northeast monsoon is responsible for an annual cycle of heavy rainfall over the east coast of Peninsular Malaysia and the east of Malaysia (Sabah and Sarawak) between November and February, while the southwest monsoon is responsible from April to September. The southwest monsoon produces less rainfall than the northeast monsoon, which can produce up to 660 mm in 24 hours. Peninsular Malaysia receives an annual average rainfall of up to 2420 mm, although Sabah and Sarawak receive greater precipitation, with 2630 mm and 3880 mm for Sabah and Sarawak respectively (Safiah Yusmah *et al.*, 2020). Figure 2.2 showing the monthly climatology of min-temperature, mean-temperature, max-temperature, and precipitation throughout year 1991 to 2020 in Malaysia. It shows that December has the most precipitation volume among all the 12 months in Malaysia due to the monsoon season.

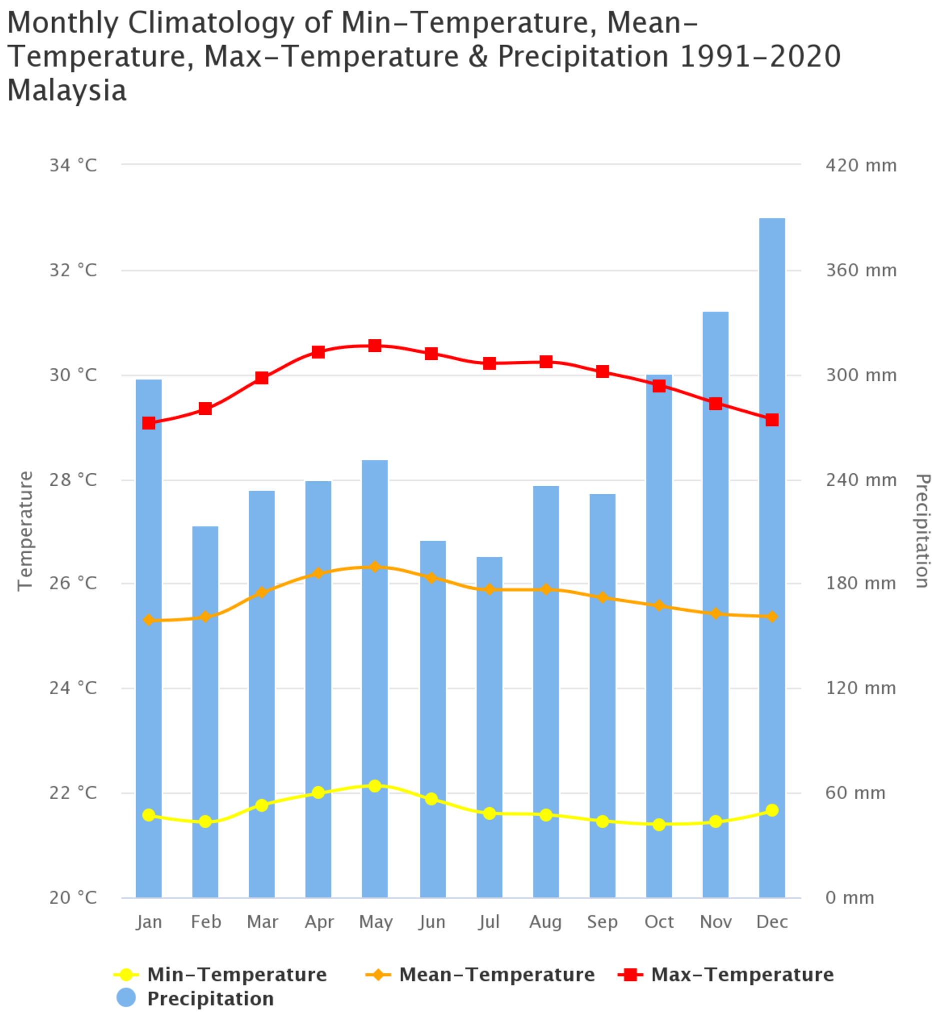


Figure 2. 4: Temperature and Precipitation bar chart (Worldbank.org, 2020)

According to Department of Irrigation and Drainage on their 2020 annual report, which is the report on the Development Status of Flood Management Projects in 2020 mentioned that flood management in Malaysia primarily employs structural and non-structural measures to mitigate flood-related damage. Implemented structural techniques include river widening, installation of river tires (boundaries bordering flood plains or river banks), diversions, and other structures. While the non-structural strategy adopted is the creation of flood hazard maps that may be used as a reference for land-use development planning, structural measures are also being taken. Malaysia and other developing countries' studies have largely adopted methodology from other developed countries, which may not reflect their own flood scenario or socioeconomic conditions. In developing countries, data scarcity is a critical issue in assessing flood damage. Historical flood damage data in Malaysia is poorly documented and difficult to access. The lack of information may jeopardize the accuracy of the damage estimates (Romali and Yusop, 2021).

2.5 Analytical Hierarchy Process (AHP) as Multi-Criteria Decision Analysis (MCDM) as flood management tool

Saatay (1990), in his articles, using the AHP, making it possible to evaluate options in terms of decision-makers, within the framework of established primary and sub-criteria, in order to address hierarchically structured problems. The ability to evaluate consistency check provides results that are close to true scores in addition to its simplicity of use. Decision makers, criteria, and sub-criterion, listing their options in the AHP's hierarchical structure while they are looking for a solution. This structure is used to create comparison matrices then the matrix is turned into a priority vector as a consequence. After that, the consistency rate is determined (Harputlugil, 2018). The goals on the AHP are to find the priorities for the factor that contribute to flooding. The criteria involve are topography, buffer, and land use. The sub-criterion for topography are slope, elevation and aspect, while for buffer are river, road, and forest, and for land use, the sub-criterion are residential, industrial, and agriculture.

2.5.1 Topography

Topography is the study of land surface shapes and characteristics. The topography of a location can be a description of the landforms and features, or it can be a description of the landforms and features. Topography is a branch of geology and planetary science concerned with local detail in general, covering not only relief but also natural and man-made characteristics, as well as local history. Topographic are directly affected by flow extend and runoff speed have important roles in flood occurrence. Despite the importance of topography in the estimate of flood extent, most flood models use only a small number of DEMs and instead focus on the uncertainty associated with other hydraulic factors (Hawker *et al.*, 2018).

2.5.1.1 Slope

The slope plays a significant role in studying flood risks since it controls the velocity of water flow and the surface runoff infiltration (Rahmati et al. 2016). According to the classification process, the area with the lowest slope is very highly affected by floods (Souissi *et al.*, 2020). In other words, this factor must be included, since it plays an important role in determining surface runoff velocity and vertical percolation, and thus affecting flood susceptibility (Rahmati, Zeinivand and Besharat, 2016).

2.5.1.2 Elevation

In general, elevations play a dominant role for the identification of the areas that risk being submerged by flooding. This factor has a major effect on the flooding spread and mainly in the flow direction control and the flood depth (Souissi *et al.*, 2020).

2.5.1.3 Aspect

Aspect referring to horizontal direction toward which slope of mountain or hill is facing. The direction a slope faces in relation to the sun (aspect) has a significant impact on vegetation, snowfalls, and construction. Using ArcGIS spatial analyst tools, the slope aspect of the research region was derived from the SRTM DEM and classified into nine classes (Flat, North, Northeast, East, Southeast, South, Southwest, West, and Northwest). Due to the rapid accumulation of water, locations with flat views are more susceptible to floods. As a result of larger sun and wind impacts in the southern aspects and a higher heating intensity in the western aspects, the southern and western exposures will be drier and less prone to flooding (Vilasan, Kapse and Vilasan, 2021).

2.5.2 Buffer

A buffer is a distance-based reclassification: a classification of within/without a specific proximity. Buffering is the process of calculating distance in all directions away from an object.

2.5.2.1 Buffer from River

The distance from rivers factor plays an important role in determining the flooding area. According to the previous studies (Fernandez & Lutz 2010), the most affected areas during floods are those near these rivers, as a consequence of overflow.

2.5.2.2 Buffer from Road

Area within the road typically have high risk of flood since the road surface is made of impermeable surface. Some of the water can be through the road surface, but the rest of the water will be overflow that causing the flood happened. Flooding, particularly flash floods caused by heavy rain, is the most common cause of weather-related disruption to the transport sector, and this is expected to continue in the future. This issue is particularly acute on urban road networks due to the high proportion of impermeable surfaces that prevent water infiltration into the soil. Heavy rain causes overland flow, which can cause drains to exceed their capacity and become clogged by debris before flood warnings are widely disseminated (Pregnolato *et al.*, 2017).

2.5.2.3 Buffer from Forest

Forest has high rate of infiltration rate that make the forest less risk to flooding. Area within the forest have less prone to flood. It decreases the surplus of rainfall over evapotranspiration (annual water yield) by increased evapotranspiration (especially where evergreen trees or trees with a large canopy interception are involved), but it has the potential to increase soil macroporosity that supports infiltration and interflow, with relatively little effect on water holding capacity measured as "field capacity." Tree cover has two contradictory effects on base flow. One of these effects is that tree cover has two contradictory effects on base flow (van Noordwijk, Tanika and Lusiana, 2017).

2.5.3 Land use

The land use or land cover have an effect on the components of hydrological processes such runoff, infiltration, evaporation, and evapotranspiration. It consists of the deposits of soil, the distribution of structures, the waterways, the vegetation cover, the bare land, and the roadways (Souissi et al., 2020). Urbanization is leading to increasing relative population growth where the areas are physically wider. The expending residential zone, industrial areas and the road and railway network resulting from the urbanization. It often includes the elimination or reduction of vegetation and the creation of impervious areas like buildings, sidewalks, parking lots, and roadways. Urbanization has two negative effects which are increasing the number of flood-prone objects, and its narrows the watercourse profile and limits land productivity.

2.5.3.1 Residential

The residential areas, which are mostly made by impervious surfaces, and bare lands increase the storm runoff (Tehrany et al. 2014b). Proper maintenance on the drainage around the residential area are needed to get away from flash flood. Flash flood may occur in any second resulting in worst condition. Distance from the drainage network is the most important factor in urban flood mapping. As a result of rainfall overflow, the areas closest to these canals are the most affected by urban floods. According to research work, the sewerage network comprises of channel wastewater systems, storm water systems, and the general system (Gigović *et al.*, 2017).

2.5.3.2 Industrial

The majority of urban and industrial areas are composed of impermeable surfaces (buildings, roads, and parking lots), which function as a barrier, lowering the infiltration capacity, hold water, and make them susceptible to flooding (Gigović *et al.*, 2017).

2.5.3.3 Agriculture

Vegetated areas have low potential to flooding due to the negative relationship between flooding and vegetation density. The infiltration rate of the agriculture areas is high. Vegetation encroachment is one of the primary causes of reduced stream channel capacity (Vilasan, Kapse, 2021).

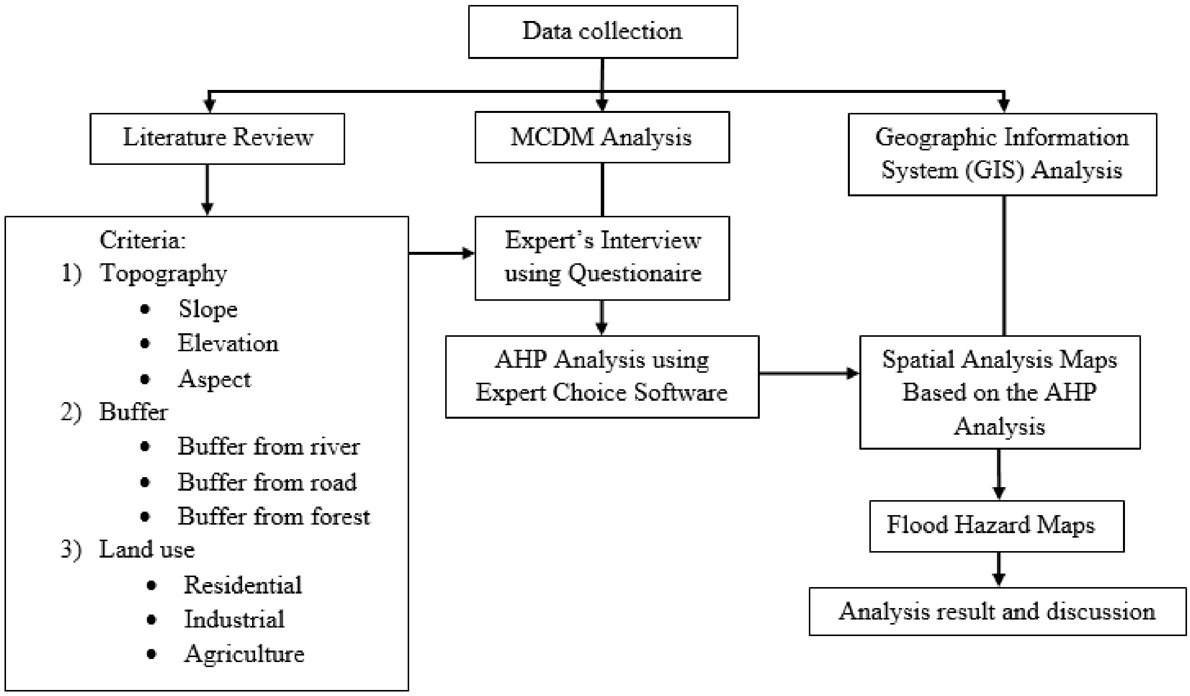
CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter is an introduction to the principles and associated terminology that will be used from this point onwards. The discussion includes some basic knowledge about the flow pattern using MCDM-AHP method. The detailed explanation of the method was presented in this chapter as an analysis for this project. Figure 3.1 shown an overview of the methodology involves in these studies. The methodology started with the collected of data from various sources including LiDAR, USGS, and other sources. A hierarchy of objectives, criteria, and indicators was established for the complex unstructured situation and compared to a qualitative pairwise comparison. Experts were given a 1-9 scale rating questionnaire to determine the weight of each criterion. Then a consistency of the comparisons was determined using the equation. Finally, the result from the AHP analysis is then compared to spatial analysis maps.

3.2 Methodology flowchart



The flowchart shown above is the methodology used for this study. The data collection was divided into three parts which are literature review, MCDM Analysis, and GIS Analysis. The critical criteria that contributed to the flood event in Meru, Klang were divided into three categories which are topography, buffer, and land use. In topography category, there are three criteria to be considered which are slope, elevation, and aspect where they played significant role in flood event. For buffer, the criteria to be considered were buffer from river, buffer from road, and buffer from forest. Lastly, the land use criteria were divided into three part which are residential, industrial, and agriculture. AHP analysis was using all the criteria for the pairwise comparison questionnaire for the expert. The expert was then being interviewed using the questionnaire. Based on the questionnaire, the result was inserted into the Expert Choice software to be analyzed. Then from the weightage resulting from AHP analysis, the weightage was used to do the GIS analysis. The data then being analyzed and discussed in the discussion.

3.3 Study Area

Meru is located in strategic location within Selangor, where it takes an average person to drive about 8km to 10km to Klang town, 20km to Shah Alam, 25km to Subang Jaya, and 30km to Kuala Lumpur. Klang has a total population of 879,867 that put Klang as top three city with high population. The area that affected by flood are Taman Daya Meru, Taman Daya Maju (Jalan Beruas and Jalan Abadi), Taman Bayu, Taman Meru Utama A, Taman Meru Utama B, Taman Meru Utama C and Kampung Meru Jalan Chempaka. One of the neighborhoods said that they move into the area in 2007 but there is no flash flood occurred, but it started to happen in March 2010.

Klang Municipal Council's (MPK) are responsible for the Klang local authorities including Pelabuhan Klang, Kapar and Meru area. MPK Engineering Department has been to several site visits in 2012 but they said nothing materialized. There are over 1000 people were displaced due to the prolonged rain and flooding during December 2021 flash flood event. The victim was sent to the nearest temporary shelter and evacuation centers. Figure 3.1 shows the geographical maps of Meru, Klang

Figure 3.1*:* Geographical Maps of Meru Klang

3.4 Data Collection and GIS Analysis

The data collection through various sources being used to conduct the multicriteria analysis. The digital elevation model (DEM) was downloaded freely from https://earthexplorer.usgs.gov/ . Each of the data were used to extract the slope that been derived through the surface analysis of DEM. The land cover was obtained from Landsat images through this website https://glovis.usgs.gov/app. The runoff speed, flow accumulation, drainage basins and stream aspect can be obtained from these data. During data preparation, the georeference basemap was applied to get the slope, aspect, and elevation analysis. The buffer from river, buffer from road, buffer from forest, residential, industrial, and agriculture were digitalized by using editing and create features tools. The buffer analysis was created using the buffer tools. The data then classified to differentiate between risk factor and safe factor. After that, the priorities from the AHP value were inserted into the weightage.