Development of Decision-Making Framework for Flood Mitigation Management

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Article Info
Page Number: 6551-6561
Publication Issue:
Vol. 71 No. 4 (2022)

Article History
Article Received: 25 March 2022
Revised: 30 April 2022
Accepted: 15 June 2022

Abstract
Flood is the most catastrophic natural disaster that Malaysia has seen. Heavy monsoonal and convectional rainfall, flat topography on both coasts, river siltation, and human activity have all contributed to the high flood risk in Malaysia. Malaysia saw major 21st-century floods in Johor, Kedah – Perlis, Kelantan, Terengganu, Pahang and Penang Island. A study was conducted to determine flood mitigation management in decision making. Engineering flood analysis, such as hydrodynamic modelling, will evaluate flood protection in existing conditions and with mitigation plans. Furthermore, the purpose of this study is to demonstrate how to use Cost Benefit Analytical (CBA), an economic analysis technique, to common flood management challenges that frequently confront decision makers.
Keywords: Decision making, engineering analysis, Flood mitigation, Hydrodynamic modelling, Flood risk management.

I. INTRODUCTION

Climate change greatly impacts flash floods in most areas in Malaysia such as (Kedah and Perlis – the northern states), and (Kelantan, Terengganu, and Pahang – the east coast states). According to MalayMail, it states that government officials profess that it is the worst flood in the country in terms of the displaced population since the 2014-2015 Malaysia floods on the east coast of Malaysia. The worst catastrophic floods in Malaysia were reported as early as 1926, and they remained so common that they occurred practically every year.

Flood damages have skyrocketed as a result of increased human activity in flood zones. To handle these issues, flood mitigation techniques are implemented, and river improvements are mostly used for this purpose (Abebe et al., 2019; Berends et al., 2018; Sammen et al., 2019; Tunas & Herman, 2019). A flood mitigation plan ought to include one or more realistic flood mitigation strategies.

Manuscript received on | Revised Manuscript received on| Manuscript Accepted on| Manuscript published on.
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Flood is not only the most catastrophic natural disaster in the world, but it has also destroyed most human lives and property. Environmental damage has taken place as a result of the detrimental consequences of flood disasters (Bogdan, 2019; Creach et al., 2020; Kousky & Walls, 2014; Miller et al., 2008; Sarchani et al., 2020; Strömberg, 2007). Therefore, sustainable development of flood plans must be included to improve the economic development of these damages. Previous research has demonstrated that in order to achieve sustainable development, environmental investments should be evaluated in terms of their costs and benefits (Fischbach et al., 2019; Harding, 1998; O'Mahony, 2021; Polasky et al., 2019; Schaltegger & Burrit, 2013; Tao et al., 2021; Tietenberg & Lewis, 2017). Moreover, the economic efficiency of flood mitigation methods suggested through engineering and hydrodynamic modeling will be assessed. A combination of engineering and economic analysis can aid in the management of institutional frameworks and administrative procedures required for the identification of efficient and cost-effective flood mitigation methods (Hong et al., 2018; Osti, 2019).

A. Defining Flood Mitigation

The frequency of flooding is determined by meteorology, geography, land use, soil composition, and observed moisture conditions (Erena & Worku, 2018). Flood mitigation entails managing and controlling flood water movement. Generally, urbanisation of a watershed worsens natural flooding by facilitating the removal of early vegetation, increasing imperviousness, canalising river flow, and encouraging the settlement of flood plains (Berends et al., 2018; Chan et al., 2018; Jacob et al., 2019; Kryžanowski et al., 2014) . Flood mitigation measures should mainly aim to lessen flood risk. In addition to this it should also contribute to the enhancement of the floodplain's environmental, social, and economic assets.

(DID, 2019) defines flood mitigation as flood control, and it is primarily focused on addressing the requirement for rapid urbanisation. Since 1971, Malaysia has been involved in this strategy. Flood mitigation strategies are classified into two types which are s tructural and non-structural. Structural measures are common engineering flood mitigation components that aid flood administrators in monitoring and controlling floods (Chan et al., 2018; Genovese & Thaler, 2020; Ventimiglia et al., 2020). For instance, dikes and retention basins were constructed as structural flood mitigation devices to control floods up to a certain design flood. Floods are mitigated in a variety of ways by various structural techniques.

The following information includes a description of each structural measure as well as the technological solutions used to manage floods (Abdul Mohit & Mohamed Sellu, 2017; Ali et al., 2019; Department of Irrigation and Drainage, 2009; Kryžanowski et al., 2014; Mosselman, 2020; Pesaro et al., 2018) :

1. Water level is controlled via the building of a barrage, a tidal gate, and flap gates.
2. Dams and detention basins serve as flood storage and control structures.
3. River restoration and channelization act in tandem with flood barriers and levees.

4. A flood diversion canal or tunnel is built to redirect flood flow is to enhance water flow efficiency and management.

5. Pumps and flood gates are mechanical components that are used to force the removal of non-gravity overflow and building drainage.

Non-structural mitigation strategies often imply risk reduction through changes to human behaviours or natural processes that do not necessitate the use of designed structures. The development of flood hazard and risk mapping, flood warning and evacuation, flood plain land use, flood proofing, and flood insurance have all resulted in non-structural interventions (Department of Irrigation and Drainage, 2009; Thampapillai & Musgrave, 1985). Non-structural methods can also be viewed as combining flood risk management with land use planning, climate change projections, and prospective urbanisation scenarios, all of which can effectively aid decision makers, water administrators, and city planners in dealing with flooding (Yik et al., 2018).

Furthermore, non-structural flood mitigation strategies include planning, programming, decision making, collaboration, nurturing, strengthening awareness, supporting, and improving government, stakeholders, and society in response to flooding threats and damages. In instance, a study has shown in Singapore Public Utility Board has established a free short message service (SMS) to inform local residents wanting to track water levels in major waterways and get warnings if heavy rain is predicted as well as sending out flood warnings through social media (Chan et al., 2018).

B. Flood *Mitigation Management and Approach*

Floods in Malaysia are caused by the region's spatial pattern, which provide an abundance of rains during the monsoon seasons between November and February and convective showers during hot and humid periods. Malaysia saw significant 21st century floods in December 2006-January 2007 (Johor - the southern state), 2009/2010 (Kedah and Perlis - the northern states), 2014 (Kelantan, Terengganu, and Pahang - the east coast states), and 2017 (Kelantan, Terengganu, and Pahang - the east coast states) (Penang island) (J. Abdullah et al., 2019; Amin & Othman, 2018; DID, 2019; Zakaria et al., 2017). In each Five Year Malaysia Plan, the.

The Department of Irrigation and Drainage (DID) has been tasked with managing Malaysia's water resources, including flood management. Figure 1illustrates DID development expenditures for major projects such as flood, coastal, urban drainage, river, and others like as dams and mechanical and electrical systems. Based on Figure 1 flood prevention investment is deduced to increase by 58.5% between the 10th and 11th Malaysia Plans where it is focused on the flood tragedy that struck the east coast states in 2014 and Penang island in 2017. Flood disasters are frequently unpredictable and cannot be avoided. Increased flood events in Malaysia every year have prompted the government to develop more flood protection projects. Furthermore, given cost and financial limits, the government should determine project priorities intelligently among flood-affected states.

Earlier, approach to flood management in Malaysia is more ad hoc (DID, 2009). Following the 1971 big flood event, flood control was assigned to DID. To facilitate flood warning and alarm systems, the Division of Hydrology was established as the national hydrological data repository (DID, 2009). Since 1971 flood event, several laws, legislation, and standards have been enacted to improve land use and establish new development criteria as part of non-structural initiatives. The Manual Saliran Mesra Alam (MSMA), Integrated River Basin Development and Integrated Flood Management were the parts of the enhanced guidelines for new urban development projects since 2001 (DID, 2009). These were to create an idea through structural and non-structural measures, as well as public participation.

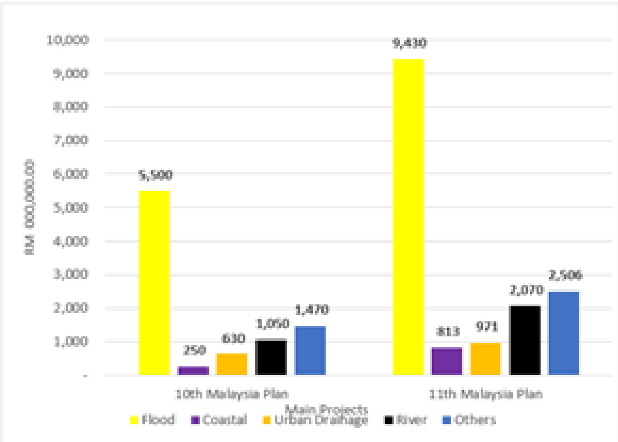

Fig. 1.Expenditure for Main Projects in DID

C. Decision Making in Engineering Perspective

Decision making is the process of recognising options, acquiring information, and evaluating potential solutions. It is also selecting among alternative courses of action in order to achieve targets and goals. It entails obtaining key information, creating goals, identifying multiple relevant possibilities, reviewing those options in order to develop action plans, and putting those action plans into action in order to make strategic decisions for the firm (Galli, 2020; Landsbergen et al., 2018; Latan et al., 2018; Sjöberg, 2003).

In an engineering perspective making a decision to develop a product or method require knowledge on how an operation is carried out and it concerns them on the environmental effects on a product or project development decisions. A conceptual framework also shows that a complicated engineering decision-making procedure, such as hydrodynamic modelling, must be performed in order to examine the technical components of the flood situation before an investment choice is made. For instance, according to (Šalić & Zelić, 2017) engineering perspective in decision making where an environmental engineer's role to coordinate and discover the best way for carrying out the work of cleaning the environment using environmentally friendly techniques.

II. METHODOLOGY

A. *Research Design*

The purpose of this research is to get a better knowledge of the use of cost-benefit analysis in decision-making about flood mitigation management. A case study method was used for this research, which will look into flood mitigation measures during the 11th Malaysia Plan (2016-2020) in states hit by large floods. Hydraulic modelling was used to evaluate the capacity and conveyance of the existing river system and flood protection of these river system with respected discharge designs (DID, 2009b). Subsequently, the model will then be used to evaluate the effectiveness of various flood prevention techniques. As a result, analysis will be the primary input for the decision-making process and CBA will be implement as a comprehensive economic analysis. Figure 2 shows the research methodology flow chart.

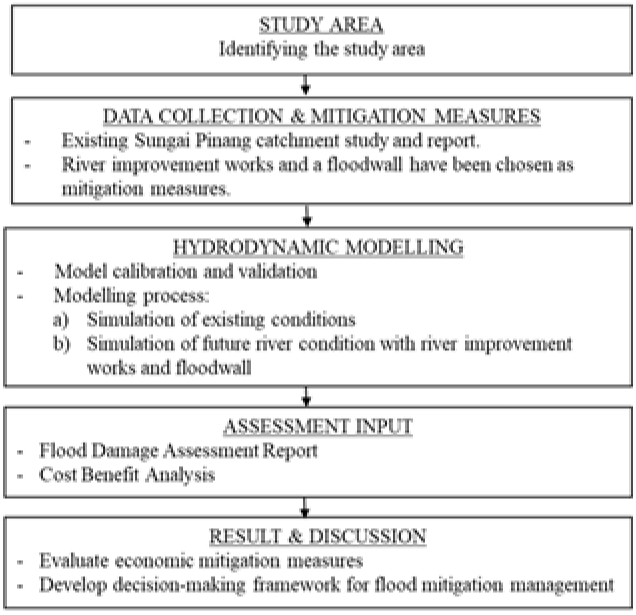

Fig. 2.Research Methodology

B. Focus Group Discussion

A focus group discussion (FGD) is a strategy in which a researcher gets information from a group of people where they debate a given issue with the objective of drawing on the members' diverse personal experiences, activities, ideas, perceptions, and attitudes through mediated interaction. It was conducted by meeting and discussion with stakeholders (Technical Departments and Authority, Local Community Representatives, Institutional Representatives and Business Owners). Three FDGs (local authority, local technical departments and local communities) were involved in the meeting on floods in November 2007 and it was chaired by the Department of Irrigation and Drainage Pulau Pinang. Table 1 shows FGD held with the stakeholders in DID Pulau Pinang.

FGD	Matters discussed	Participants	Date of discussion
FGD 1	Reviewing proposed mitigation measures for social impacts before, during and after construction	24 participants from Majlis Bandaraya Pulau Pinang and technical departments from Pulau Pinang State.	14th January 2020
FGD 2	Identifying flood issues in the affected area and informing stakeholders of the flood mitigation project.	21 Participants from head and representative from Kawasan Rukun Tetangga who represents the community affected by flood, religious and education's institutions as well as local traders of the affected area in the Sg Pinang catchment.	14th January 2020
FGD 3	Identifying flood issues in the affected area and informing stakeholders of the flood mitigation project.	26 participants from Ahli Dewan Undangan Negeri and *ADUN & MPKK*	20th January 2020

Table- I: Summary of FGD held with the stakeholders

C. Model Setup

This research focus on two different flood mitigation measures in Sungai Pinang sub-catchment by using Infoworks Integrated Catchment Modelling for river improvement works and flood wall. Three elements such as hydrology, hydraulic and floodplain analysis were combined and merged to provide an immersive and dependable hydrodynamic mode. The purpose of hydraulic modelling is to analyse the capacity and conveyance of existing river systems based on design flood hydrographs produced from rainfall-runoff models in order to devise flood mitigation strategies.

III. REVIEW CRITERIA

A. Decision Making Framework

This research will assist the Department of Irrigation and Drainage clarify the economic costs and advantages of flood mitigation solutions before deciding on a flood mitigation project. The engineering and economic assessments conducted for the study will be combined to create a decision-making framework for flood mitigation management.Hydrodynamic modelling using Infoworks Integrated Catchment Modelling (ICM) is combined with cost-benefit analysis to determine the most efficient and cost-effective flood control techniques.

Figure 3 shows the process flow of the flood mitigation projects implementation in DID.

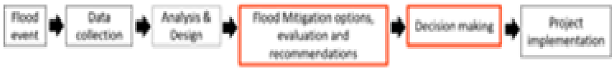

Fig. 3.Process flow of flood mitigation projects

This technique entails combining hydrodynamic modelling with cost-benefit analysis to determine the most efficient and cost-effective flood prevention solutions.

B. Guidelines for decision making in flood management

The outline of guideline for flood mitigation measures and protection scheme is shown in Figure 4. In stage 1, planning and defining analysis where flood damage will be identified during a specific flood event. This data will be assessed and moved on to the design stage. The engineering analysis is completed in stage 2 to create the hydrological analysis effect for this project. The evaluation will include modelling and estimating flood levels and flows, as well as creating a flood hazard map for the chosen flood mitigation methods. The 3rd stage, economic analysis, will also include determining the present value of both benefits and expenses using a discount rate. The last stage, Stage 4, involves assessing the outcome by comparing the advantages and costs of the chosen flood prevention techniques. The methodologies proposed for this study will serve as a guideline to aid DID in making flood management decisions since, in flood-prone river basins, correct information of physical and sociocultural dynamics, as well as hydrological events, is essential to make safe urban planning and operational risk management decisions utilising CBA.

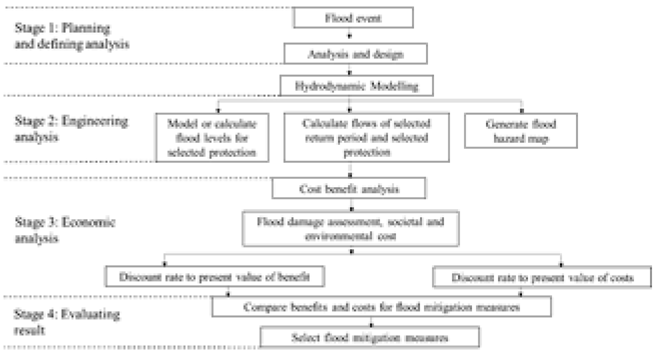

Fig. 4.Guideline for flood mitigation measure and protection schemes

ACKNOWLEDGEMENT

The author expresses their gratitude to River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia for providing the facilities and Ministry of Higher Education for their financial support.

VIII. CONCLUSION

In this research, a quantitative method was used to investigate how cost benefit analysis application might be used as a tool throughout the decision-making process in order to identify the best flood mitigation techniques. The adoption of flood mitigation methods to aid in flood management decision-making has been economically analysed, taking into consideration social and environmental benefits. The application of the hydrodynamic model in conjunction with the cost-benefit analysis method forms the foundation of a flood management decision-making process has an outcome where flood mitigation project decisions are made in a sustainable, affordable, and holistic manner.

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