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FOREWORD

Welcome to the 8^{th} volume and issue number 1 of the ESTEEM Academic Journal UiTM (Pulau Pinang): a peer-refereed academic journal devoted to all engineering disciplines. This issue of journal sees a new Chief Editor and marks the journal's first electronic publication. Using the e-journal inauguration as an occasion, I would like to thank many people who created the opportunity for this e-journal to be born and who made it happen. First and foremost, I would like to extend my sincere appreciation and utmost gratitude to Associate Professor Mohd Zaki Abdullah, Rector of UiTM (Pulau Pinang), Associate Professor Ir. Bahardin Baharom, Deputy Rector of Academic Affairs and Dr. Mohd Subri Tahir, Deputy Rector of Research, Industry Linkages, Community & Alumni for their unstinting support towards the successful publication of this e-journal. Not to be forgotten also are the constructive and invaluable comments given by the eminent panels of external reviewers and language editors who have worked assiduously towards ensuring that all the articles published in this journal are of the highest quality. A special acknowledgement is dedicated to all committees, publication department, and many other relevant parties for making this journal a success. Their affective commitment and close cooperation have facilitated the realization of this journal. Last but not least, my greatest thanks go to all the authors for their interest in publishing with ESTEEM. Their manuscripts are an expression of their commitment towards research and development which, in due course, would benefit the local, national and international communities. Hence, I would like to extend my warm invitation to all researchers who are actively involved in the field of engineering to publish their work in ESTEEM.

Dr. Chang Siu Hua
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COST-BENEFIT ANALYSIS FOR OPTIMUM RETURN OF FLOOD CONTROL MITIGATION

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ABSTRACT

Flood is a problem caused by precipitation and runoff particularly during periods of excessively high rainfall. Nowadays in Malaysia, flood has become a serious problem to the extent of imposing impact to the environment. This problem may cause damage to properties, loss of life, loss of utility services, loss of trading and others. However, with sophisticated technologies, some flood mitigation measures have been designed by engineers and the government allocates a lot of money for the projects. A study on flood damage assessment is necessary to identify, predict and evaluate the benefits of flood control projects. In this study, a model on flood damage assessment was developed by using Visual Basic language and the data which is used in this calculation is hypothetical data. Besides, this study is important to ensure that floods are controlled by implementing mitigation measures in order to minimize destruction to the environment. From the economic point of view, the best approach to establish the most economical flood control system was selected based on a suitable system that gives the largest benefit-cost ratio analysis or the maximum return of the net benefit. This model will be able to assist engineers in making the best decision during planning for flood control projects before the intended design can be executed.

Keywords: maximum net benefit; flood mitigation; benefit- cost ratio; flood control

1. INTRODUCTION

Flood is a natural phenomenon which occurs everywhere that has harmful effects on people and the environment. Nowadays, flood has become a serious problem to the extent of imposing impact to our natural environment. Two major types of floods occur in Malaysia, including monsoon floods and flash floods. Floods have become a serious problem that may cause damage to crops, properties, public facilities and others. Besides, loss of life may happen if extreme flood occurs. The main causes of flooding in Malaysia are increased runoff rate due to urbanization, inadequate drainage systems, inadequate river capacities and others. The Department of Irrigation and Drainage, Malaysia (DID) has estimated about 90% of the total land area which is equivalent to more than 4.82 million people are affected by flooding annually (Ghani, Zakaria, & Falconer, 2009). A research in the Netherlands shows that the total amount of urban area that can potentially become inundated due to floods from sea or main rivers has increased six-fold during the 20th century and may double again during the

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21st century (De Blois & Wind, 1995). Therefore, the government needs to allocate huge amount of money for flood mitigation measures.

There are two types of flood control measures, consisting of structural and non-structural gauging installations to reduce or prevent detrimental flood waters and damage to environment. Structural measures represent the traditional flood destruction by way of physical means e.g. embankments i.e. dikes or levees, floodwalls (to confine the floodwaters), upgrading of river channel (to enlarge their discharge capacity by straightening, widening and deepening), construction of bypass and diversion channels (to channel out the excess floodwater) and elevated reservoir (temporary storage of floodwaters) (Kamarouz, Szidarovszky, & Zahraie, 2003).

Engineers can build anything to control floods; however financial aspect is one of the major problems in implementing flood control projects. Without sufficient funds, the desirable flood control project could not be constructed as per anticipated designed. Hence, economic analysis modeling plays an important role to balance the relationship between benefits and project costs after these flood control systems were installed. Therefore, the aim of this paper is to investigate the application of cost benefit analysis (CBA) methods in decision-making on a desired flood protection strategy in Malaysia.

Flood damage assessment is necessary to identify, predict and evaluate the benefits of flood control projects. The loss estimation model is formulated based on stage-damage relationship between different flood inundation parameters and landuse features (Dutta, Herath, & Musiake, 2003). The economic loss of different landuse features can be calculated based on the simulated flow parameters obtained from the hydrologic model for any flood event. Besides, the economic demand for flood control is measured using different between the expected flood damages before and after flood mitigating measures are installed (Shamsudin, 1986). In economic perspectives, CBA involves comparing the total expected cost of each flood control measure against the total expected benefits to see whether the benefits are greater than costs and by how much. Therefore, an economic analysis plays an important role in deciding between various alternative projects available. A model of flood assessment was developed in order to assist engineers, hydrologists, town planners, researchers and the authorities concerned in making decisions for planning and design of flood control from the cost economic point of view.

This study focuses on direct tangible damages due to flood occurrence using hypothetical data. Direct tangibles are those which occur due to the physical contact of flood water with humans, property or any objects (Merz, Kreibich, Schwarze, & Thieken, 2010). Furthermore, it only considers the structural measures such as reservoirs, channel improvements, dikes and diversion schemes because these alternatives can reduce flood damages immediately compared to non-structural measures.

In an economic analysis of water development projects, it is recommended to assign a limited period of time to the useful life of a project. The life of private projects is relatively short while the life of public projects can be as long as 20 to 100 years (Kamarouz et al., 2003). Hence, the useful life of a water development projects is usually assumed at 50 years and the interest rates of these projects are available at 4%, 6% and 8%.

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2. METHODOLOGY

The methods used for the decision making of flood control projects are based on the procedure that had been stated by Penning-Rowsell and Chatterton (1977). There are four (4) types of structural measures used in the analysis namely reservoir, channel improvement, river diversion and dikes and its combinations. In this model, fifteen (15) flood control projects are used for the analysis as shown in Table 1. The economic analysis has been done in order to select which alternative gives the greatest economical method of flood control based on the largest B/C ratio and maximum net benefit.

Table 1: Type of flood control projects

No.	Flood control projects	No.	Flood control projects
A	Dikes	I	Diversion + deepening
B	Diversions	J	Reservoir + deepening
C	Reservoirs	K	Dikes + diversion + reservoir
D	Deepening	L	Dikes + diversion + deepening
E	Dikes + diversion	M	Dikes + reservoir + deepening
F	Dikes + reservoir	N	Diversion + reservoir + deepening
G	Dikes + deepening	O	Dikes + diversion + reservoir + deepening
H	Diversion + reservoir		

3. FLOOD DAMAGE ASSESSMENT

The flood damages can be determined based on the flowchart as shown in Figure 1. De Blois and Wind (1995) indicate the hydrologic relations such as frequency of occurrence, river discharge, river water level and the damage estimates as the important uncertainty sources. From Figure 1, 3 stages of analysis involved which are the main basic data that are required for the calculation. In the first stage, the data on the relationship between stage and damage is obtained based on assumption of catchment data. The stage- damage data is obtained by expressing the amount of damages for every flood interval. The damages are depended on the characteristics of flood event including the depth and flow of the floodwater, the duration of flooding, sediment content of the water and the nature of development (Wordsworth & Bithell, 2004).

In the second stage, the rating curve data has been introduced for the analysis. The discharge-stage curve is a graph to show the relationship between stage and discharge at the time of measurement. The discharge-stage data is obtained before and after flood control scheme has been installed in a river. It depends on the geometry of the river and erosion or deposition of sediment and it may change the rating from time to time (Linsley & Franzini, 1979).

The third stage is the relationship between probability and discharge requires knowledge on the flood hydrology of the catchment. Probability concept is used in the analysis and it has been conducted by a statistical method for estimating the frequency of rare events. The concept of linear interpolation is applied in the probability- discharge data to obtain discharge values by interpolation of the probability values. The discharge values are then is applied into discharge-stage data to obtain the corresponding stage values in the analysis. Finally, the damage values are obtained by interpolating the stage values into the stage-damage data.

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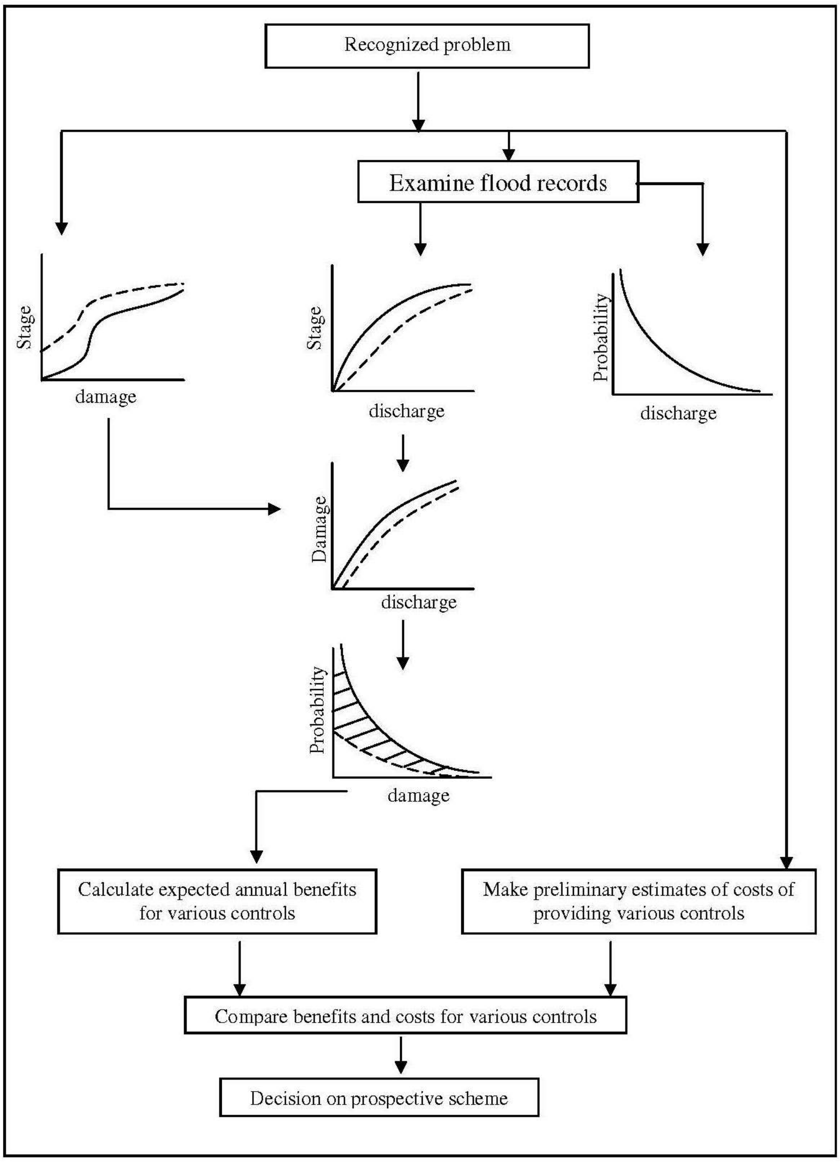

Figure 1: Stages in Evaluation of Flood Control Schemes (Penning-Rowsell & Chatterton, 1977)

After interpolation is done, the probability-damage data is obtained and represented in graphical form. From these 3 relationships, the probability-damage curve was developed in order to determine the damages with or without implemented flood control schemes and from there the benefit of flood control projects can be obtained. The probability-damage curve is established using the probability distribution of annual peak discharges together with the stage-discharge curve and the stage-damage curve (Oliveri & Santoro, 2000). From the probability–damage curve, without any control, the average annual damage is determined by the area under the graph. Because there is no equation to integrate the graph, therefore Trapezium Rule is applied into the analysis to obtain the sum of area under the graph as shown in Figure 1. In order to obtain more accurate of the result, the area under the graph is divided into more slices. A large number of strips may yield a good approximation to each strip, but it involve a lot of calculation, with the possibility of consequent rounding error accumulation while a small number of strips will obviously involve a large error in the

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approximation to the area of each strip. The annual damages without and with implementation of flood control are obtained after determining the area under the graph.

The same step and computation are repeated to obtain the annual damage with flood control structures are installed. When the flood control structures are installed, the new data of stage-discharge curve, probability-discharge curve and stage-damage curve must be considered in determining the damages after implementing flood control measures. The data of three basic relationships depends on the various types of flood control measures as shown in Table 1.

4. COST – BENEFIT ANALYSIS (CBA)

After the analysis on flood damages has been done, then the average annual benefit of a flood control project is determined by the differences between the damage without control and with control. The annual benefit of flood control project can be calculated from Equation 1.

$$Benefit = D_0 - D_C \tag{1}$$

D_0 = damage without control

D_c = damage with control

The following equations are used to determine the annual cost of projects.

$$Annual\ interest\ payable\ (a) = Capital\ cost\ x\ i\ (\%) \tag{2}$$

$$Sinking\ fund\ factor\ (f_S) = \frac{i}{(1+i)^u - 1} \tag{3}$$

$$Ann.\ sinking\ fund\ (b) = fs\ x\ Capital\ cost \tag{4}$$

$$Ann.\ cost\ of\ project(c) = a + f_S + d \tag{5}$$

Where:

a annual interest payable

f_s sinking fund factor

b annual sinking fund

c annual cost of project

3 parameters are used in the CBA which is the B/C ratio, the net benefits and the rate return (Kuiper, 1971). In this study, it is focusing on B/C ratio and the net benefit. The B/C ratio has much popular because it gives an immediate indication of the degree of desirability of a project. The equation to determine B/C ratio is:

$$B/C\ ratio = \frac{D_0 - D_C}{\sum Cost} \tag{6}$$

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If the B/C ratio is less than 1.0, the project is evidently undesirable. If it exactly 1.0, it is a marginal project while if it is less than 1.0, its implementation would seem justified. The B/C ratio parameter is not enough to make an economic choice among the alternatives (Garg, 2009) . Thus, an additional parameter is necessary to calculate the net benefit. The net benefit may be defined as the sum of all benefits minus the sum of all costs. If the net benefits of the project are maximum, it shown that the project is most economical. The maximum net benefits can be expressed simply in Equation 7.

$$Max.\ net\ benefit = \sum Annual\ benefit - \sum Annual\ Cost \tag{7}$$

5. RESULT AND DISCUSSION

The selection of a project is based on the largest B/C ratio and the maximum net benefit obtained. A graph on annual benefit versus annual cost is plotted to show B/C relationship. The benefit-cost ratio depends on what interest rate is assumed. A lower interest rate will increase the B/C ratio. Furthermore, the interest rate also affects the net benefit. A lower interest rate will increase the net benefit while a higher rate will decrease it. Flood control projects are usually classified as public projects, which mean they are financed and operated by federal, state or local government organizations. These projects may be of any size but are usually very large. In such a case, it is more advantageous to proceed to a larger project as long as the increment in benefits is larger than the increment in costs. Therefore, maximum net benefit is a parameter used to determine the desirability of a project. This project can be immediately recognized in a graphical plot by dropping a 45^o line (incremental B/C ratio = 1). The first point that the line touches will represent the project with maximum net benefit. From Figure 2(a), project L (Dikes + Diversion + Deepening) is having the maximum net benefit. Therefore, it has been concluded that under the stated assumptions, the project that is most desirable from an economic viewpoint is selected based on the maximum net benefit. However, some knowledge on indirect and intangible benefits has to be considered in CBA. Basically, intangible and indirect benefits are those that do not based on monetary values. However, it may be extremely important and should be considered in the decision making process.

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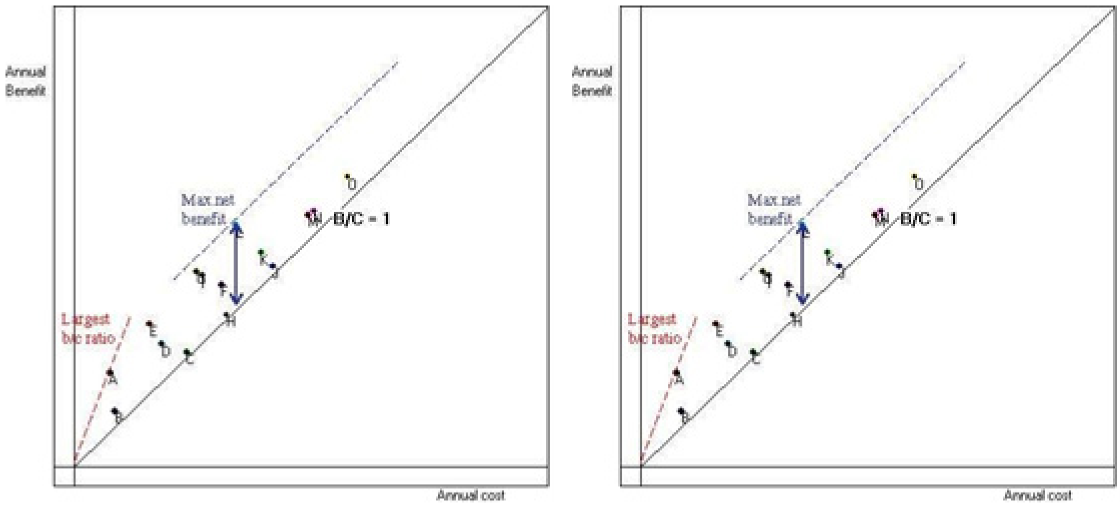

(a) (b)

Figure 2: Decision making of flood control projects for 4% (a) and 6% (b) interest rate

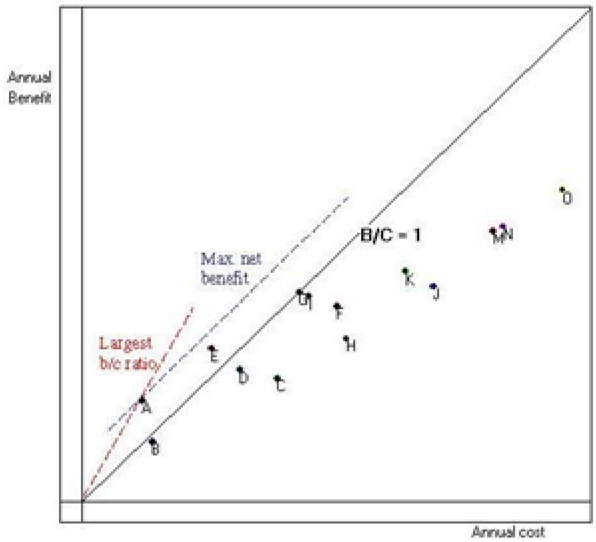

Figure 3: Decision making of flood control projects for 8% interest rate

Accordingly as shown in Figure 2(a), it can be suggested that there are sufficient capital funds available to finance all the 15 projects with 4% interest rate since all 15 projects have B/C ratio greater than one. All flood control projects would merit consideration. Project O having the largest benefits however the annual cost of this flood control scheme is very expensive. By considering the CBA, Project O is not the best scheme. Moreover, it may be seen that project L (dikes + diversion + deepening) has the maximum net benefit while project A (dikes) gives the largest B/C ratio. It is obvious that it is more advantages to develop project A compared to project L. Therefore, project A must be constructed first in order to assure the greatest flow of future economic values and followed with project L.

Meanwhile, Figure 2(b) shows the result on benefit and cost of 15 flood control projects for 6% interest rate. The most economical flood control project is project A which gives the largest B/C ratio and the maximum net benefit. Project A which is provision of dikes will

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increase the flood levels before flood will start to occur. Besides, it was observed that project A, B, D, E, G, I and L give B/C ratio greater than one and would merit consideration. However, the other projects having B/C ratio less than one and therefore the projects are evidently undesirable. Project A must be constructed first and then followed with project E.

For 8% of interest rate, Project A is the best scheme which gives largest B/C ratio and maximum net benefit value as in Figure 3. From the figure, it proved that only project A, E and G have B/C ratio greater than one and thus would merit consideration. However before final decision is made, it must be emphasized that this model is based only on direct tangible damages. Therefore, it is most desirable to construct the project that gives the largest B/C ratio.

From the results, it may be seen that there is an increase in the annual cost for every flood control project with increase in the interest rate value while the annual benefits are not affected. Therefore, from the 3 differences of interest rates, it can be seen that project A is the best scheme which gives maximum net benefit and largest B/C ratio.

6. CONCLUSION AND RECOMMENDATIONS

This study is to achieve the objective in order to make decisions for planning and design of flood control by considering cost economic criteria. A model was created to determine the damages due to flood occurrence and hence determine the costs and benefits after flood control schemes are implemented. It can be applied in various places such as residential, industrial, agricultural, urban and other low areas during the flood occurrence.

By developing this model, it will help engineers to make the best decision in planning of flood control projects before the design can be implemented. Therefore, this model is very useful for engineers, hydrologists and any people involved in flood control projects. However, there are few limitations in developing this model and it may affect the accuracy of this model. The model required 3 basic catchment data curves for the detail analysis. The model limits the data for maximum of 100 coordinates for probability-discharge, discharge-stage and stage damage data. The more coordinates will give more accurate result. From economic point of view, the study must be including indirect and intangible benefits for further research. Moreover, the model is based only on B/C ratio and net benefit to indicate desirability of a project. Therefore, the model may only be used as a guideline in selecting the most economical project among the various flood control projects.

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