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Optimisation Model for Problem Solving of Bandung Urban Basin flood using Value Engineering Approach

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***Abstract*— A problem solving of floods in urban area is a complex process. There is no a generale solution can be used to solve the problem of floods in any cases. The solution of floods should be adjusted to the characteristic of flood fenamenon in a certain location. There are some alternative solutions could be created to solve the problem, it is however the best decision should be found out. This research contributes to carry out an optimisation model to find out the most effective and efficient solution. The concept of optimisation is based on value for money approach using value engineering tool to choose the best solution from any possible alternatives. The result shows that the best solution is an alternative succeding to avoid the flood with the highest impact in disturbing socio economic activities.**

***Keywords*—flood, urban area, risk, value engineering, optimisation**

I. Introduction

Bandung urban flood has a specific charateristic because of its topographical condition. The location of urban floods takes place in basin areas, which are surrounded by any higher elevation of lands or hills. Citarum river flows in this area, which starts from Wayang Mountain into Java Sea and its flow through the flood basin areas. The flood is usually due to the overflow of Citarum River which receives accummulated storm water from many drainages during heavy rain in Bandung. The critical area is occured in the lowest area of urban basin land, especially where there has no possibility to take the water trapped out from this place. It depends on the infiltration into the land.

The characteristic of floods in Bandung basin can be decribed into three fenomena as follows:

Floods are usually occured due to the overflow of Citarum River, which its condition is influenced by the intensity of rain fall not only in flooding area but also in the catchment area of upstream Citarum. The surface level of Citarum River may rise and down 1meter per hour.

The problem was commonly happen when the overfow of the River has ceased, however, the water overflowed was still trapped in the basin area. During the high intensity of rain fall the frequency of overflows may be occured in several times causing the accummulation of water trapped then the level of flood becomes higher and higher in that basin area.

There are two kinds of basin areas which are located north side and south side of Citarum River. The north basin has wider area from the south one. The most problem of floods occured in the south basin is due to the flood and it may only be spread in a small area and the highest flood reach 3 meter.

The policy of Indonesian government tends to relocate the community in the south basin and build a concrete wall in the north basin as the berrier of Citarum River water overflow.

Moreover, there are two kinds of impacts of floods in Bandung basin. Firstly, it is the direct impact of floods, which cause any damages of buildings and public facilities. Secondly, it is the indirect impact of floods, which cause any interferences of socio-economic activities.

This research is concerned with the two kinds of impacts. The direct impact causes any physical damages in the flood area, otherwise the indirect impact influences many poeple activities. The greatest value of this indirect impact is caused the traffic jam during flooding. The traffic jam may happen in the situation of small and high floods.

The aim of this paper is to show the role of value engineering approach in the decision making process in order to achieve the best solution of floods under the case of Bandung basin flood problems.

II. Literature Review

There were many solution of urban floods have been carried out over the world. The case of urban flood becomes important due to its high impact to many people with any expensive assets in the cities. The consideration of urban floods is commonly concerned with three aspects. The first is the cause of flood; the second is the impact of flood, and finally what is the best solution avoiding floods. [1]

The reason of urban floods is due to natural factor and it is related with the situation of climate change. This can be shown by hydrological data. The data may be converted into the volume of water rain fall using hydrology model, for example Nakayasu. However, the data may show the possibility of occurence, however, it could be very expensive if the design will refer to the greatest value of occurence.

The variety of rain fall intensity becomes an input for the decision making proces that the intensity level shold be considered as an aspect inflencing the flood level as well as its infrastructure build to solve flood problems.

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There are many impacts due to floods which can be stated as direct and indirect impacts. This paper will be only concerned with measuring the impact using economic parameter. The calculation of impact may be carried out in some alternative approaches. The direct impact is any impacts causing building damages. This is suggested to be calculated by using depreciation cost rather than the renovation cost. The indirect impact, which is focused on interferencing traffic flows, may be calculated using cost benefit analysis. Using this method will compare the cost of flood impact to the cost of infrastructure built avoiding floods [2].

The solution to reduce or to avoid floods has been carried out over the world. Value engineering approach uses function analysis to explore any possible ways to achieve the objectives. The analysis is to find out any basic functions required for reducing or avoiding floods. The basic questions used in this approach are why, how, what and when for any steps to achieve the objectives [3].

Optioneering process may create some possibilities of real functions can be built to achieve the objectives. Therefore, it needs an evaluation process to obtain the best solution. Value for money is a kind of criteria used. The idea of this is to find a flood solution which may achieve the greatest function for reducing or avoiding flood occurence.

The value for money may not only just choose the chepest one as a selected result, but also consider the value of benefits may be obtained in a solution. Any criteria of value should also required to evaluate any alternatives created. Consideration to all stakeholders related are also used as a value parameter that can be used in this case. [3]

III. Research Method

The research metodology is principally a case study. It may involve qualitative and quantitative approach. This research will create a decision making model, which is built and adjusted during the research process until meeting with the case requirement. This can be shown in Figure 1.

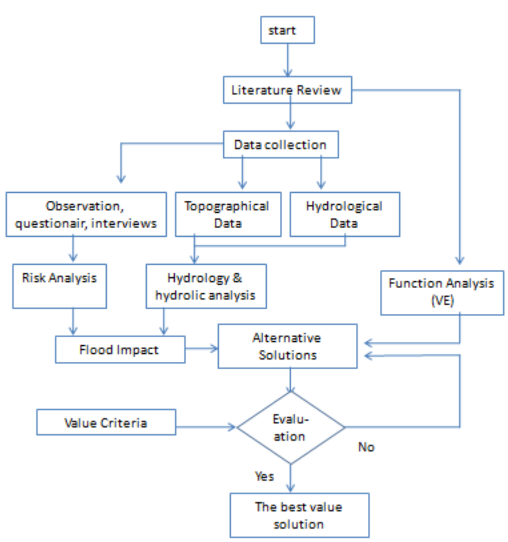

Figure 1. Research Method

IV. Result

A. *Topographical Data*

Location of Upper Citarum River Basin is on the coordinate as follows: $107^0$15’36’’-$107^0$57’00’’ East Longitude, 06^{0}’43’48” - 07^{0}’15’00” South Latitude. This can be shown in Figure 2.

Figure 2. Location of Upper Citarum River Basin

Topographical data of the Upper Citarum River stream is on the elevation of 625 to 2,600 meter from sea level. The ilustration of this topography can be shown in Figure 3.

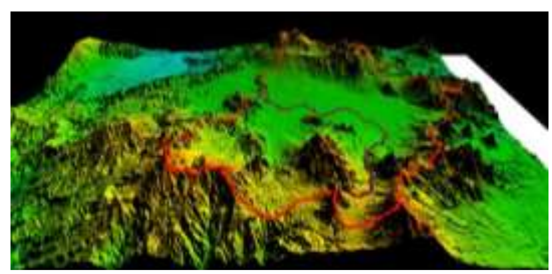

Figure 3. Topographical Model
Source: Source: PSDA West Java

B. *Hydrology Analysis*

Hydrology studies are necessary in order to determine peak flow rates or the design hydrograph, the focus of hydrologic flood modeling is to represent rainfall-runoff transformation. It is also often necessary to determine a predicted rainfall, as it is the basic input considered in this process. To determine a storm hydrograph can be carried out by the aid of synthetic unit hydrograph methods. The storm hydrograph peak flows for the catchment of Upper Citarum River Basin based on Nakayasu method and various return periods are presented in Table 1.

Table 1. Storm hydrograph peak flows(m^3/s)

Storm Return Period	Peak Flows (m^3/sc)
2	108.689
5	176.657
10	242.221
20	325.826
50	463.635

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C. Hydraulics Analysis

1D flow modeling with HEC-RAS is done to identify overflow potential along Citarum River for various storm return periods. Maximum water surface profile is shown in Figure 4. It shows that flow capacity along Citarum River cannot accommodate peak flow and causes river bank overflows entire the reach.

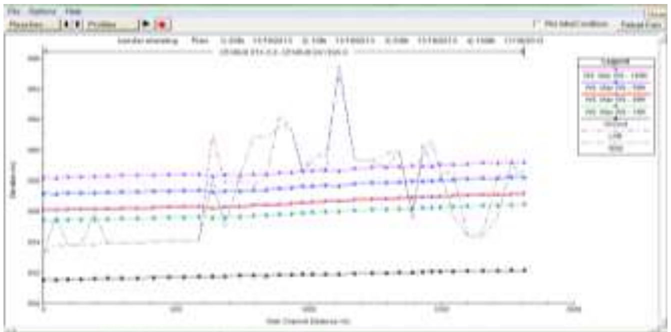

Figure 4. Maximum Water Surface Profile

D. Risk Analysis of Flood Impact

Risk analysis is used to quantify the magnitude of flood impacts. This calculate the direct and indirect impacts. The result of observation shows that the impact of loods is mostly in residential area. Any commercial and industrial facilities surrounding flood areas have been protected by their owner using barrier walls. The most damage houses were owned by the low to middle income peolple, which have no protection.

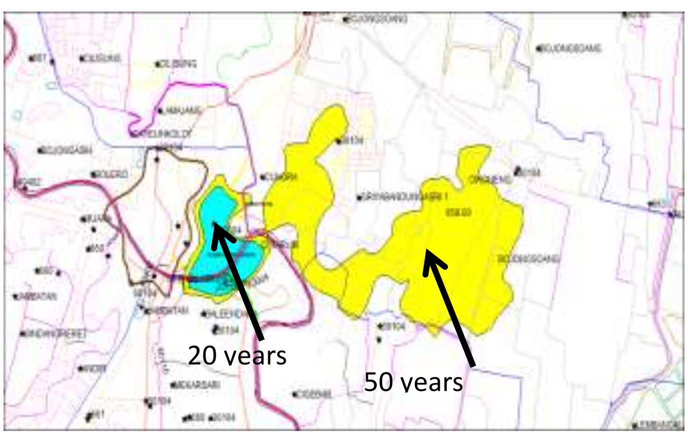

Figure 5. Flood area for 20 years and 50 years period

The area of flood area for 20 years and 50 years return period can be shown in the Figure 5. The south basin which is in the small area surrounding by higher elevation land This will be the most critical area in the occurance of high intensity of rain fall. The north basin has wider area, therefore it will receive a lower level of floods.

The focus of this research on evaluating the both basins especially in the most critical area. The direct impact of floods is calculated based on the residential damages and the reduction of productivity of people who suffer from floods. The calculation of indirect impact, which is focused on measuring the reduction of productivity of poeple due to any traffic jams occured during floods.

The population in this place is 55,967 people with 11,200 households in 11,000 houses. The everage of houses price is estimated Rp 100 million. The depreciation due to the floods is the highest, middle and lowest damages are estimated 50%, 20% and 5% respectivelly.

The data survey shows that the highest damage of flood area is 9-14%, mostlikely at 12%; the lowest area is 45-51%, the most likely at 48%; and in between is 40-41% with the most likely at 41%. The hydrology data shows that everage of possibility of occuring heavy floods is two times, middle floods is 10 times and small floods is 22 times annually. The result of risk analysis run by Crystal ball 2.0 with 80% confidence level is shown in Figure 6.

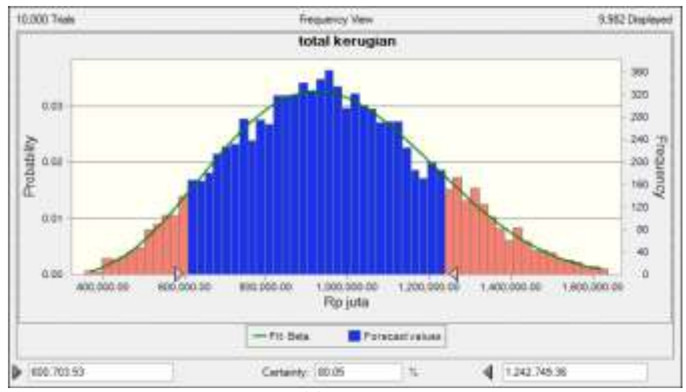

Figure 6. The direct impact of floods causing residential damages

The result of risk analysis shows in Figure 7 describes that the cost of residential damages per year is the mean at Rp 957.25 million, the minimum at Rp 600 million, and the maximum at Rp 1,240 million.

The reduction of productivity is calculated base on their absence to go work of people, who their residence are interference by floods. Based on the questionair, they consist of low until middle income with the everage of Rp 100 thousand/day. The number of productive age of them is in amount of 30% from the total population of this area. The number of absence is about 12 to 28 and the most likely 18 days per year. Using the same sofware is found that the mean, minimum and maximum of direct cost due the reduction income is Rp 2,990 million, Rp 2,060 million, and Rp 4,200 million respectivelly. Thus, the total of anual direct cost of floods in Bandung basin is Rp 3,947.25 million, Rp 2,660 million, and Rp 5,440 million.

The indirect cost, which is focused on the cost of traffic jam reducing productivity, consists of the interference during small, middle and high floods. The time of interferences 0.5 to 1 hour, 1 to 2 hour, and 3-5 hours respectivelly. This may cause the reduction of productivity is about 10%, 20% and 50% respectivelly. The number of vehicle is calculated based on the data of daily traffic passing the flooding road, which consists of 12,240 cars and 41,040 motor cycle per day. Based on the result of interviews, which is used as a representative

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data for all passangers. The reduction of car passenggers productivity is twice than the use of motorcycles. The standar income of the use of motorcycle is Rp 100,000.00 perday.

Using the same method as house damages, the result of total impact of the traffic jam has a significant value. The mean, minimum and maximum cost of reducing productivity of traffic jam is Rp 35,680 million, Rp 24,850 million, and Rp 47,130 million, respectivelly.

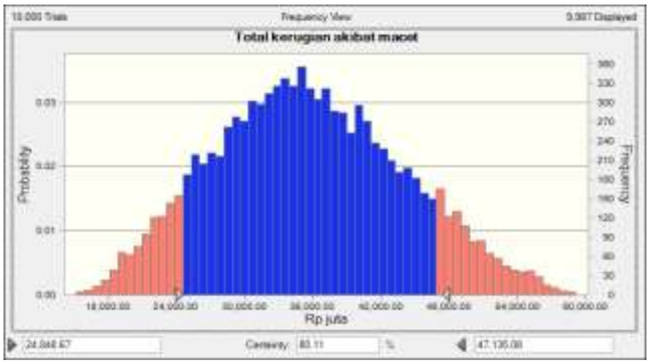

Figure 7. The indirect impact of fllods caused by traffic jam

The risk analysis result using economic paramerter shows that the traffic jam has higher cost compared to the residential damages using economic parameters. This indirect impact is usually not to be considered by the government because this influence is borne by many people. The sensitivity analysis shows that the most sensitive impact is due to the small flood. This means that although it has a small value impact but its repetition makes the accummulation value is higher than the greater impacts in small number of occurence. This can be ilustrated in Figure 8.

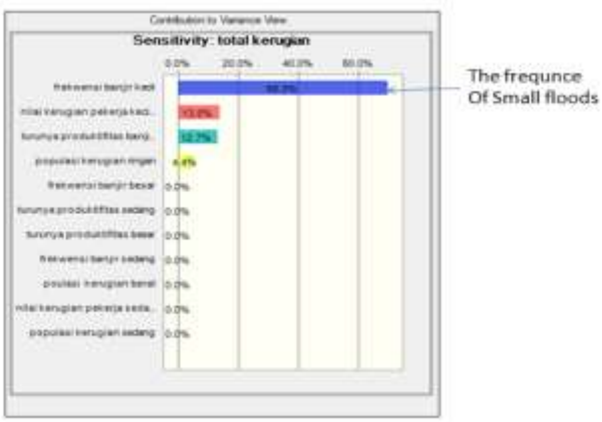

Figure 8. Sensistivity Analysis of the total impct of floods

This result desribes that the best solution of flood problems should not only focus on the direct impact but also on the indirect impact.

V. Alternative Solutions

Using value engineering approach, any alternative solutions to control floods will be generated following the result of function analysis carried out. Funcion Analysis in the case of Bandung basin floods is shown in the Figure 9. However, the implementation of this result should also be adjusted to the real situation of the site condition.

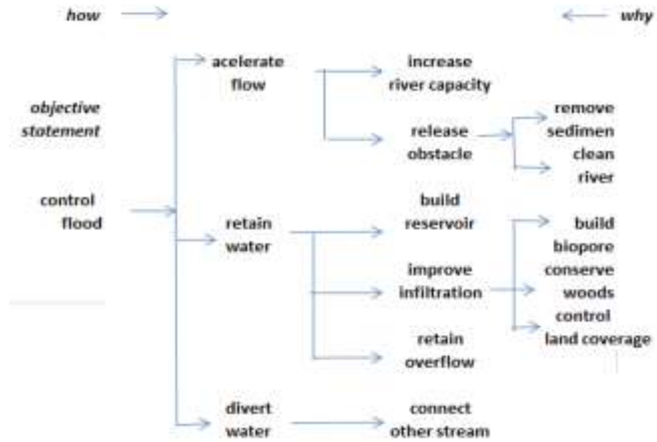

Figure 9. Function Analysis to Control Floods

There are some alternative funtions may be carried out: a) increasing river capacity, b) clean river, c) remove sedimen, d) build reservoir, e) retain overflow. The result of function analysis consists of two kinds: a) short term and b) long term solutions. The functions required should be carried out altogether, however, considering the objective of controling floods is an emergency need which should be done immediatelly, therefore the focus should on fulfiling the short term need. Increasing river capacity is classified a short term period which is related to cleaning river as well as removing sedimen. The cleaning river and removing sedimen alternatives are operational actions which have been carried out periodically. Increasing river capacity is very expensive which will be classified as the longterm period suggestion. The two possibilities building reservoir and/or retain the overflow are the most prospective alternatives. The diverting water is also considered as the additional solution, which is related to divert the stormwater before coming to the basin areas.

Functions of retaining overflows from the river as well as from the drainage system as well as building a reservoir could be done by many alternatives. The best alternative solution should principally fulfil the value for money criteria, namely effectiveness and eficiency. The effective retaining wall achieved if it may solve the floods overflowing from the river until 3m high. In term of effeciency refers to choose the minimum cost from any alternatives with the same or better output. The value added for any solutions which has additional benefits also considered.

The two alternatives of retaining walls created, the first is by using concrete wall structure and the second is by using flexible steel wall. The substructure of both alternatives with the same design using concrete foundation and small pile. The steel structure may also be used as diverting storm water but the concrete structure cannot be used.

VI. Optimisation

Optimisation process is carried out by comparing the effectiveness and cost effeciency of alternatives created. The first optimisation is to choose the level of flood to be considered, whether to use 10-20-50 years storm return period. The comparison is shown in the Table 2.

Table 2. The comparison of condition of floods

	Storm Return Period		
	50 years	20 years	10 years
Existing condition			
Volume of water overflow	204,999 m^3	137,019 m^3	102,219 m^3
The maximum height of overflow in South basin	3.38m	2.81m	2.13m
The maximum height of overflow north basin	3.88m	2.81m	2.13m
Using 3m Barrier wall			
Overflow of South basin wall	0.48-1.06m	0	0
Overflow of north basin wall	0.48-1.06m	0	0
The Use of reservoir and 3m barrier wall	0	0	0

Concerning with the peak discharge of 50 years storm return period, the simulation shows that the problem of floods in Bandung basin will totally be free from floods if it uses the 3m barrier wall and the use of reservoir. This reservoir was the unused river, which was the previous Citarum river stream before the normalisation was carried out. This combination is better than the solution which is only concerned with the solution either 10 or 20 years storm return period. This may improve the safety level because the trend of flooding due to the climate change becomes higher .

The second comparison considers to the cost of barrier wall, whether it will use a concrete or flexible stell structure. The length of the barrier wall of the basin is 300 m to protect water overflow from the river. This is shown in the Table 3.

Table 3. The comparison of Wall Barrier Structure

Aspect considered	*Concrete structure*	*Flexible Steel*
Effectiveness	Avoid flood	Avoid flood
Impact	Have a negatif impact for river aesthetic	no impact for river aesthetic
Initial Cost	Rp 2,994 million	3,887 million
10 years Maintenance cost	Rp 100	1,000 million
Total Cost	Rp 3,094	4,887million
Effectiveness	-	Avoid traffic jam
Cost	-	200 million
		83 million 283 million

The concrete barrier wall is the cheapest one, however, the panorama of the river will be covered by the wall, which may cause the problem of aesthetical performance. The flexible structure has the same effectiveness in term of avoiding river overflows without covering the panorama. It means the flexible stell structure has more benefits but more expensive. This means it can be choosen if there is no financial constraint to build it.

The last solution is to reduce or avoid traffic jam by using the flexible stell structure gate. This may use 1 m height steel structure to divert the water run off entering the basin, which is used as a road. This will divert the stream to the drainage system directing to the river before coming to the road of basins. This solution will stop the traffic during the heavy rain fall occured, however, it may reduce the duration of traffic jam because no water trapped in the basin area. The cost for this solution is approximatelly Rp 283 million, which is relatively low compared to its benefits.

VII. Conclusion

The contribution of value engineering in the problem solving of flood is to assure the objective achievement. This will be obtained during the process of thinking from identifying any functions required, generating alternatives until evaluating process to select the best one from any possible alternative solutions. This also accommodate exploring any valuable analysis which will direct the decision making process into the correct way. This value consideration process may also contribute in improving the quality decision making model is due to the use of integrated analysis relating the natural characteristic of floods, economic analysis of impacts as well as engineering analysis to solve the problem of floods. Those comprehensive analysis may achieve the best decision from some point of value considered.

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