# THE VALUE OF CITY INFRASTRUCTURES IN MITIGATING URBAN FLOOD RISKS

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**Abstract-** The provision of flood infrastructures is an important response in the process of mitigating risk floods in many countries. The two common critical impacts of urban floods are the damage of buildings in critical zones and the disturbance of commercial activities in wider areas including the occurence of traffic jams. In addition, the mitigation process of urban floods in developing countries also often faces socio-economic problems especially in associating with high density recidential buildings. This paper is concerned with the value of risk respons in the condition of complex problem solvings. Combining value and risk analysis as a research method is used as a tool in evaluating the process of problem solvings. The benefit/cost ratio is the criteria considered among available alternatives for achieving the best value solution. As a result, this paper suggests the provision of three infrstructures such as supporting infiltration, detention dam, and controlable city ponds which are located in some critical zones as a valuable solution.

**Key words-** infrastructures, urban floods, value engineering, risk mitigation

## I. INTRODUCTION

The trend of urbanization in many countries enhances the fast growth rate of building constructions in urban areas with less consideration to sustain environmental aspects. A common impact regarding this fast growth rate is the decrease of the infiltration capacity of land [3]-[5]. Then it increases run-off during rainfalls which potentially causes floods. Moreover, in developing countries the urbanisation also causes the growth of slums. They grow faslty without a proper environmental design. Some of them are built near the basin areas where become the critical zone of urban floods.

This paper is concerned with the way for achieving the best value of flood infrastructures to be applied in urban areas. The situation of floods in Bandung, Indonesia is chosen as the case study of this research. This represents a complex situation, which includes two specific situations. Firstly, the density of recidential buildings in the city is very high especially in slum areas. Secondly, there are some variation of topographical conditions due to this city is surrounded by hills. The research is focused on the catchment area of Citepus where is divided into three zones namely zone1, zone2 and zone 3.

The case of floods can be classified into two conditions. The first is the case of flash floods in zone2 caused by the high velocity of water overflows. This is derived by the steep slope of topographical conditions because the water flows from the hills to the lower elevation. The oferflows are due to the existence of buildings built near the river which shrinks its capacity. The second is the case of high floods in zone 3 where has a lower elevated topography. This is derived by changing the land use. It was previously a wet land area with high infiltration capacity then it becomes a high density recidential area with a very low infiltration. The aim of this paper is to investigate valuable infrastructures as the result of three researches carried out by the same team but different approaches in mitigating the risk of floods. The term of value is aimed at achieving a high value for money based on more benefits than its costs.

## II. LITERATURE REVIEW

Controlling floods in urban area is a complex problem to solve [1]. The idea of the Gravitational Models of Spatial Interaction states that any activity or evidence taking place in a city is like entropy within a system which may influence other elements of the city[2]. The flood is a kind of entropy which may cause a snowball effect on other city activities. This means that floods are the kind risks to be mitigated immediately in order to create a benefit for people who live in the city. A quick mitigation may potentially sustain their activities without disturbing the growth of the city's economic development. The value of mitigations is the provision of suite infrastructures agreeing on the need. The infrastructure is a long term investment based on its life cycle costs matching its life time design. The cost should be lower than the negative impact of floods including the future escalation if there are no responses.

The value achieved in problem solving is dependent on the satisfaction level of the stakeholders involved [8]. The use of value and risk analysis is a tool to achieve the best solution by reducing any potential risks. The support of people involved increases the value of the solution and this may also reduce the potential of future conlicts. The process of achieving value solutions is started by generating some alternative possible solutions. The process of generating alternative models to meet the requirement defined uses a kinematic similarity in which the ratio of prototype characteristic velocities scale to the model velocties [4].

Two comparable cases are considered in this research, the first in relation to NRC River Team who conducted an integrated revitalisation of the Whangrei River by increasing its capacity control [7]. The three engineering solutions are required to revitalise the Wangrei River such as increasing the capacity of river, eliminating any 'bottlenecking' flows and building some check dams to control the velocity of river flows [6]. Similar efforts were also conducted in Manuwatu, which built 53 detention dams to protect the city from floods in the period of between1960 to 1980 [9]. Those proven efforts show that any kinds of dams, if adjusted to its environment can effectively to be used to control floods in urban areas.

## III. RESEARCH METHOD

The method used in this research concerns with engineering and economic views. This combines the use of experimental models in a laboratory scale representing scientific engineering views with the qualitative and quantitative approach in collecting data from people involved representing social and economic views. The analysis is conducted by using value and risk analysis for evaluating the performance of models. The process can be divided into seven steps as follows:

- The first step: determining the research aim;
- The second step: collecting primary and secondary data, literature reviews, observation to the site, distributing the questionnaire to respondents and interviews.
- The third step: identifying the cause of floods and their impacts;
- The fourth step: defining the concept of solutions;
- The fifth step: generating alternative models which are to be tested and modifying them gradually as required;
- The six step: evaluating the selected models using benefit/cost analysis; and
- The seventh step: concluding the result.

## IV. RESULTS AND DISCUSSION

Source of Risks

The result of obseravations shows that there are different characteristic the source of risks in the three zones determined. The area of zona1 is 1035.52 ha which consists of two catchment areas 579.06 ha along Citepus Hulu River and 465.46 ha along Cilkalintu River. The tophograpical situation of zone1 has the slope is relatively steep, namely between 2,5% to 15%. This location is also surrounded by hills. The critical aspect of this zone is caused by its steep slope which may cause the high velocity of river flows which cuases the flash floods in zone2. The area of Zona2 is 604.12 ha which consists of two catchment areas 383.42ha along Ciroyom River and 220.92ha along Cilkakak River. The slope of zone2 is only 1.08% to 1.95%. The area of zona3 is 464.29 ha along Citepus Hilir River. Zone3 is the lowest elevated area. The flow of the river in zone 3 has a lower velocity than zone1 and zone2 because its slope is only about 0.54%, therefore the accumulation of water flows causes high floods. The quantification of risks is carried out by using the hydrological data under 25 years storm return period. The process of risk occurences is illustrated in Fig.1 below.

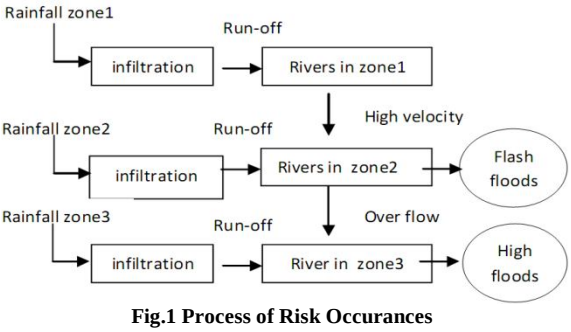



**Fig.1 Process of Risk Occurances**

### *Flood Impacts*

There are three impacts of floods considered, namely traffic jams, the interference of commercial activities and housing damages. The result of observations and processing data can be shown in the table below.

**Table 1: Total impact of floods**

| Impact of floods | Value of Impacts/year (Rp IRD million) | Value of Impacts for 20years (Rp IRD million) | (%) |
|---|---|---|---|
| Traffic jam | 10,886.42 | 217,728.40 | 28% |
| Commercial activities | 4,341.48 | 86,829.60 | 11% |
| Housing damages | 24,250.00 | 485,000.00 | 61% |
| Total Impacts | 39,477.90 | 789,558.00 | 100% |

### *Problem Solving*

The process of generating the idea of controlling floods is carried out by using the influence diagram process which shows two possible responses. The first is 'do nothing' response which may represent the existing condtions and the second is by providing infrastructures as a kind of responses. The response may represent three mitigation scenarios which be illustrated in the Fig.2.

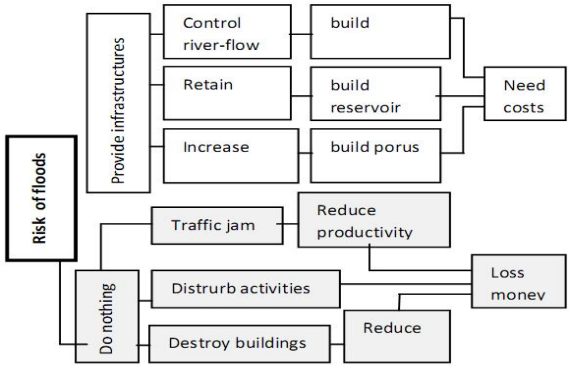



**Fig.2 Influence Diagram**

***Model***

Some models are developed to represent the three infrastructures required and are tested their capacity. The description of three tested models are as follows:

a) the supporting infiltration model: this model is developed in the form of a porous concrete instead of traditional trenches. This infrastructure is to improve land infiltration responding the decrease of infiltratrion in cities since the increase of building coverage coefficient allowed. This model has been tested and may infiltrate storm water up to 65% of land filled volumes. The use of this infrastructure will be built in the green land of each zone. The estimated number of uses allowed in the community is a point for 25m$^2$ up to 100m2 or the average of 50m$^2$ with the volume of each point is 1m$^3$. This may be built average of 120 points/ha in zone1, 60 points/ha in zone2 and 20 points/ha in zone3 agreeing on the building coverage allowed of 40% in zone1, 70% in zone2, and 90% in zone3. The result of tested models can be shown in the Fig.3 below.

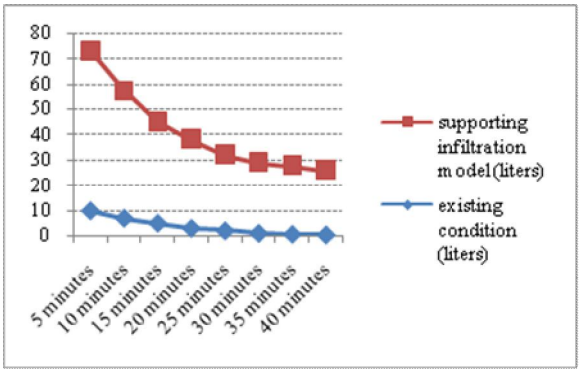



**Fig.3 Supporting Infiltration Model**

This scenario may contribute infiltration about 35.88m$^3$/ha in zone1, 17.91m$^3$/ha in zone2, and 5.91m$^3$/ha in zone3. The calculation refers to the 20 years storm return period with the volume of storm water is about 521 m$^3$/ha for the average duration of rainfalls about 10-30 minutes. The reduction of water run-off due the increase of infiltration in zone1, zone2, zone3 is about 6.88%, 3.44%, and 1.15% respectively.

b) the control river model: this model is to investigate the contribution of detention dam infratructures, called double box check dam. The design considers the slope of river bases which follows the topographical conditions. This model may be located in zone 1, zone 2 and zone 3 to control the river debits flowing from higher elevations to the critical area of zone2 and zone3. The use of this infrastructure is mainly to reduce the river velocity as the source of flash flood risks. However, this also contributes to reduce the floods in zone3. The concept of this design is by widening a part of rivers to be utilised as reservoirs in order to reduce the velocity of river flows. A ontrolable water gate is provided to control its debit.

The result of existing model experiments shows that the existing condition of river debits at the first station of zone1 is 18m$^{3/}$second whereas in the fifth station is 22m$^{3/}$second. The result of detention dam models experiments shows that the debit of the fifth station becomes 6m3/second. The reservoir capacity of this detention dam required is 2,000m3 for the distance of 100m. This result shows that the use of the detention dam has reduced the river velocity becoming 33% from the initial velocity. The result of double box models is shown in the figure below.

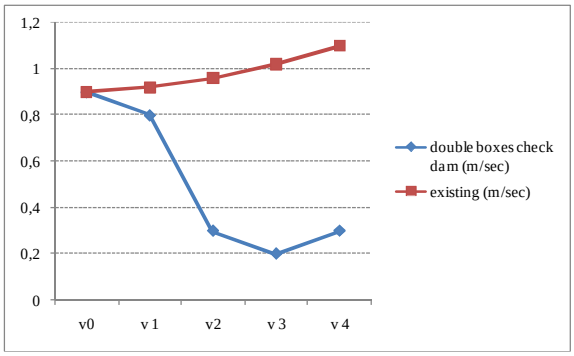



**Fig.4 Velocity Reduction**

Based on the estimation, it needs the land area of 54,302m2 to eliminate the risk of flash floods in zone2. The depth should be adjusted to the location following the river's base. This may also contribute to reduce the water volume sent to zone3 of 46%.

c) The reservoir model: this represents a pond which may be built by either a Local Authority or local people. This reservoir may retain residual storm water flows which cannot be coped with the supporting infiltration and control river models. This is a flexible model which may be built in many places. The capacity of reservoirs is dependent on the availability of land areas and the affordability of people lived in each zone to build them. The capacity of zone3 is the lowest because the building coverage allowed very high and there are mostly from the low-medium income poeple. The zone1 has the highest capacity and the capacity of zone2 is in between of the two zones. Based on the existing condition, the capacity of possible reservoirs in all zones is about 59.18% of total storm water run-off. The result of tested model can be shown in the Fig.5 below.

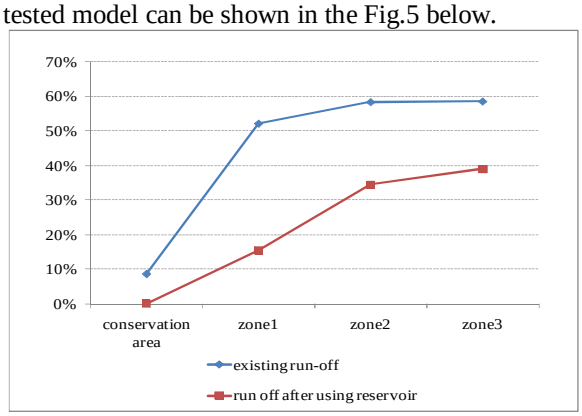



**Fig. 5 Reservoir Capacity**

This model as well control river models are the two efforts to involve poeple who live in higher elevation to make a contribution for reducing floods in lower areas. The participation of all parties to involve in controlling floods is a suitable solution to be implemented in developing countries. The solutions with the involvement of all parties altogether are the best real response to be implemented. The risk of floods should not only be borne themselves by people who are suffered from floods but also should be helped by people who have a capacity to do it. Although the occurrence of floods is often in the lower elevated areas, it is however, the higher elevated areas may also contribute to solve the problem of floods. Moreover, the provision of small infrastructures in some places by many poeple may also distribute its cost. Moreover, it will be more applicable if the local government may also support its implementation by issuing the regulation.

The result of evaluation shows that the value hierarchy using benefit/cost ratio shows that the best value is the infiltration model, the second is the reservoir model and the last is the river control model. The potential capacity of those models is 17% more than the target. The best solution to meet the target may be achieved by utilising the supporting infiltration and reservoir models in full capacity and reduce the use the river control model. The summary shows in the table below.

**Table 2: The Contribution of Infrastructure Models**

| Model | Potential Contribution | Cost (Rp IDR million) | The best contribution | Cost Rp (IDR million) |
|---|---|---|---|---|
| Supporting Infiltration | 11.82 % | 40,000 | 11.82% | 40,000 |
| Reservoir | 59.18 % | 143,990 | 59.18% | 143,990 |
| River control | 46% | 489,804 | 29% | 308,789 |
| Total Capacity | 117% | 673,794 | 100% | 492,779 |
| Benefit/cost ratio | 1.17 | | 1.60 | |

## CONCLUSION

The mitigation of flood risks in urban areas may be solved by providing flood infrastructures in order to sustain their economic activities. The use of infrastructures which may support increasing land infiltration is the most valuable function. These should firstly be developed to respond flood risks because they are not only effective and efficient infrastructures but also have an additional contribution in recharging the water tabel of cities. The existence of rivers has a siginficant contribution to catch and flow storm water to the sea. However, it needs a control in the form of detention dam infrastructures. This is important infrastructure to cope with the problem of flash floods as the consequence of topographical variations. City ponds are the most powerfull infrastructures to contro floods in a city when the capacity of land infiltrations and rivers cannot cover the problem of floods. The three kind of infrastructures may proportionally be combined as required agreeing on the condition of cities.

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