

**DEVELOPING AN AHP-BASED MODEL FOR EVALUATING MITIGATION PROGRAMS  
FOR FLOOD DISASTER: CASE STUDY IN JAKARTA, INDONESIA**  
*Pengembangan Model AHP-Based untuk Mengevaluasi Program Mitigasi Bencana Banjir :  
Studi Kasus di Jakarta, Indonesia*

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**Abstract**

*Throughout the centuries flood disasters have taken a loss of human lives property damage, and economic impacts all over the world. In Jakarta, Indonesia, various alternatives of strategies after flood disasters have been implemented during the past reconstruction project due the high severe damage losses. Unfortunately the programs just issues, based on the damage and losses assessment after recent disasters happened, it indicated the necessity of better flood disaster management for future life's people in Indonesia. The research focused on flood disaster mitigation program and used as some implementation program from other countries for comparison to propose an appropriate design of mitigation and planned. The approaches use the Analytic Hierarchy Process (AHP) as a decision analysis tool, in order to develop a Program Evaluation Model (PEM) for flood disaster management in Jakarta. In addition, data will be gathered through direct survey with experts. The PEM's concept is concerned with the selecting the major factors which influence the management of flood disaster in Jakarta, and use the identified factors to evaluate different flood mitigation program from other countries (Taiwan, Japan, Netherlands, United States, and United Kingdom).*

*Keywords : AHP, Flood, Jakarta, Mitigation, Post-flood disaster.*

**INTRODUCTION**

Disasters are repeated events that may strike at random but impact on both the rate and pattern of development (Arriens and Benson, 1999). From the beginning of time, water has been a major determinant of settlement development and accounts for the situation of many ancient towns along river bodies since civilization. The city of Jakarta commonly refers to the administrative unit DKI Jakarta (Daerah Khusus Ibukota, or special district of the capital city). DKI Jakarta is one of the 33 Indonesian provinces and further comprises five municipalities (North Jakarta, South Jakarta, West Jakarta, East Jakarta and Central Jakarta). Located in a low-lying plain area close to the sea, Jakarta is particularly exposed to flood risk. In the years 1996, 2002, 2007, and 2013 Jakarta experienced large scale flooding. The last major flood happened in 2013. In January 2013, heavy downpours within and around Jakarta resulted in excessively high river and dam levels

Various alternatives of strategies after flood disasters have been implemented during the past reconstruction project due to the high severe damage losses in Indonesia, unfortunately based on the past reconstruction project, the programs suffer from recurrent issues/problems, such as cultural or climatic inappropriateness, poor location, and social problems inside the area. Based on the damage and losses assessment after recent post disaster happened in Indonesia, it indicates the necessity of better flood disaster management for future life's people in Indonesia, especially in Jakarta. The result from this study are a set of preliminary design of alternative for flood disaster management and also

create a new design programs which never implemented in Jakarta to overcome floods which adopted from other countries.

Evaluation and selection of programs are a typical multiple criteria decision making (MCDM) problem involving multiple criteria that can be both tangible and intangible. The analysis of criteria for selecting and measuring the programs of mitigation has been the focus of many researchers and purchasing practitioners as to provide a comprehensive view of the important criteria in the programs selection decision (Noorul Haq A, 2006). In this study, a very comprehensive application of Analytic Hierarchy Process (AHP) for a case is presented along with sensitivity analysis to choose the best alternatives; the AHP is designed to solve complex multi-criteria decision problems. It is based on the innate human ability to make sound judgments about small problems. It facilitates decision making by organizing perceptions, feelings, judgments, and memories into a framework that exhibits the forces that influences a decision (Saaty, 1990).

## **LITERATURE REVIEW**

Jakarta, located on the northwest coast of Java, is the economic, political, and cultural capital of Indonesia. The metropolitan area, Jabodetabek, is the 6th largest metropolitan area in the world with a little under 20 million people. About 9 million people live in Jakarta itself, in an area of 660 km<sup>2</sup> (Forstall, 2004) 13 natural rivers intersect the city. The biggest river, the Ciliwung, finds it origins South of Jakarta, near the volcano Mount Gede.. As a mega metropolitan region, Jakarta itself is extremely densely populated relative to Jabodetabek,

More than a quarter of Jakarta's area was affected by flooding in 2002. However, the most disastrous flood to date, occurring in February 2007, displaced more than 400,000 people, and destroyed 1,500 homes, damaging many others. Total losses to property and infrastructure were estimated at USD695 million (Worldbank, 2013). Extreme weather events bring on overloading of the existing drainage system, while sea level rise coupled with land subsidence is making Jakarta progressively vulnerable to tidal floods along its coastal edge. Extreme weather events bring on overloading of the existing drainage system, while sea level rise coupled with land subsidence is making Jakarta progressively vulnerable to tidal floods along its coastal edge. Along with seal level rise, land subsidence is one of the problems facing Jakarta. Furthermore, there is currently no city-wide solid waste management plan for Jakarta.

### **Identification of Vulnerability and Flood Risk**

(Wisner, 2004) introduces the concept of the evolution of vulnerability. It suggests that the vulnerability is produced gradually and exacerbated by the social political setting involved in process. Therefore it is important to understand how the development occurs in JMA (*Jakarta Metropolitan Area*) and how it contributes to the increase of vulnerability. The vulnerability in Jakarta and JMA is increased by exposing more people, properties, and infrastructure in the flood prone and low lying areas.

**Table 1. Historic flood in Jakarta, Indonesia**

No	Year	Effect
1	1699	Ciliwung river flood “Oud (Old) Batavia “after Mount Salak erupts
2	1714	Ciliwung river overflows after clearing forest areas in Puncak
3	1854	“Nieu (new) Batavia” is a meter underwater, caused by the raging Ciliwung
4	1918	Extensive flooding. The Dutch colonial government begins work in the Western flood canal
5	1942	The Canal is completed, but Jakarta still floods
6	1996	A flood sweeps through the capital. Approximately 10 people die
7	2002	The Dartmouth flood observatory notes it as the largest flood in Jakarta’s history, 25 people died
8	2007	The greatest flood to hit Jakarta in the last three centuries
9	2013	A 30-meter long section of Jakarta’s West flood canal dike on Jalan Johannes L in Menteng collapsed. Up to 20.000 people was evacuated.

Source:(WHO, 2007)



**Figure 1. Floodwaters in Central Jakarta in January 2013**  
 Source : *The Jakarta Globe*, January 18<sup>th</sup> 2013

**Adoption of Alternative Selection methods**

There is no specific method for every problem because each problem is unique. A number of studies have been devoted to examining vendor selection methods. The common conclusions of these studies is that the adaptation is a Multi Criteria Decisions Making (MCDM) problem (Nydick RL 1, 992). The procedure will carry out comprehensive evaluations of alternatives and objectives for the purpose of selecting the best alternatives. Identification of these objectives or requirements constitutes an important component of the MCDM (Saaty, 1980).

AHP is a multiple criteria decision-making approach based on the reasoning, knowledge, experience, and perceptions of experts in the field. It is a robust technique that allows managers to determine preferences of criteria for selection purposes, quantify those preferences, and then aggregate them across diverse criteria. AHP avoids the main drawback of the traditional linear scoring model, which assigns weight and scores arbitrarily. At the same time, it can make trade-off between the quantitative and qualitative criteria. The important advantages of AHP are its simplicity, robustness, and the ability to incorporate “intangibles” into the decision making process (Saaty, 1980).

**RESEARCH METHODS**

**AHP - Based Model Development**

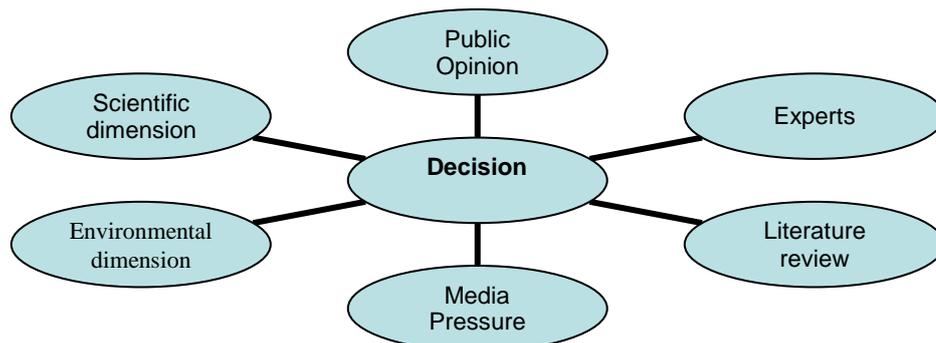
The main objectives of this research were first of all identifying the difficulties and relevant issues of the rehabilitation and reconstruction plan in Indonesia after flood disaster. The second objective of this research is using these selection issues or criteria and the AHP to develop a new mitigation

program. Finally determine the new mitigation include which can address the difficulties and can be suitable for Jakarta, Indonesia.

According to (Al-Besher, 1998), the first step to make structural hierarchy is breaking down a complex issue into different levels is particularly useful for a group with widely varying perspectives. In order to derive a particular set of criteria and employ pair-wise comparisons of selection criteria for use in this study, it is necessary to identify the influential factors to do that. Factors of vulnerability were identified as a result of literature review, public opinion, and survey agency/ experts. These criteria were used as major factor that must be considered during the mitigation selection process and also will contribute to establishment of minimum and acceptable requirements to the selection of the best mitigation program. Several factors that influence the characteristics of the tidal flood in Jakarta, and it shown in Table 2

This goal is placed on the first level of the hierarchy, thus three main major to be considered when different flood management programs are evaluated for Jakarta, namely the flood control facilities, environmental aspects, and social aspects, are identified to achieve this goal, which form the second level of the hierarchy. The third level of the hierarchy is 13 sub-criteria. The criteria and sub-criteria used in these two levels of the AHP hierarchy can be assessed using the AHP approach of pair-wise comparisons of every factor on each level. All these with corresponding sub-criteria are presented in an aggregated manner in Figure 3.

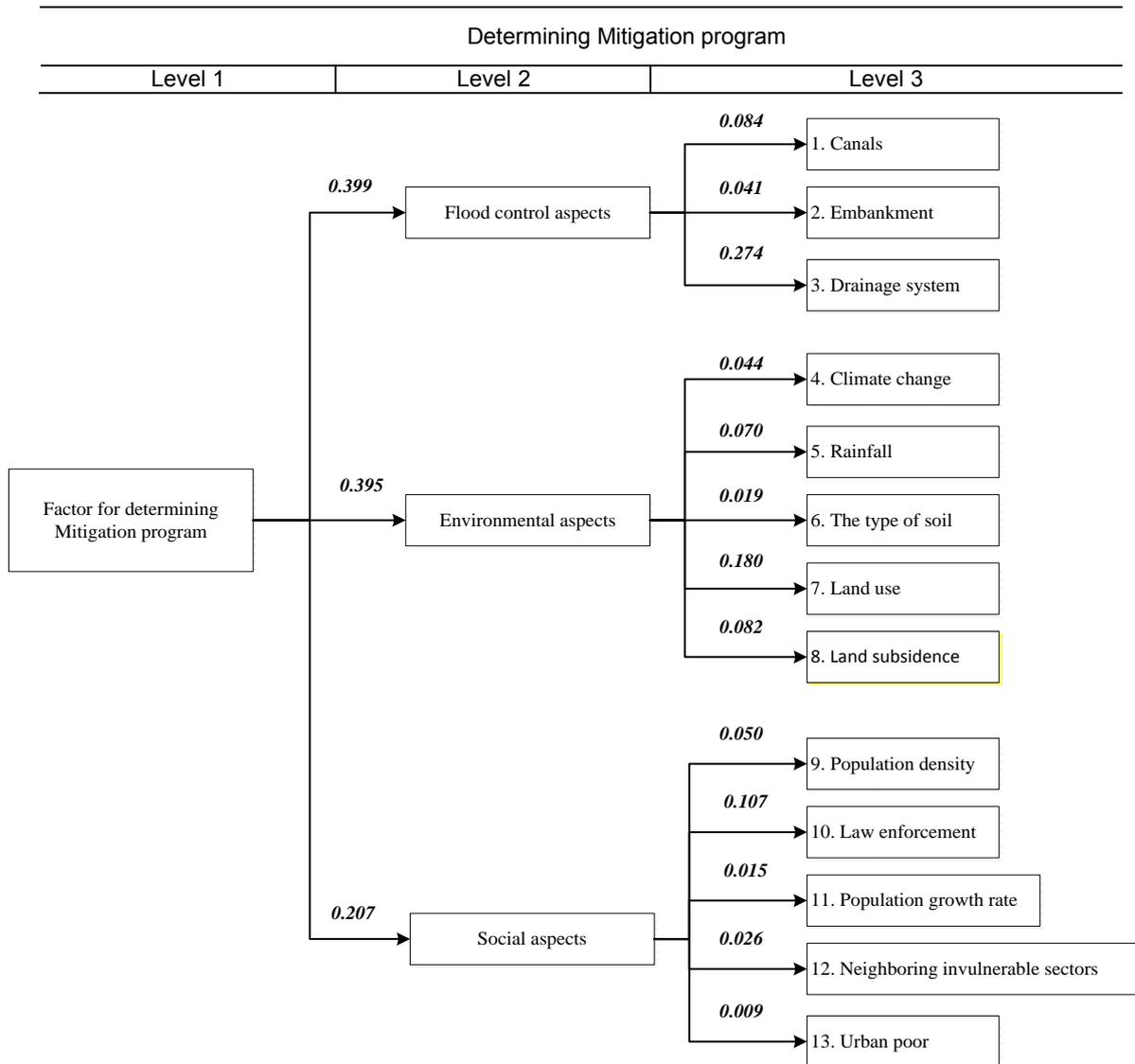
In order to determine the weights of factors based on the AHP, the predetermined criteria and sub-criteria must be objective. According to descriptive analysis and interview stakeholders i.e. National Disaster Management Agency, the factor for determining mitigation program are identified, then the next step in developing the PEM is to list the program evaluation model available for selection alternatives. All the criteria are compared fairly to determine their relative weights. To find the final (global) weight of each sub-criterion is the main criteria weighting are multiplied by the corresponding sub-criteria weighting.



**Figure 2.** Development AHP model

**Table 2.** Factor for determining program

No	Criteria	Sub-criteria	Reason
1	Flood control facility aspects	Canal	In real condition Jakarta is already overpopulated. In the west flood canal, as well as trash and sediments carried by human activities into the channels. Siltation reduces the capacity of the west flood canal
		Embankment	According to Jakarta's experience in 1996, 2002, 2007, and 2013. The embankment along in the east of Jakarta can't handle when flood come. In the 2013 Jakarta flood, recorded water level data and a simple scour analysis, it can be surmised that the mechanism of failure of the west drainage canal embankment at Lathari was likely overtopping of the embankment.
		Drainage system	In the 2013 Jakarta flood, In northern Jakarta was the failure of the pumps at pluit. Due to inadequate maintenance and poor solid waste management, there is significant sediment and solid waste build up in these channels. It can't cope with the amount of water.
2	Environmental aspects	Climate change	Jakarta is now highly vulnerable to the impacts of climate change. It's natural phenomenon. Yet, the Jakarta administration still does not have a strategy to design and implement flood management to deal with climate change
		Rainfall	According to the 2013 Jakarta flood, heavy rainfall in and around Jakarta city due to tropical monsoon may have been a main factor contributing to the flood.
		Type of soil	Type of soil in Jakarta has coefficient of permeability which is very small or $k < 0.00001$ cm/s. This means that the water will flow very slowly when flowed.
		Land use	Rapid urbanization of Jakarta city due to economic growth and a rapid increase of the population in the city also contributing increase the flood risk in Jakarta. Change in land use and land cover from vegetated to urbanized land has resulted in a reduction water infiltration from the land surface to ground
3	Social aspects	Land subsidence	As Abidin et all (2007) argue that the land subsidence in several of Jakarta reached up to 80 cm during 1982-1991; 160cm during period 1991-1997; 20cm during 1997-1999. A worrying prospect is that subsidence is still ongoing and according to recent measurements, the rate increases.
		Population density	Because Jakarta is the megacity in Indonesia, the population of Jakarta has consistently increased every decade and become overpopulated, this affect to unbalance ratio between population and its area
		Law enforcement	One of problem in term of Ciliwung river is illegal residential. The densely populated banks of the Ciliwung river in Kampung Pulo, East Jakarta, one the area hit hardest by the flood, could be the priority.
		Population growth rates	As the Jakarta post 2013, Jakarta's population has doubled within just 40 years from 119 million in 1971 to almost 240 million in 2010. It indicated to land use aspect – Land subsidence – Flood happened
		Neighboring in vulnerable sectors	Many of neighboring is extremely vulnerable to the hazards, because they tend to settle near bodies of water like Ciliwung river, canals, and reservoir.
		Urban poor	The urban poor have important role to play in addressing Jakarta's vulnerability to climate change and disasters. They live in self-constructed settlements like under of bridge.



**Figure 3.** The final hierarchy with global weight of factor affecting determining mitigation programs

After determining the criteria and sub-criteria used in the selection of major factors, the criteria and sub-criteria were inserted in in the second questionnaire survey. Group decision team were was requested to compare each programs from different countries (Taiwan, Japan, Netherlands, United States, and United Kingdom) by identifying to what extent one criterion is more/less important/preferred to some program from other countries. Researcher has selected some of the programs that are considered important and have not been implemented in Jakarta, Indonesia. The second questionnaire was established, the content validity test was conducted by consulting by 5 experts from Indonesia (National Disaster Management Agency; Indonesian Agency for Meteorology, Climatology, and Geophysics; Lecturer of Brawijaya University; Ministry of Public works; Practitioner and Consultant). The first was requested to evaluate and identify whether the questions agreed with the scope of items and to know that the questionnaire was designed enough to provide relations and between variables. The experts did agree that the questionnaire was valid and suitable enough to measure the concept of interest with real condition in Jakarta.

## RESULT AND ANALYSIS

The respondents were asked to provide their opinions on the importance of the mitigation program selection used in the questionnaire by scores 0, 25, 50, 75, 100, where "0" represent the least important and "100" the most important.

**Table 3.** Relative importance and ranks for Jakarta's program

No	Program	Value					Total	Average	Rank
		R1	R2	R3	R4	R5			
1	East and west flood canal	50.20	85.60	65.33	50.20	86.63	337.95	67.59	4
2	Maintenance of river in 14 location	71.68	83.63	81.65	68.60	83.63	389.18	77.84	3
3	Take anticipant and making embankment	35.23	61.40	53.25	34.58	60.75	245.20	49.04	6
4	Pump construction	32.38	70.55	67.83	30.70	70.55	272.00	54.40	5
5	Watershed management	99.65	86.45	65.10	99.65	86.45	437.30	87.46	2
6	Drainage system	99.43	86.93	72.70	99.43	85.18	443.65	88.73	1

**Table 4.** Relative importance and ranks from other countries

No	Program	Value					Total	Average	Sub-field rank	All rank
		R1	R2	R3	R4	R5				
<b>Taiwan</b>										
1	Reservoir detention	73.83	79.10	72.93	73.83	66.73	366.40	73.28	3	13
2	Establishment of flood warning system	79.15	66.03	93.95	79.15	58.80	377.08	75.42	2	12
3	Coastal protection	96.88	95.85	63.20	96.88	94.83	447.63	89.53	1	3
4	Flood insurance	56.23	62.03	91.50	53.93	32.10	295.78	59.16	4	15
<b>Japan</b>										
5	Flood hazard map	89.73	85.13	96.75	80.38	91.90	443.89	88.78	1	5
6	Safety level using Air bone laser surveying technology	68.33	89.38	78.75	66.90	79.03	382.38	76.48	2	10
7	TEC-FORCE	72.43	87.18	58.40	69.28	76.55	363.83	72.77	3	14
<b>Netherlands</b>										
8	"Room for the river program"	89.55	99.63	83.73	89.55	99.25	461.70	92.34	2	2
9	Multi-layer safety for flood risk management	71.95	92.05	67.20	71.95	82.65	385.80	77.16	3	9
10	Developing a sustainable spatial planning	93.20	93.95	90.95	93.20	91.90	463.20	92.64	1	1
<b>United States</b>										
11	Adapting to climate change	95.55	83.53	65.83	95.55	82.88	423.33	84.67	2	7
12	National strategic infrastructure framework	79.58	99.45	89.10	79.58	94.70	442.40	88.48	1	6
13	Flood risk communication	79.58	91.43	68.13	49.20	89.68	378.00	75.60	3	11
<b>United Kingdom</b>										
14	Managing the risk of flood and coastal erosion	93.58	92.60	75.08	93.58	91.58	446.40	89.28	1	4
15	Land use change and flood risk management	79.68	91.50	71.65	79.68	88.48	410.98	82.20	2	8
16	The flood forecasting center	77.63	73.68	62.63	47.25	32.03	293.20	58.64	3	16

According to the result of the questionnaire for Table 3, all of the respondent rank “drainage system” as the first rank with total average equal 88.73 then followed by “watershed management” as the second rank with total average equal 87.46. It’s mean that all of factor selection method or vulnerability factor have big contribution to drainage system and watershed management program. The currently implemented programs should be upgraded. The objective of this area is to maintain the conservation function for sustainable water supply and flood control of downstream, but in this area the housing and settlement development is still dominant.

According to Table 4, there are top five ranks which are related from opinion’s experts. The top five programs means that the programs have related with 13 sub criteria of factors affecting determining mitigation program and the experts evaluated, give prioritize for the top five programs. These programs have biggest potential benefit for Jakarta, Indonesia.

### **1. Development sustainable spatial planning**

The Netherlands was one of the first countries to develop this program. To adopt this program, Jakarta should resolve their problems/ challenges: reduce greenhouse, gas emission and accelerate transition to more sustainable energy sources, use the limited space in Jakarta with strong law enforcement and integrated water management. To improve the spatial quality of Jakarta, need the spatial improvement program.

### **2. Room for the river program**

The objectives of this program for Safety: improving flood protection in the rivers region up to the required level, and spatial quality: contributing to improving the spatial quality of the river region.

To adopt this program, Jakarta should learn how Netherland planed this program, and the important this is to make negotiation with people who lives in Jakarta to do this program.

### **3. Coastal protection**

Coast seawall is the first line of defense function to reduce the impact of tide on the coast in Taiwan. Development within coastal area has increased interest in erosion problems; it has led to major efforts to manage coastal erosion problems and to restore coastal capacity to accommodate short- and long-term changes induced by human activities, extreme events, and sea level rise. In Indonesia, coastal erosion started in the northern coast of Java Island in the 1970s. US\$79.667 million was provided by the Indonesian government to combat coastal erosion from 1996 to 2004, but in 2013 flood happened in Jakarta. To adopt this program, Jakarta must understanding the key process of coastal dynamic and how coasts developed in the past and present, because coastal erosion may occur without cause for concern.

### **4. Managing the risk of flood and coastal erosion**

The national FCERM strategy in UK provides a framework to enable the organizations involved in flood and coastal risk management to work together with communities to improving the detection and forecasting of floods and the provision of flood warnings. The strategy also set out the main measures or actions that need to manage risk. These include:

- Improving understanding of the risks of flooding and coastal erosion, making sure that any flood and coastal risk management plans use the most-up-to date information and raise awareness of these risks among affected communities.

- Avoiding inappropriate development in areas of flood and coastal erosion risk.
- Reducing the risk of flooding from rivers, the sea and reservoirs.

Jakarta can adopt this program, making combining between exist regulatory role in with this police.

##### 5. Flood hazard map

Flood hazard map will be useful in Indonesia to complete the early warning system that has been developed. In making FHM surely will involving many government organization, university, and community to flood fighting. To adopt this program, Jakarta has to face our problem about financial aspect because the local government is facing many problem to solved e.g. mass transportation, housing for unfortunate's people, etc. In Indonesia the organization that should designate is the Ministry of Public Works.

**Table 5.** The relationship between "Room for the river program" with 13 sub criteria

No	Sub criteria	Description
1	Canal	With this program, Jakarta can handle lack of canals recently happened. Because this program have measures to make high-water channel which can make the main river discharge some of the water via a separate route
2	Embankment	The embankment is the first line to prevent the flood damage happened, but in Jakarta, the capability of embankment is not enough, so this program can strengthen the weakness of embankment in Jakarta
3	Drainage system	When the existing drainage system can't handle heavy rainfall, this program can provide second channel to evacuate the water.
4	Climate change	It's natural phenomenon, this program can improve existing drainage system to face the extreme change of the weather.
5	Rainfall	Because of the climate change, it will strengthen the rain than before, the increasing of capacity of river basin can provide enough space when the flood come
6	Type of soil	The permeability of soil in Jakarta is $k < 0.00001$ cm/s, will easy to cause the obstacle of drainage system, especially the existing drainage system lack of the space to storage the accumulate soil and water. The advantage of this program is the created river basin can help to improving the spatial quality of riverine area, and promote the capacity of river or drainage system to against the flooding simultaneously.
7	Land use	Highly develop of Jakarta cause the change in land use that reduction water infiltration from the land surface to ground. But this program make a lower river basin to increase the flood storage capacity can avoid the over-use of land.
8	Land subsidence	The land subsidence will cause the river bed higher than ground level. But this program will lower the flooding plains and relocation dyke far away than before, its will reduce the risk of flooding damage.
9	Population density	The development of the river bed has a negative impact on the ecosystem and makes an uncertainty about future levels of risk. Especially the highly density of population in Jakarta, it will force the poor to develop it or be distributed to live in sub urban section. Therefore, the relocate of dyke can increases the width of the floodplains and provides more room for the Ciliwung river then can strengthen the safety capacity.
10	Law enforcement	There are illegal residential along Ciliwung river, this program can help government to reclamation for the resident for people who lives in this area and remove obstacle under the bridge, but the face problem, Jakarta's government makes negotiation.
11	Population growth rates	The growth rates of population will cause the more development of urban city and cause low capacity of against flooding. Thus this program can promote the safety of flooding and water quality that can supply the increase of population.
12	Neighboring in vulnerable sector	When flooding come the vulnerable sector is inevitable be damaged, thus this program will divide the river into two part to reduce the vulnerable section of river.
13	Urban poor	The poor in Jakarta extremely vulnerable to the hazards, the urban poor also contribute to the overall susceptibility of Jakarta to the effects of climate change. Therefore this program can make the construction of a green river which would serve as a flood bypass, it will result in lower flood levels if government can't handle urban poor problem.

## CONCLUSION AND RECOMMENDATION

### Conclusion

The research concludes that there are a large set of the factor for determining mitigation program in Jakarta, Indonesia. These factors are developed and ranked by experts in order to understand their view with the help of questionnaire survey and used AHP. The major factors were identified and ranked, as follows Environmental aspects, Flood control facilities, and Social aspects.

The PEM was developed and implemented for solving the complicated selection problem. The PEM's concept is concerned with selecting the major factors which influence the management of flood disasters in Jakarta, Indonesia and use the identified factors to evaluate different flood mitigation programs from other countries based on AHP.

Five programs are already identified, the evaluation was conducted by consulting from experts. The experts agree the top 5 rank programs are suitable to be implemented in Jakarta, Indonesia.

### Recommendation

- The model can be used in the evaluation and selection of the best program from another country's programs
- The flexibility of the model enables the user to modify it as required
- In the future, this study intends to develop such a new system for generating post-flood disaster reconstruction plans.

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