Flood Management Model in Digital Era, Using SAST (Strtategic Assumption Surfacing and Testing) and the Exponential Comparison Method (ECM): A Case Study in Jakarta

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Flooding is a regular annual disaster in Jakarta, especially in December to February. Geographical position of Jakarta which is 40% below sea level, causes flooding not only from rain, but also from rob due to rising sea levels. In the last 5 years the impact of flooding became more serious, leading to economic and human losses.

This study aims to determine the right strategy of flood mitigation by public involvement in the digital era. The method used includes combination of quality input data from experts representing BNPB (National Disaster Agency), Local Goverment, Academics, Community Leaders, Businessmen, and Practitioners, in addition to vulnerable field research. Data analysis uses the ECM (Exponential Comparison Method) and SAST (Strategic Assumption Surfacing and Testing).

The result of the study indicates that the most appropriate strategy to mitigate flood disaster is establishment of "Disaster Information Center" and "Disaster alert groups" involving every stakeholder from the community. Utilization of social media, especially WhatsApp, Facebook, and Instagram has been very helpful to share information of flood, especially how to prepare an emergency action to reduce economic and human losses.

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1. INTRODUCTION

Jakarta faces devastating routine flood almost every year. The height of the flood waters in the last 5 years (2013-2017) on an average has reached 4 meters, usually within a time span of 4-8 days. The most devastating flood occurred in 2013 with a maximum water height of 4 meters for more than 5 days. Economic losses exceeded more than 20 trillion dollars [1]. One of the causes of human casualties during floods was drowning (44%), [2]. Floods come without warning and they take lives of tens, hundreds and thousands of people. The resulting loss depends on the vulnerability and lack of resilience of the affected population to resist the hazard. If this type of disasters continue it would lead to considerable socio-economic losses, leading to prolonged setbacks to a large number of citizens the land is affected during floods due to overflowing of 13 rivers crisscrossing Jakarta. The rivers include Ciliwung River, Pesanggrahan River, Kali Baru River, Krukut River, and others. When the rain falls, the overflow of water from the 13 rivers submerges most of the area of Jakarta, especially several densely populated villages.

Of the 13 rivers surrounding Jakarta, Ciliwung has the most extensive impact during the rainy season, because it flows through the center of Jakarta and crosses many villages, crowded markets, and densely populated slum residential areas.

The floods in Jakarta are getting worse in last 5 years, in addition to the damaged watershed (DAS) in the upstream of Puncak and Bogor. The watershed in Jakarta has also experienced narrowing and siltation due to illegal buildings along the river. Flooding in 2013 was the worst and its impact was extensive; average inundation height was 1-3 meter with duration of 20 days. Loss of economic potential reached IDR 20 trillion, 20 people died and 33,500 people were displaced [3,4].

To anticipate flooding, the Government of Jakarta has built East Flood Canal (BKT) and West Flood Canal (BKB). BKT with a length of 23.5 km was built with the aim of protecting the East Jakarta and North Jakarta areas from the overflow of Ciliwung, Cipinang, Sunter, Buaran, Jatikramat, and Cakung rivers, due to water flow discharges at the peak of the rainy season, which was not accommodated. Whereas BKB, with a length of 17.4 km, was built to drain water through the Angke River through the Krukut Canal to accommodate water overflows from Ciliwung, Krukut River and Cideng River, which will then be channeled to the sea.

Along with the development of the city of Jakarta and its surroundings, the construction of the two canals to drain rainwater is found not adequate. Water overflows caused by overland floods or due to heavy rains still submerge some parts of Jakarta. In addition there are around 400 business activities that directly or indirectly dispose of their wastewater including solid waste into Ciliwung River [5]. There are 26,818 households, who inhabit the banks of the Ciliwung River are also throwing garbage into the river every day. This causes sedimentation, narrowing of the river, and high rates of pollution in the river. To handle flooding in Jakarta, government has built western canal flood, and east canal flood. But the increase of population and urban development, the two canals are no longer able to accommodate the flow of water when it rains.

A major problem facing Jakarta residents is the handling of yearly floods have not been integrated and well planned. This lapse has made the people clueless regarding the application of appropriate flood management. This vulnerability has resulted in loss of hundreds of human lives and millions of infrastructure's damage. The people are always confused when they are facing flood. In turn the overall chaotic situation has resulted in ill planned area specific shelter homes by the government, leading to temporary shelters making the entire mitigation process an useless and costly. To make the disaster mitigation works useful and cost effective, well planned right mitigation strategies are needed so that the impact of the flood can be reduced.

Along with the development of digital technology, anticipation of flooding by involving the community can be improved through social media. If flood disaster occurs, the public must immediately get information about the dynamics of floods, including the magnitude of the flood to quickly migrate in an orderly manner to the well planned area specific shelter homes. Some of the vital details can be provided by social media. Social media can be used to support flood

mitigation, so the people are quickly informed of the status and actions that must be taken [6]. Social media has become a valuable means of communication in many places affected by a natural disaster, which allows people to keep in touch with family and friends and access important information. Social media also has emerged as a popular medium for providing new sources of information and rapid communications, particularly during natural disasters [7,8].

This study aims to determine the most appropriate mitigation strategy by involving the community at every stage, in accordance with objective condition of the peoples, in digital era.

2. METHODS

This research is expert based. Data collection is done through expert discussions. In these discussions it is essential to include all the stakeholders, including policy makers, disaster experts from BNPB (National Disaster Agency), Academics and Community Leaders. In addition to high level experts' discussions, members of the study team should gather additional information by interviewing local influential leaders, and affected common people. During this study 75 representative respondents were interviewed who were randomly selected to find out the types of social media used in flood disaster communication and their perception to disater management system.

Data analysis uses SAST (Strategic Assumption Surfacing and Testing) and ECM (Exponential Comparison Method). SAST and ECM are experts based method. SAST selected for mapping the most important and Certainty aspects through the picture, while ECM method selected for determining priority strategy based on multi criteria, [9]; the formula of ECM is as below:

$$\text{Value Total (TNi)} = \sum_{j=1}^{m} \ (RK_{ij})^{TKK_J}$$

Where:

TN_i : Total alternative value to - i
RK_{ij} : The degree of relative interest j^{th} in choice decisions i
TKK_j : Degree of interest of criteria j^{th} decision; TKKj> 0; even
N : Number of decision choices
M : Number of decision criteria

3. LITERATURE REVIEW

Disaster can be defined as a source of danger, and its consequences can adversely affect humans in terms of life, property and environment when the level of danger, and the consequences, exceed the ability of the affected society to cope using its own resources [1]. The Flood disaster is a puddle in an area due to overflow of water, which causes material and non-material losses [3,4].

Mitigation means reducing risk of loss from the occurrence of any undesirable event, [1]. There are two types of mitigation, structural and non structural (Indonesian Geography Center, 2016). Structural mitigation means flood prevention with physical development (dam, levees, reservoir), while non structural mitigation is an effort to reduce the impact of flood other than structural, it included public awareness, establishment of flood alert group, zoning and mapping of flood prone area [1,5].

There are 6 important aspects of mitigation strategy: (1) prevention (planning and zoning, drainage system maintenance, beach maintenance); (2) property protection (elevation, relocation, flood proofing, storm shutters, insurance); (3) public education and awareness (Real estate disclosure, hazard information center, flood map and data); (4) natural resources protection (sediment and erosion control, stream corridor restoration, watershed management); (5) emergency services measure (emergency response planning, evacuation, and critical facilities protection); (6) structural project (flood walls, levees, dams), [1,10,11]. There are 4 aspects of flood control: (1) Modification of flood vulnerability and losses by determining of zones of land use arrangements, (2) Normalization of reservoir or river (3) Modification of the impact of flooding with the use of technical mitigation such as insurance, flood proofing, and (4) regulation of maintaining natural capacity, including reforestation, [11,12].

Indonesia is one of the countries with the high disaster risk, as several types of disasters are most likely to arise. They include: floods, landslides, earthquakes, Tsunamis, volcanic eruptions, Tornados, forest fires, etc. Indonesian trend of disaster events in 2016 as the following (Table 1): [3].

The Table 1 displays that flooding is the highest occurring disaster with the most severe impacts

on education, religious and health facilities. Floods can be classified into several types: (1) Flash flooding, which is large and occurs suddenly and lasts only for a short period of time; (2) Groundwater flooding occurs due to the overflow of very heavy rainwater, especially if the riverbanks are fragile and unable to withstand enough water; (3) River/overland flooding, which occurs due to water delivery from other regions, and may extend for a long time; (4) Coastal flooding (ROB), due to rising tides in areas near the coast; and (5) Headwaters flooding, which occurs in residential area near the upper reaches of the river. Flooding usually occurs due to the high flow of water, which can have destructive effects. Some of the factors that cause flooding include: (1) Illegal logging leading to deforestation, (2) Waste dumped carelessly into rivers, (3) Residential area on river banks, (4) Dense rainfall, (5) Poor drainage system, (6) Broken dams, (7) Spatial errors and (8) Tsunamis. Floods can cause damage to infrastructure, buildings, and the environment, which causes huge economic losses and human casualties, [1]. One of the causes of flooding is changes in land use, and low community participation, and the role of the community in handling floods is very much needed both in planning, implementing and supervising the development [13,11,14].

Disasters occur rapidly, instantaneously and indiscriminately. Generally there are four steps of disaster. Disaster always closed with civilization and poverty, the way the people respond and deal with disaster depends on local culture. There are four phases of disaster management: mitigation, preparation, response, and recovery, [15]. The four disaster management phases do not occur sequentially and separately. Often phases of the cycle overlap and the length of each phase greatly depends on the severity of the disaster. From these 4 stages, mitigation is an important stage before disaster [16].

In general, there are two approaches to the problem discussed, including the structural and non-structural methods dealing with flood mitigation [3]. The core of structural method is a physical approach, such as normalization, dam building, channel construction and others, while the non-structural method is a non-physical approach, such as socialization, erosion control, watershed utilization arrangements, and so on. Included in non-structural approach is the use of information technology for disaster mitigation, to involve the wider community.

Flood handling in several developed countries, including in Japan, has used information technology. Disaster management in Japan is under the Ministry of Land, Infrastructure and Transportation (MLIT/Ministry of Land, Infrastructure, Information and Technology), which oversees the problem of flooding (irrigation problems), sediment deposits, volcanic eruptions, earthquakes, by using information technology (IT) for reducing the impact of natural disasters in Japan. The infrastructure handled includes rivers, roads, sea and airports, sewage systems and parks. Similar to what already exists in Indonesia, the basic elements of disaster management in Indonesia consist of regulatory aspects, management systems, plans, preparation, emergency response and recovery. Information technology greatly helps disaster mitigation management, [17] especially in terms of public awareness and education.

There are five priorities of Hyogo Framework for Action/ HFA 2005-2015: 1) Make Disaster Risk Reduction as Priority; 2) Know The Risk and Take Action; 3)Build Understanding and Awareness; 4) Reduce Risk; 5) Be Prepared and Ready to Act, [18]. While Sendai Declaration for disaster mitigation (2015-2030) stated four important aspects: (1) Understanding disaster risk; (2) Strengthening of risk governance (3) Investment for Resilience; and (4) strengthening of risk management [3].

Table 1. Disaster events in Indonesia in 2016

No	Type of disasters	Number of events	Damage facilities		
			Education	**Worship**	**Health**
1	Flood	850	1.119	265	81
2	Tornado	687	62	36	4
3	Landslide	626	49	47	18
4	Forest fire	178	na	na	Na
5	Tidal Wave	23	1	na	Na
6	Earth quake	13	254	258	127
		2384			

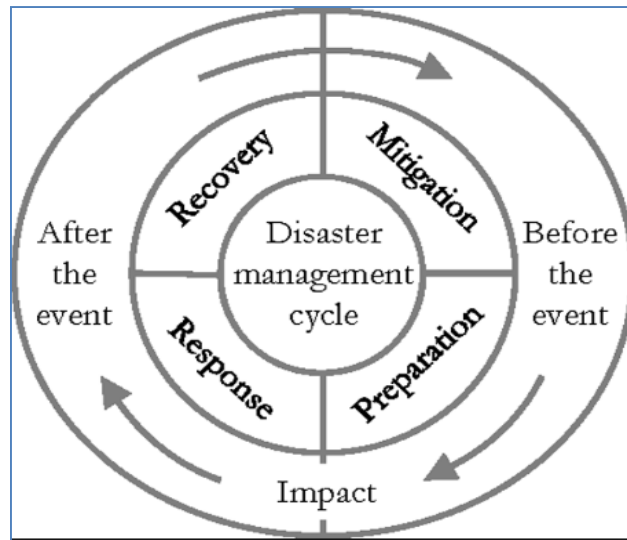*National Disaster Agency (2017)*

Fig. 1. Disaster management cycle (Khan, 2017)

Flood preparedness needs to be done in stages, starting from prevention, handling during flood (response/intervention), and recovery after flood. These stages are cycles of continuous flood preparedness, including several types of activities as shown in Table 2.

Flood prevention activities follow a life cycle, which begins at flooding, then studies it as input for prevention before a flood occurs. Prevention is carried out thoroughly, in the form of physical activities such as the construction of flood control in river areas (in-stream) to floodplain areas (off-stream), and non-physical activities such as land use management to early flood warning systems.

The result of study in Japan showed that 44% human casualties were caused by drowning [2]. Flood mitigation can be done not only by physically protecting buildings through the construction of dams, but also by making appropriate spatial plans.

There are 3 most famous social media in Indonesia: Facebook (41%), WhatsApp (40%), and Instagram (38%); Most of social media users are for gaining information (46%), virtual communication (25%), on line shopping (15%), culture adoption (8%) and others (6%), so social media has a very significant role in disaster mitigation [19].

Table 2. Stages of flood preparedness

Cycle	Activities
Prevention	1. Structural strategies
	a. In-Stream strategies
	b. Off-Stream strategies
	2. Non-structural strategies
	a. Long-term flood prevention strategies
	b. Short-term management strategies of floods
Intervention/Response	1. Notification and information with regard to forecast of floods
	2. Immediate Reaction and Emergency Support when floods occur
	3. Handling of the flood
Recovery	1. Immediate Assistance for Daily Life Needs and Repair of Facilities and Infrastructure
	a. Post-Flood Mop-up and Reconstruction
	b. Rehabilitation and Recovery of Physical and Non-Physical Conditions
	2. Damage/Loss Assessment and Flood Disaster Insurance
	3. Review of the Causes of Floods

Source: Directorate of Research and Community Service – UI (2006)

Stakeholders in flood prevention are grouped into three categories: (1) beneficiaries, communities that receive benefits/impacts directly or indirectly; (2) intermediaries, community groups or individuals who can provide consideration or facilitation in flood mitigation, including: consultants, experts, NGOs, and professionals in the natural resources sector; (3) decision/policy makers, institutions authorized to make decisions and legal basis, such as government institutions and water resources councils. The type and level of community participation will differ depending on the type of policy or activity [20].

Digital era has changed the whole situation of people's lives, even including social life and behaviour. The impact of digital age on the social life of the society today is connected with one's position in the society, his social class and also his social background. Nowadays, there are so many changes in the social aspect of our lives. What's up, Instagram, facebook, line, email are the most popular for dissemination of news, information, images and video (Ministry of Informatic, 2016), so this social media is also possible to support mitigation of flood [21].

4. RESULTS AND DISCUSSION

As the capital of Indonesia, flood handling in Jakarta involves many agencies, they are: BMKG (Bureau of meteorology, Climatology and geophysics), BNPB (National disaster agency), BASARNAS (National Search and rescue agency), BPBD (Regional disaster agency), PMI (Indonesian Red Cross), Local governments, and Community Organizations (Youth groups, religious groups, students, and the general public). BPBD is local disaster agency that is organizationally responsible to the governor. Over lapping between agencies always occurs during every flood. There is no coordination. Individual organizations carry out their main duties but do not cooperate with other organizations. As a result flood disaster management has become inefficient and costly. As the institution that is responsible for meteorological and geophysical information, the BMKG only informs about the weather and the possibility of heavy rain, but not details of places/shelters for evacuation. BMKG does not include level of water and flooded area. PMI and BASARNAS carry out almost the same task of helping victims, but there is no mutual coordination, so that information overlaps with the voluntary works carried out by community group and youth organizations. Based on experts interviews involving BNPB, BMKG, PMI,

community leaders, and academics; a disaster information center needs to be established that involves all components, to provide and share an official information of flood disaster online. Only information released by this center can be used as a reference. Most respondents (68.9%) stated that they need official information from the government, which is distributed digitally, so that the community will quickly access through mobile phone via WA, facebook or instagram to get the latest information about flood.

Based on experts' discussion, there are 8 important aspects that need to be considered in flood control operations, in Jakarta: (A) Facilities; (B) Collaboration; (C) Coordination; (D) information; (E) Public Involvement; (F) Public awareness; (G) Technology; (H) Institution; and (I) Disaster management. The results of SAST analysis showed that Important and certainty aspects based on experts discussion is showed in Fig. 2.

The most strategic assumptions (Fig. 2) are coordination (C) and information (D). These two aspects have the highest level of certainty and importance. Coordination is the biggest problem. Various agencies work with their own methods and expertise, there is no cooperation and certain competency standards that must be possessed; so there are often misunderstandings and even increased property damage that must be saved. This means that coordination is very important aspect. The involvement of various agencies will cause overlap without good coordination. This is confirmed by the opinion of most respondents (78.6 %), that flood handling in Jakarta always overlaps management, rehabilitation and mitigation works from the various institution involved.

Disaster information is a very important component in disaster management, 84.3% respondents said that they don't know how to save themselves when flooded, only a small percentages (15.7%) can save themselves because they have information how to save and what to do, information technology is very important for the distribution of disaster information to reduce disaster risk [22].

Other strategic assumptions in flood handling are Facilities (A) and Technology (G). Flood handing requires a lot of equipment such as boats, water suction machines, transport vehicles, communication equipment etc. Without adequate facility and technology support, handling floods is difficult.
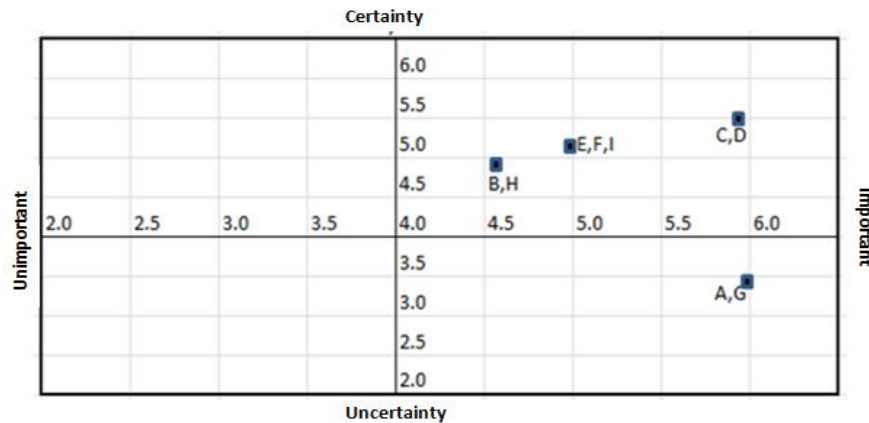

Fig. 2. Certainty and important aspects of flood management in Jakarta
Descriptions: A: Facilities; B: Collaboration; C: Coordination; D: Information; E: Public involvement; F: Public awareness; G: Technology; H: Institution; I: Disaster Management

Table 3. Strategic priority to flood handling in Jakarta (ECM analysis result)

No	Strategy	Weight (1-5)	Indicators (1-5)				Total	Rank
			Economic	Social	Environment	Institution		
1	Development of disaster alert groups	4.5	3.2	2.9	3.8	3.3	568.4	2
2	Public awareness development	3.6	3.3	3.4	3.5	3.1	305.1	5
3	Revitalization of the west and east flood canals	3.6	3.4	3.4	3.4	3.4	327.6	3
4	Public involvement	3.5	3.3	3.5	3.5	3.5	305.9	4
5	Development of disaster information center	4.0	3.6	4.2	4.0	4.0	991.2	1
6	Construction of flood control center	3.5	3.1	3.4	3.4	3.4	269.9	6

Strategic priority based on multi criteria (Economic, Social, Environment and institution) according to ECM analysis results are showed in Table 3.

The Table 3 showed that the highest priority of flood handling in Jakarta is the development of Disaster Information Centre (ranking-1), and then development of disaster alert groups. Through this centre all information about flood disaster and the role of each group/elements can be coordinated: BMKG (National Agency of Metereology and Geophisics), BNPB (National Agency of Disaster Management), BPBD (Local Agency of Disaster Management), BASARNAS (National Agency of Reach and Resceu) and PMI (Indonesian RedCross); community groups and local government can be coordinated.

So, the people can receive official information about the flood in a complete and reliable manner. In addition overlapping of works between groups can be avoided. Community involvement is done by utilizing social media. Local leadership have to provide an SOP (standard operating Procedure), how to distribute information about flooding to the community through social media. Most respondents (87.6%) stated that communication through social media is very effective in disseminating information on disasters faced. The most common social media uses for disater communication are WA (45.4%), Youtube (32.5%), Instragram and Line. The use of social media will be very effective if the news delivered is accurate and pictures are attached. Through social media, the public can find out about the current conditions, so that they can quickly anticipate what to do. Broadly speaking, the utilization of information technology in disaster mitigation based on data analysis and experts discussion can be described as follows:
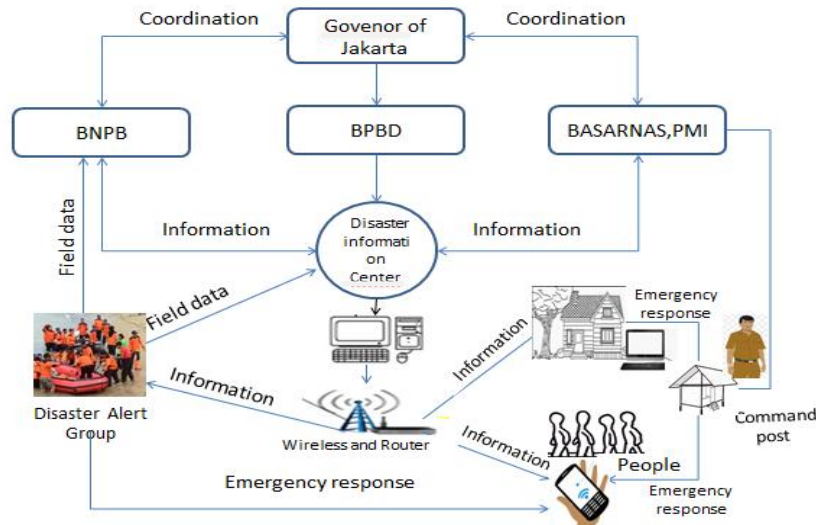
Fig. 3. Disaster information center model

Actions that must be taken in this centre include:

- Update information about flood profile and affected area every time
- Distribute information online to affected community, and Disaster alert groups
- Provide direction to disaster alert groups to rescue victims and secure areas with security forces

Disaster alert groups are a flood conscious group that formed in each region under supervision of sub-district in charge. This group consists of young people and some community members who must be trained in disaster management and action to save victims. The trained can be deployed when the annual disaster flood comes. For activities to run optimally, a management organization needs to be developed, taking into account the organization's structure, functions and governance.

Based on the reality, the most crucial phase is the emergency response, including the rescue of goods and the people. Therefore, community groups identified need to be able to contribute their best. So, they have to be trained how to save human lives and help the victims. They also must know how to manage and distribute aid effectively.

5. CONCLUSIONS

a) The priority strategy for flood mitigation according to the objective conditions of Jakarta is development of disaster information centre and Formation of Disaster Preparedness team (disaster alert groups), involving all components of society

b) Community involvement becomes a key success factor in flood disaster mitigation

c) The use of digital technology through social media will increase the effectiveness of the flow of information about floods, so that people can find out the current situation.

d) Official information from the government is very important when flooded, to avoid fake news, which actually confuses the public

6. SUGGESTIONS

a) It is necessary to map the potential and capability of the community in their respective regions, and to socialize the plan to involve the community in mitigation through the formation of disaster preparedness team.

b) To avoid overlapping and emerging conflicts from community groups, disaster information centre needs to be formed by involving relevant agencies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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