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System Dynamics Model of Flood Mitigation for City Sustainability

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ABSTRACT

Water is the main element of life for mankind, but water can also be a powerful enemy if not well laid out, as experienced by many countries in the world and not only in Indonesia. In 1945 Article 33 paragraph (3) mentioned that the utilization of water resources should be devoted to for the greater prosperity of the people, control flooding in the capital should be a national priority supported by all agencies and flood knows no boundaries of man-made based on the administrative territory, economic, and social. Through a system dynamics simulation can be created or imitation behavior symptoms of flooding that can be used to understand the symptoms, making the analysis, and forecasting the behavior of symptoms or in the future so that the process of decision making can be easier because of the support model that can be simulated to meet the criteria of integrity utilization of environmentally sound and sustainable. The role of information technology systems and can be optimized to contribute in building an alternative model of flood control solutions through the implementation of the concept of decision support systems or decision support systems (DSS).

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INTRODUCTION

The main problem is the loss of a flood loss of life, destruction of infrastructure, and paralysis of economic activity. And experts say human activity that is not capable of dialogue with the natural development of atmospheric dynamics associated with global climate change is uncertain, making a loss that continues to grow. Increased loss of flood impacts of human-induced global phenomenon now compounded. More recently, hot south of the equator reaches new record 41.8 ° C in the capital city of Tasmania, Hobart, and Australia. Then, the United States recorded an average count of 2012 as the warmest year. In meteorology, an increase in temperature of the earth will increase the evaporation of water, thus increase the formation of rain clouds. Rain clouds more abundant in the atmosphere, plus a massive ecological destruction, floods, and landslides become inevitable, and in times of drought, water crisis into certainty. According to Emil Salim (1990), sustainable development aims to improve the welfare of the community, to meet human needs and aspirations. Sustainable development in hekekatnya intended to seek equitable development between generations in the present and in the future. Meanwhile, according to Iwan *et al.*, (2010), the concept of sustainability to contain at least two dimensions. First is the time dimension because sustainability is nothing about what will happen in the future. Second is the dimension of the interaction between the economic system and the system of natural resources and the environment. On the other hand, the experts agreed to temporarily adopt the terms that have been agreed upon by the Bugheri (2005) which states that "Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their needs". There are three aspects of sustainable development, namely economic, environmental and social aspects.

Current information has become a necessity for human beings, in order to get the comforts of life ranging from information about the meteorological and geophysical (primarily associated with transportation issues), changes in land use, flooding, landslides, disaster, drought, until the problem economic, political, social and cultural. Information is needed, especially for decision makers such as government, business and economic actors, politicians, lawyers or researchers and academic circles. The need for the information against the clock in order to be exploited or communicated to the user. One way to get the information quickly based primarily on system dynamics models can be done by utilizing Software Powersim. This model can simulate the changes that occur and the results can be displayed in a graphical form the results of the analysis and tabulation. Graphical analysis will be able to describe the relationship between the parameters or variables in graphical form. Graphic

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trend line can be displayed in graphical, stems from interrelated variables. Tabulation analyzes describe relationships between variables in the form of numbers or numerical (Sehlk, 2005).

With a true picture of the flooding process into a model and show the inter-relationship between availability and demand, then the model can be further developed as the basis of experimental investigations that are relatively inexpensive and time saving when compared to when conducting experiments on the real system (Forrester, 1961). Of models that have been obtained will be carried out simulation or testing to determine the state of the system changes in the system to be known behavior. By Muhammadi *et al* (2001), simulation is defined as the imitation of a phenomenon or process behavior and behavior analysis and forecasting behaviors or symptoms that process in the future.

Methodology:

System dynamics modeling is a method introduced by Jay Forrester in the 1950s and was developed at the Massachusetts Institute of Technology America (Susilastuti, 2009). As its name suggests, the use of this method is closely related to questions about the dynamic tendencies of complex systems, the behavior patterns generated by the system with time.

System dynamics is an approach to understanding the behavior of complex systems over time. It deals with internal feedback and time delays that affect the behavior of the whole system (Iyyapazham, 2007). What makes the system dynamics different from other approaches to studying complex systems is the use of the feedback loop and stock and flow. These elements help to explain how a seemingly simple systems show nonlinear models are confusing. There are two main types of schematic diagrams used in system dynamics to convey the relationship between the variables. First is the Causal Loop Diagram (CLD) and the second is a Stock and Flow Diagram (SFD). Steps to build a system dynamics models (Mohammad *et al*., 2001) is drafting a model CLD (Causal Loop Diagram), making the model flow diagram or SFD (Stock and Flow Diagram), simulating the form of charts time and time tables and validate simulation results. Based on the idea that the environment is a dynamic and complex systems, assessment issues flood conditions examined in this study through the assessment system. In this study, the natural environment is represented by the phenomenon of flooding (lyneis, 2000), the social environment and the population dynamics represented by the built environment is represented by land conversion. Outline the relationship can be illustrated in Figure 1.

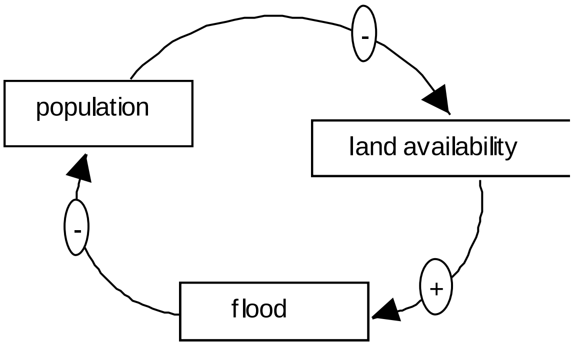

Fig. 1: Relationship between Population Growth, Land Conversion with flood conditions Mitigation Planning To flood.

The study was conducted in the area of Jakarta, from June 2013 to November 2013, the research method using system dynamics. The relationship between the variables simulated using software Powersim 2.5 (Chao *et al*.,, 2008). Simulations generate Powersim equation, causal loop diagrams, flow charts, time charts and time tables. The simulation results were analyzed qualitatively. Variables in the system dynamics, according to Avianto (2006) are grouped into two types, namely the level (stock) and rate. Level declares state of the system at any time (state variable system). Level is the result of accumulation in the system, while the stated rate system activity. Level is a quantity that accumulates over time and rate is the activity or movement or streams that contribute to changes in the level of per unit time. Each variable will be defined in an equation that level equations, rate equations, auxiliary equations or constant expression. Based on the grouping above, then factors in the sub-sub-systems are grouped into variables and variable types as follows.

1. Level : number of population, land area is open. availability of land.
2. Rate: births, deaths, in-migration, out-migration, conversion of open land,
3. Auxiliary: the rate of in-migration, out-migration rate, mortality factor multiplier, multiplier-migration factors, population density, health status, the ratio of open land, a factor the rest of the land, undeveloped land, undeveloped land ratio, the pace of development, natural water accretion, accretion PAM production, domestic consumption, saving behavior, behavioral clean;

4. Constants: crude birth rate, crude death rate, area, rainfall, shallow soil infiltration power, the increase in the production rate of PAM, the degree of pollution, consumption per capita, the rate of increase in domestic consumption, the rate of increase in non-domestic consumption.

Primary data (health status, degree of pollution, saving behavior and the behavior net) sourced from respondents and direct measurement. Primary data samples taken three stage cluster sampling purposive. Secondary data were obtained from the data recording for four (4) years ie 2003, 2004, 2005 and 2006, primary data collection technique is done by using an open interview list of questions to guide the interview, and direct observation to obtain data on flood behavior and health status of data associated with flooding.

Stages of the construction of the model is done as follows:

1. Making the concept in a model of CLD (Causal Loop Diagram).
2. Modeling SFD (Stock-Flow Diagram) or flow charts.
3. Input data.
4. Simulation of a timing diagram and table time.
5. Validation with a Mean Absolute Error saw (AME) deviation between the average value of the actual simulations. The model is valid if the AME less than 5%.
6. Policy Analysis (Sensitivity Test).

Furthermore, in chart form, the steps above can be presented as Figure 2.

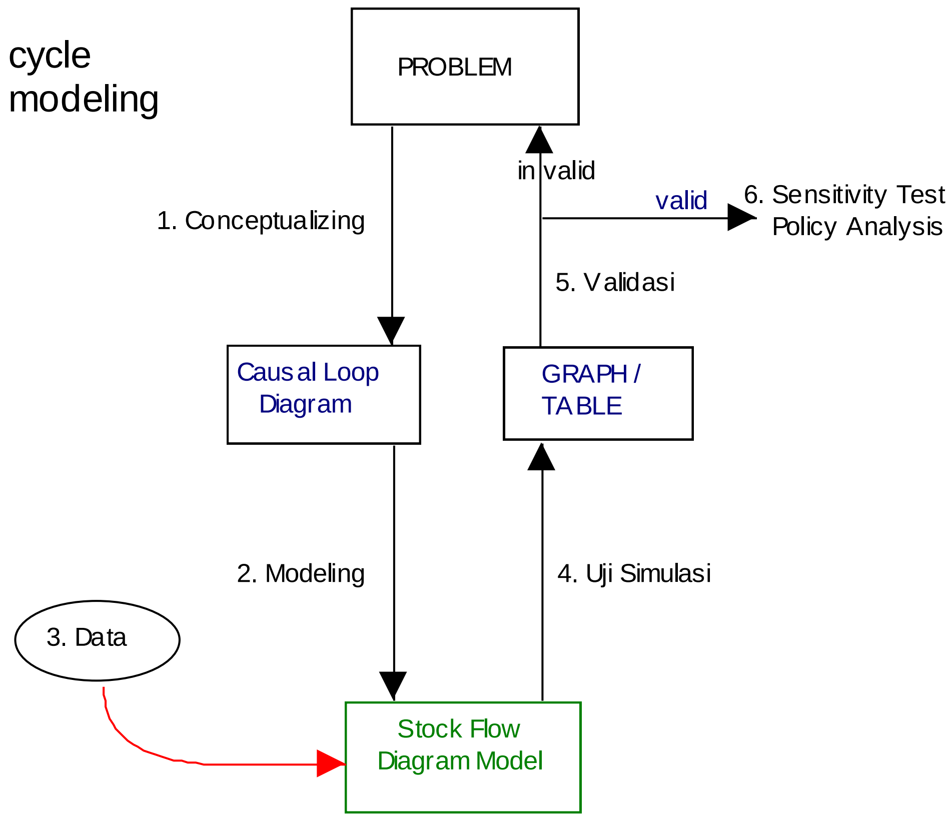

Fig. 2: System Dynamics Cycle Modeling.

In this study saving behavior and behavioral elements clean as exogenous variables in the model diintervensikan, respectively diinter-vensikan to provide the IF function to factor water consumption and pollution factors in 2008 a policy statement or scenario tested, namely: if the Government of DKI Jakarta population increase positive behavior towards flood conditions that increase behavioral discipline and clean behavior starting in Jakarta area from 2014 until 2040.

The method of data analysis is a method of system dynamics. Analysis of the data was done to see causal relationships and feedback between elements (variables) that can be determined the effect of each element in a system. Sequence to build a system dynamics model of the draft in a model CLD (Causal Loop Diagram), making the model flow diagram or SFD (Stock and Flow Diagram), simulating the form of charts time and time tables and validate the simulation results. (Figure 3.1.)

Australian Journal of Basic and Applied Sciences, 8(16) October 2014, Pages: 372-377

RESULT AND DISCUSSION

Simulation of the development of flood management model for the sustainability of Jakarta City was based on secondary data sourced from the Bureau of Statistics in 2008 and the Jakarta previous studies, including data on the number of the population, the number of deaths, and the number of births in Jakarta. The composition of the population, the number of deaths, and the number of births in Jakarta can be seen in Table 1.

Table 1: The composition of the population, the number of deaths, and the number of births in Jakarta.

Tahun	Jumlah Penduduk	Laju kelahiran	Laju kematian	% kelahiran	% kematian
2003	7.456.931	217.951	3.246	2,92	0,04
2004	7.471.866	222.088	3.344	2,97	0,04
2005	8.842.346	125.873	-	1,68	-
2006	8.979.716	128.757	-	1,72	-
2007	9.064.591	-	-	-	-
2008	9.146.181				
2009	9.223.000				
2010	9.607.787				
Sumber: BPS DKI Jakarta (2014)			Rata-rata	2,32	0,04

(Source: The data processing research, 2014)

Causal Loop Diagram (CLD) system is the relationship between population and land conversion with flood conditions depicted in Figure 2. Overall there is a causal loop model of 1 (one) reinforcing loop (R) and 2 (two) balancing loop (B). Between subsystems population, land conversion subsystems and subsystem flood conditions generally balance each other, meaning that if one of the subsystems is not controlled, there will be a causal feedback is negative (opposite direction) so that will reduce the presence of one of the subsystems with the constituent elements.

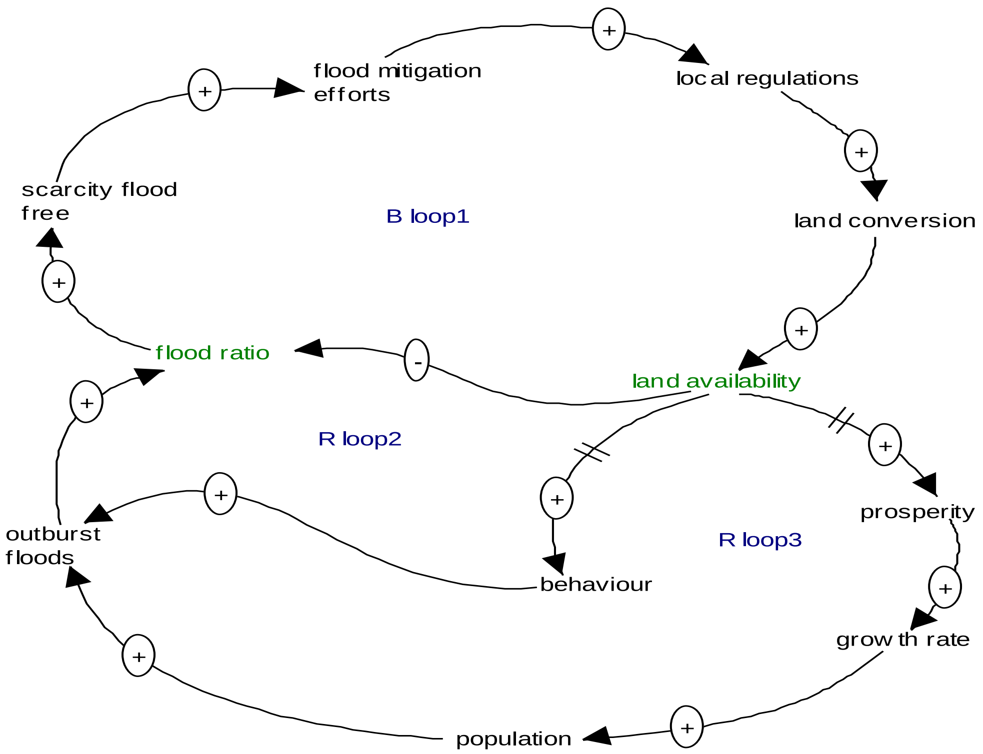

Fig. 2: Model Simpal Kausal Hubungan Penduduk dan Konversi Lahan dengan kondisi banjir (Sumber: pengolahan data Powersim 2.5).

Based on the model of the causal loop diagram of the dynamic flow model of a causal relationship between population feedback, land conversion, and flooding conditions, as shown in figure 3.

Simulation models that depict the dynamic behavior of the model is shown in the graph (time graph) and the time table (time table) are described as follows.

Based on the assumption that there is no disaster that can lead to shock the population up to the year 2040, the model over time generate simulation graphs as follows Figure 4.

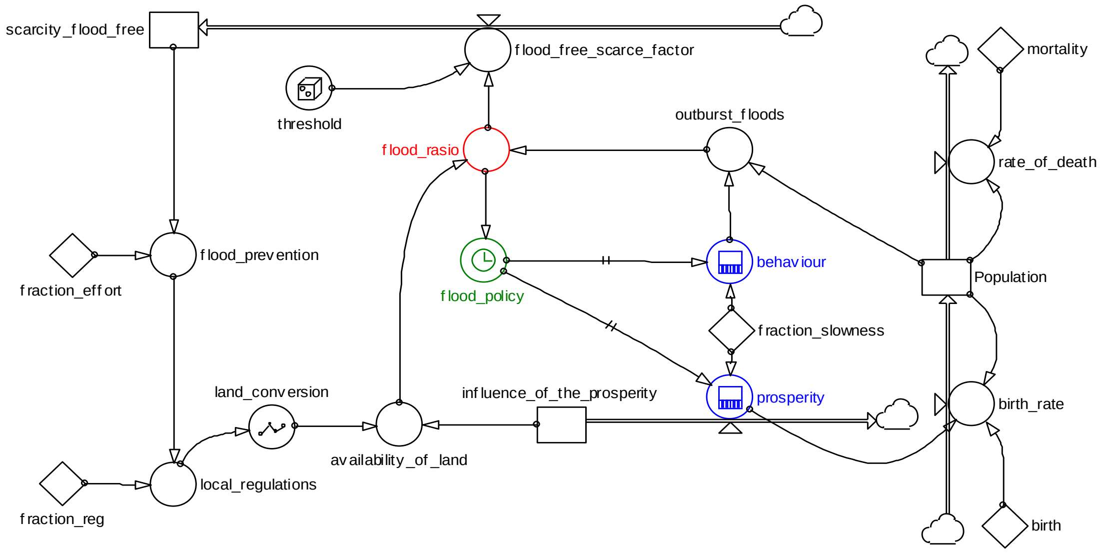

Fig. 3: Stock Flow Diagram – System Dynamics Model between population, land availability, and floods in Jakarta (Source: processing Powersim 2.5).

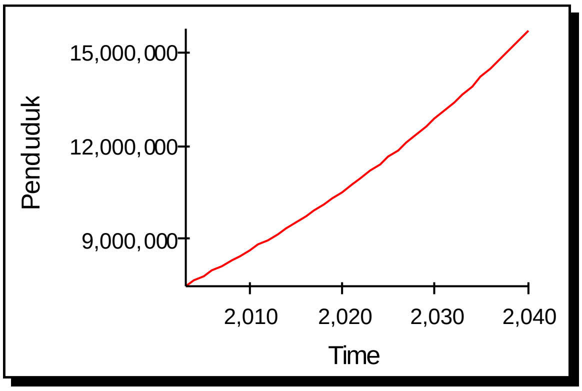

Fig. 4: Graph Simulation Time in Jakarta area residents Year 2005-2040.

Specific areas of the capital Jakarta helpless face flooding, tens of thousands of homes, public facilities, city hall, even the State Palace completely submerged (Kompas, 2013). causes:

1. evenly distributed rainfall in the area ranges from 40-100 mm bead.
2. rainfall ranges from 100-114 mm in the upstream, downstream range 40-125 mm.
3. flooding in the region upstream to downstream flows and downstream flooding due to drainage can not accommodate,

National disaster management agency noted, floods have inundated the neighborhood of 500, and 203 neighborhoods in 44 villages spread over 25 districts in Jakarta. The population is submerged 25 276 families or 94 624 people and displaced people reached 15447, economic loss ranges between 1 billion and 1.5 billion per hour, retail business losses sebesar460 billion dollars, and other effects such as: number of roads were flooded and cause traffic congestion, disrupted transportation modes (train, bus trans jakarta, buses are, and large buses), a number of trade area flooded and submerged state palace area 30m. Flood prevention efforts will not succeed without real support from the community. residents who live on the river bank and the edge of a lake are invited to volunteer shift (not displaced) into flats. residents are required to make the house or yard water infiltration wells, office park, and neighborhood parks (Joga, 2014).

Conclusion:

Based on the simulation results using the data, processes, and assumptions that effect the system dynamics modeling of flood mitigation for city sustainability well as analysis of existing simulation results, can be summarized as follows:

1. Anticipation of flooding, consider information from a variety of media in case of flash floods, lifted up to place higher. wary undercurrent, waterways, puddles, and other places flooded.
2. Secure home, home furnishings and put valuables in the higher part of the house. turn off all power lines and do not touch the equipment is electrically charged when standing on the water. When leaving the house, do

Australian Journal of Basic and Applied Sciences, 8(16) October 2014, Pages: 372-377

not walk on water flow, walk on ground that is not moving. use sticks or the like to check the density of the beachhead. Do not drive a car in the area of flood, when the water began to rise, ignore the car and get out to a higher ground in order not swept away.

3. The addition of two negative loops (balancing loop) in the standard model of the target has changed can be used as an alternative solution towards the achievement of anticipation targets that have been set. That is what is meant by the development of models and recommendations on setting the flood mitigation in specific areas of the capital Jakarta.

4. Urban spatial structure which is not in harmony with nature and not friendly to the water will make the development of the city destroying the source of the water of life. awareness of the importance of spatial planning needs to be fully understood by the local government.

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