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WEB-BASED SPATIAL DECISION SUPPORT SYSTEM (SDSS) FOR FLOOD RISK MANAGEMENT IN SURAKARTA: A PRELIMINARY RESULT

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Abstract

The aim of this research is to develop a web-based GIS on implementation as SDSS for flood hazard management in terms of giving information about the area, slope, land use, soil type, predict flood inundation area, and number of houses and people were evacuated when the floods in the Solo Basin area, so that expected to provide insight into the theoretical and applicative regarding the role of SDSS in flood disaster management. The processes are involved several government institution relate to their specific role and duty in the program. Therefore, the accessibility and interoperability of SDSS is important to convince that flood information is distributed well to all user concerned. Based on the explanation, web-based SDSS seem to be possible solution. The prototype shows that spatial information of risky area can be distributed widely among responsible Agencies trough web-based technology. This finding can be used to provide statistical data as well as spatial extent, distribution, location on other spatial information aspect of risk. Therefore, decision making process in flood disaster risk management can be conducted collaboratively.

Background

Natural disasters seem increasing from year to year caused by natural processes and human being itself. Direct loss of lives, property and material large enough. Natural disasters can be triggered by the presence of deforestation, land clearing in the slopes of the mountains, and the farming fields activity at areas of steep slopes. According Sutikno (1995), Indonesia is a country prone to natural disasters because it lies in the area of active tectonics and volcanism as a result of the confluence of three tectonic plates, the Indian-Australian Plate, the Pacific, and Eurasia. One of the natural disasters that become big disaster in Indonesia is a flood (Susetyo, 2008). In addition, compare to another South East Asian Countries, Indonesia has biggest number of flood disaster events during 2000-2004 (CRED, 2005 cited by Sagala, 2006). Surakarta is one of flood prone city in Indonesia. It is increased because of the location is between hills and mountains or called the natural intermountain basin. In a couple year later, several flood events occurred in Surakarta city. The big one occurred in 26 December 2007 is considered as biggest flooding during 50 years later. Over 11,000 house was inundated in this events (Zein, 2010).

Marfai *et, al.* (2003) said that flood is defined as extremely high flows or levels of rivers, lakes, ponds, reservoirs, and any other water bodies, whereby water inundates outside of the water bodies area. Flooding is not unusual, because flooding occurs anywhere on the earth. Flooding may occur due to high rainfall, because the ice melts, because of the tsunami, hurricanes and other ocean. Therefore, flood hazard is the chance that a flood event of a certain magnitude will occur in a given area within a given period of time (Alkema, 2005)

Handling flood events, often hampered due to the information received is confusing, both in terms of number of victims and material losses suffered. One reason is lack of information about the inundated area. This is the main source of problems, although aid is often fast enough to come, there is always a problem of coordinating and recording all the victims who need help, because not knowing which areas are experiencing flooding.

Information technology, particularly Geographic Information System (GIS), can help the flood problems as Spatial Decision Support System (SDSS) by providing information about the physical condition of an area include slope, soil type, use of land, the level of vulnerability of flooding and the number of houses to be evacuated if the region occurs flooding. It also can help the government and donors in channeling assistance to be more effective. Billa (2006) said that SDSS have significant role in improving and speeding up communication between the various proponents of comprehensive disaster management program. Moreover, SDSS has important role in disaster management and damage estimation (Teimouri, 2008). SDSS is an interactive, computer-based system designed to support a user or group of users in achieving a higher effectiveness of decision making while solving a semi-structured spatial decision problem (Malczewski, 1998).

The aim of this research is to develop a web-based GIS on implementation as SDSS for flood hazard management in terms of giving information about the area, slope, land use, soil type, predict flood inundation area, and number of houses and people were evacuated when the floods in the Solo Basin area, so that expected to provide insight into the theoretical and applicative regarding the role of SDSS in flood disaster management.

SDSS is generally developed in desktop-based GIS with several limitation related to accessibility and interoperability (Peng dan Zhang, 2004). There is a need to develop more web-based tools to share the geospatial datasets and information with users because web-based GIS has the potential to share data, assemble data, and allows users with limited GIS knowledge to access the information customized for specific topics (Norasma, *et al.*, 2008). In case of flood risk management related decision making, it is involved several government institution relate to their specific role and duty in the program. Therefore, the accessibility and interoperability of SDSS is important to convince that flood information is distributed well to all user concerned. Based on the explanation, web-based SDSS seem to be possible solution.

Spatial Decision Support System (SDSS)

A Decision Support System (DSS) is a computer program that provide information in a given domain of application by means of analytical decision models and access to database, in order to support the decision maker in making decision effectively in complex ill-structured (non-programmable) task (Klein & Methile, 1995; Sauter, 1997). Decision support System emerged as a field from the study and research of ill-structured problems already in the 1960s (Klein & Methile, 1995). Malczewski (1999) said that SDSS is an interactive, computer-based system designed to support a user or group of users in achieving a higher effectiveness of decision making while solving a semi-structured spatial decision problem.

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Turban (1988) recognized four major characteristic of DSS: (1) DSS incorporate four major characteristic of DSS; (2) They are designed to assist managers in their decision processes in semi structured (or unstructured) task; (3) They support, rather than replace, managerial judgment; (4) The objective of DSS is to improve the effectiveness of the decision, not the efficiency with which are being made.

The concept of ill-structured problems is in general better described by comparing to well-structured problems. Well-structured problems are routine and repetitive, because they are unambiguous (since each such a problem has a single solution method). A less structured problem refers to situations where there is no known or clear method or solution either because the problem arises for the first time, or because the nature of the problem itself is complex or unclear. It has more alternative solution methods and the solution may not equivalent. A completely unstructured problem has unknown solution methods or too many solution methods to evaluate effectively (Klein & Methile, 1995).

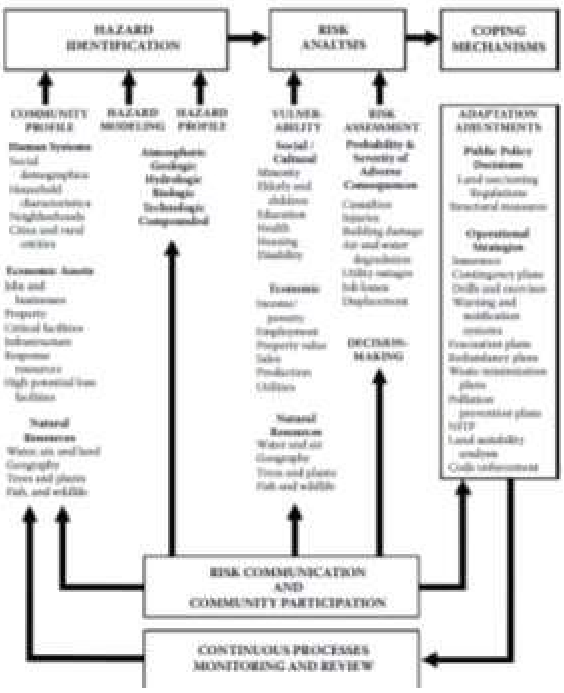
Risk Management

Hazards refers to a potential harm which threatens our social, economic, and natural capital on a community, region, or country scale. Hazards may refer to many types of natural (flood, hurricane, earthquake, wildfire, etc.), technological (hazardous materials spill, nuclear accident, power outage, etc.), or human-induced events (biochemical, bombing, weapons, mass destruction, terrorism, etc.). Compounded hazards are those that result from a combination of the above hazard types, such as urban fires resulting from earthquakes, failures of dams or levees resulting from flooding, or landslides resulting from wildfires and heavy rains (Pine, 2009).

To analyze a hazard, it must be determined exactly how that hazard exists within the specific community or country. Each hazard will be different in this respect, due to climate, geography, settlement patterns, regional and local political and stability, among many other factors. Disaster managers commonly create what is called a risk statement, which serves to summarize all of the necessary information into a succinct report for each identified hazard (Coppola, 2007).

On the other hand, risk is defined as (1) the possibility of suffering harm or loss, and (2) the danger or probability of loss occurring to one's insured assets (Broder, 2006). Risk analysis is described by the EPA as an assessment of the likelihood (probability) of an accidental release of a hazardous material and the consequences that might occur, based on the estimated vulnerable zones. The risk analysis is a judgment of probability and severity of consequences based on the history of previous incidents, local experience, and the best available current technological information. It provides an estimation of (Coppola, 2007): (1) The likelihood (probability) of a disaster based on the history of current conditions and consideration of any unusual environmental conditions (e.g., areas in flood plains), or the possibility of multiple incidents such as a hurricane with tornadoes (e.g., flooding or fire hazards). (2) Severity of consequences of human injury that may occur (acute, delayed, and/or chronic health effects), the number of possible injuries and deaths, and the associated high-risk groups. (3) Severity of consequences on critical facilities (e.g., hospitals, fire stations, police departments, communication centers). (4) Severity of consequences of damage to property (temporary, repairable, permanent). (5) Severity of consequences of damage to the environment (recoverable, permanent).

Figure 1 shows how the hazards analysis process builds on the U.S. EPA approach of hazard identification, vulnerability assessment, and risk analysis by stressing the need for the use of the results of a risk analysis in hazard adaptation adjustments. Risk communication, citizen participation, problem solving, risk management, hazard mitigation, and ongoing assessment are all parts of comprehensive emergency management. This approach stresses an action orientation through the adoption and implementation of comprehensive hazard risk management and hazard mitigation strategies and monitoring the effectiveness of hazard adjustments that are adopted and implemented. The ultimate goal of these hazard adjustments is to build resilient and sustainable organizations and communities (Pine, 2009).



After Pine (2009)

Figure 1. The Hazard Analysis Process

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Disasters are not the inevitable consequence of natural hazards. A volcanic eruption on an uninhabited Alaskan island is unlikely to be a disaster, but a similar eruption in the densely populated Asia–Pacific region could be catastrophic (Simpson, *et al.*, 2008). Disasters of all kinds happen when hazards seriously affect communities and households and destroy, temporarily or for many years, the livelihood security of their members. A disaster results from the combination of hazard risk conditions, societal vulnerability, and the limited capacities of households or communities to reduce the potential negative impacts of the hazard (Baas, *et al.*, 2008). Disaster risk is usually described as a function of the hazard and the vulnerability context, including the resilience (coping capacity) of the societal system under threat (Baas, *et al.*, 2008).

Furthermore, Coppola described comprehensive disaster management that is based upon four distinct components: mitigation, preparedness, response, and recovery. Although a range of terminology is often used in describing them, effective disaster management utilizes each component in the following manner (Figure 2): (1) *Mitigation*. Involves reducing or eliminating the likelihood or the consequences of a hazard, or both. Mitigation seeks to "treat" the hazard such that it impacts society to a lesser degree. (2) *Preparedness*. Involves equipping people who may be impacted by a disaster or who may be able to help those impacted with the tools to increase their chance of survival and to minimize their financial and other losses. (3) *Response*. Involves taking action to reduce or eliminate the impact of disasters that have occurred or are currently occurring, in order to prevent further suffering, financial loss, or a combination of both. Relief, a term commonly used in international disaster management, is one component of response. (4) *Recovery*. Involves returning victims' lives back to a normal state following the impact of disaster consequences. The recovery phase generally begins after the immediate response has ended, and can persist for months or years thereafter.

After Coppola (2007)

Figure 2. The Disaster Management Cycle

SDSS System Development Method

The development of Flood Hazard Management SDSS will be developed as follows:

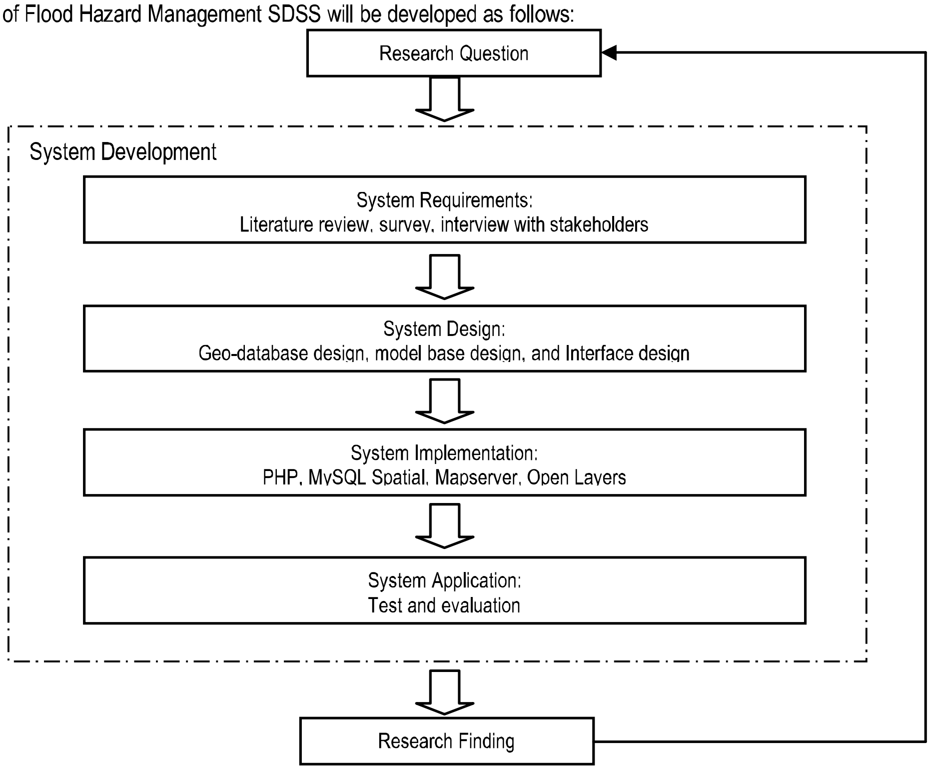

Figure 1. System Development Method

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Geodatabase Development

A geodatabase can be created by collecting all data objects from identification list (based on user requirements) and combining them into an integrated relational database or multiple data files (Tsou and Curran, 2008). In this research, the geodatabase development method will mainly contained three phases i.e. conceptual, logical, and physical design phases (Artur and Zeiler, 2004; Longley *et al.*, 2005) using integrated relational database (RDBMS).

In detail, Nyerges (2011) described each phase as follows: (1) *Conceptual Design* of the Database Model, the products of a conceptual design stage in database design helps analysts and stakeholders carry out a discussion about what is the intent and meaning of the data that is needed to derive information, placing that information in the context of evidence and knowledge creation. That is, both groups want to get it "right" as early as possible in the project. (2) *Logical Design*, data processing operations to be performed on the spatial, attribute, and temporal data types individually or collectively derive the information (from data) to satisfy step 1. Such operations clarify the needs of the logical design. (3) *Physical Design*, specify data fields, valid values and ranges for all domains, including feature code domains, primary keys and types of indexes. The geodatabase development was referred to user requirements assessment and analysis, therefore the geodatabase development framework in this research is described as follows.

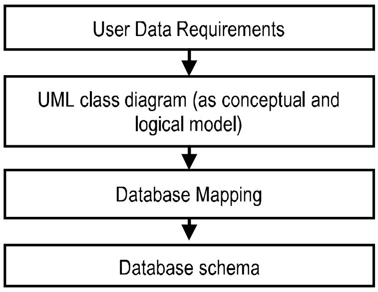

Figure 2. Geodatabase Development Frameworks (adapted from Meng, 2003)

Model Design

The model base is composed of models which can be used to analyze the particular application area, to make preliminary processing of the data, and to make forecasting about future trend (Qiao *et al.,* 1999). The model developed mainly from scientific algorithms and decision makers' knowledge base. Specifically in this research, the model will be used to answer decision maker question related to flood disaster risk management activities. In this case, the model will use Multi-Criteria Decision Analysis (Malczewski, 1999) for problems which are decision-makers' preferences involved strongly in the decision making processes. On the other hand, data mining techniques were used for problems which are statistical analysis and visualization are adequate to support decision making processes. The following figure describes the framework of model base design.

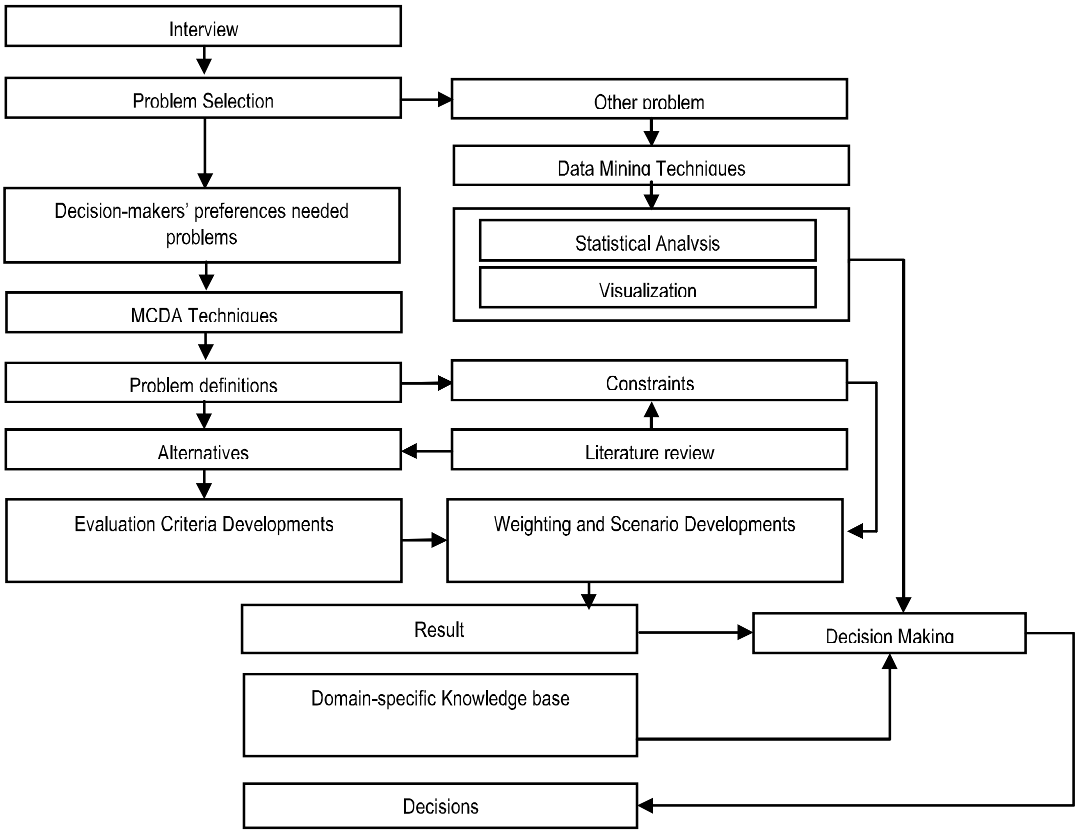

Figure 1. Model Base Development Framework (modified from Malczewski, 1999; Yeung and Hall, 2007)

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System Design

Web technology makes it possible to present and disseminate geospatial data and maps independently and huge number of users can access it anywhere at any time (Kraak, 2004). Web GIS has advantage on disseminating spatial data, widely over the internet for a wider audience. So that, this would make the data more accessible to the public and the decision-making process (Haron and Majid, 2010). To accommodate this was developed in web-based technology implementing Geoserver for establishing map services, MySQL for storing attribute data, Apache for web server and OpenLayers for interface design. The application prototype is provided in the following figure.

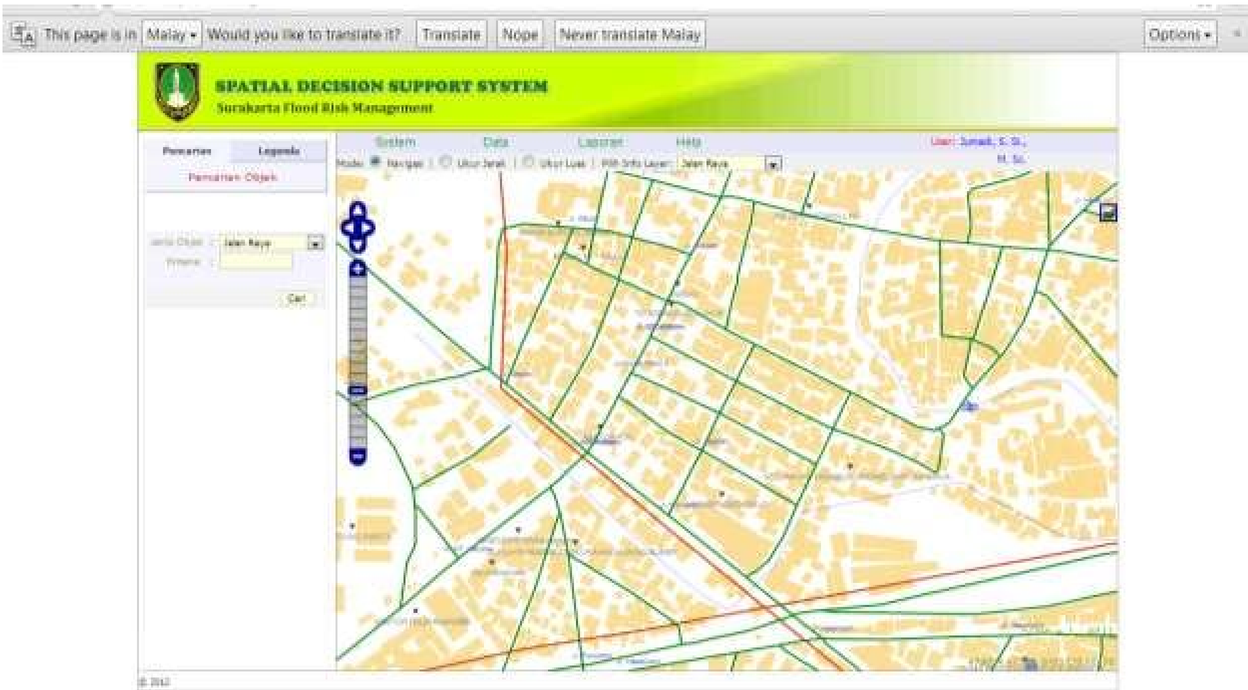

Figure 4. SDSS Prototype Interface

Conclusion

The prototype shows that spatial information of risky area can be distributed widely among responsible Agencies trough web-based technology. This finding can be used to provide statistical data as well as spatial extent, distribution, location on other spatial information aspect of risk. Therefore, decision making process in flood disaster risk management can be conducted collaboratively.

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