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Spatial Decision Support System for Environmental Disaster Management

Prof.Madya Dr.Shattri bin Mansor
Fakulti Kejuruteraan UPM

Spatial Decision Support System for Environmental Disaster Management

Shattri Mansor
Spatial & Numerical Modeling Laboratory
Institute of Advanced Technology
University Putra Malaysia
shattri@eng.upm.edu.my

Abstract

Environmental disaster management consists of three phases before a disaster occurs, risk identification, disaster mitigation, and disaster preparedness, and two phases that happen after the occurrence of a disaster, emergency response, and rehabilitation and reconstruction. Many types of information that are needed in environmental disaster management have both an important spatial as well as temporal component. The prime concern during any disaster is the availability of the spatial information, and the dissemination of this information to all concerned. The development a spatial decision support system has been driven by the need for better decision-making. Early innovators were motivated by the belief that experts in a wide variety of fields could make better decisions if they had better tools for analyzing and visualizing geographic data. Spatial decision support system provides an easily understandable assistance for decision makers to be able to find the best managing method in shorter time. Decision makers need to be able to discover, access, integrate and share spatial data and services from multiple online sources. The variety and quantity of spatial data needed for decision making continues to increase-as does the frequency of updates. The number of applications and devices continues to grow. New handheld, wireless and location-based technologies are becoming essential for field personnel. The challenge is to streamline, integrate and otherwise improve data sharing efforts, even as data proliferate and new technologies are added to the toolkit. Several initiatives case studies are presented here so that these can be of help at the time of Malaysia's need.

INTRODUCTION

Natural disasters are inevitable and it is almost impossible to fully recoup the damage caused by the disasters. But it is possible to minimize the potential risk by developing

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disaster early warning strategies, prepare and implement developmental plans to provide resilience to such disasters and to help in rehabilitation and post disaster reduction. Space technology plays a crucial role in efficient mitigation and management of disasters. Remote sensing and Geographical Information System (GIS) in evolving a suitable strategy for disaster management and occupational framework for their monitoring, assessment and mitigation, identifies gap areas and recommends appropriate strategies for disaster management using these technologies.

A complete strategy for disaster management is required to effectively reduce the impact of natural disaster, which is referred to as disaster management cycle. Disaster management consists of two stages. The first phase takes place before disaster occurs and consists of disaster prevention and preparedness. The second stage happens after the occurrence of a disaster and consists of three phases i.e. disaster relief, rehabilitation and reconstruction.

In disaster prevention phase, GIS is used to manage the large volume of data needed for the hazard and risk assessment. In disaster preparedness phase it is a tool for the planning of evacuation routes, for the design of centers for emergency operations, and for integration of satellite data with other relevant data in the design of disaster warning systems. In the disaster relief phase, GIS is extremely useful in combination with Global Navigation Satellite System (GNSS) in search and rescue operations in areas that have been devastated and where it is difficult to orientate. In the disaster rehabilitation phase GIS is used to organize the damage information and the post-disaster census information, and in the evaluation of sites for reconstruction. Hence, GIS is the useful tool in disaster management if it is used effectively and efficiently (Pearson et al., 1991).

The real strategy to disaster management should address issues related to risk assessment, mitigation, preparedness and recovery. Towards evolving this strategy, it is imperative to identify, disaster-by-disaster, the crucial information needs in order to work out the risk appraisal including vulnerability analysis of particular terrain, prediction, warning and prevention of the disastrous events (Table 1). While the International Decade for Natural Disaster Reduction (IDNDR) provides a broad framework for assessment of risk worldwide, individual countries must concentrate on (1) identification of hazard zones (ii) risk assessment, (iii) creation of awareness at various levels, (iv) evolving systems for

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monitoring, prediction and warning, (v) designing long term preventive measures and preparedness, (vi) early intervention measures, (vii) education, training, and (ix) research on improved technology and disaster management. The present article briefly narrates some of case studies as how remote sensing and GIS technologies were integrated with knowledge-based system in relation to disaster management.

SPATIAL DECISION SUPPORT SYSTEM

Decision-making is a complex process, influenced by many factors, both human and non-human. Academic research in the Decision Support System (DSS) field dates from the work of Gorry and Scott-Morton in 1971 (Keenan, 1997). A DSS may be defined as an integrated, interactive and flexible computer system that supports, not replace, all phases of decision-making with a user-friendly interface, data and expert knowledge (Fabbri, 1998). Some, but by no means all, recent DSS textbooks are including GIS as a component of management support systems (Fabbri, 1998). GIS software provides a link between the interface and database to allow the user to easily query spatial data. Or even it can be used as a Decision Support System (DSS) generator to create Spatial Decision Support Systems (Keenan, 1997). Five main components make up the module and architecture of a spatial decision support system which may be implemented for flood disaster management. These SDSS models include (1) a database management system (DBMS), (2) analysis procedures in a model base management system (MBMS), (3) a display generator, (4) a report generator and (5) a user interface (Malczewski,1997). The interrelationship between these components is further illustrated in figure 1 that shows a schematic design of the structure of general SDSS.

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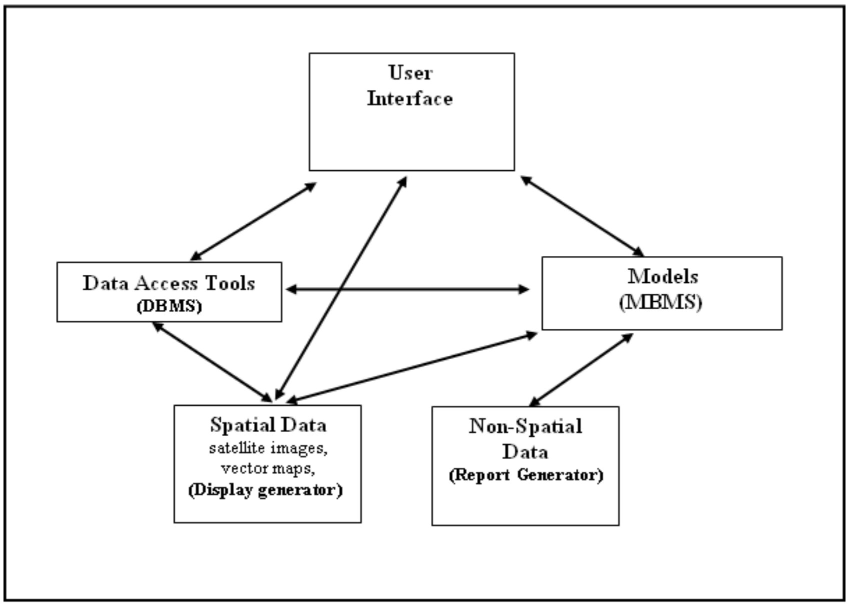

Figure 1: Schematic Structure of General SDSS(Modified from Parker et al.,1994)

- **Flood Disaster Management**

Flooding is the most commonly occurring form of natural disaster and includes both riverine flooding and coastal flooding. Coastal areas are particularly susceptible to flooding from tsunamis, which may be aggravated at high tide periods. Floods often cause tremendous damage to prime agricultural lands and to government infrastructure such as roads, bridges, irrigation dykes and flood-control structures. In Malaysia riverrine floods resulting from extreme monsoon rains cause extensive yearly damage.

Disaster experiences in many parts of the world have shown that flood hazard mitigation needs to shift its approach from a disaster-response driven system to a system based on pre-disaster or ongoing risk analysis, to become proactive rather than reactive to flood hazard events. A look at the flood disaster management in Malaysia will required that emphasis and value are placed on the planning process as an approach to mitigation that must be promoted and supported in order to build sustainable, flood disaster management program. According to Penning-Rowsell and Fordham (1994), it is also important to note that besides the available financial resources and the degree of co-operation between management agencies, the requirements on flood monitoring will depend on the specific hydrological and hydrometeorological conditions in the catchment and the river sections. Pre-flood mitigation planning and decision making can be encouraged based on regulation and floodplain maintenance. The maintenance of ditches, streams and river channels is a very important flood preventive measure. Rubbish and waste dumped in channels must be constantly cleared to unplug bottlenecks; grass and overgrown weeds must also be removed. Building and construction regulations are needed to check shoddy constructions and restrict development in river flood plains. Table 1 lists the detail structures, activities, proponents and key factors of a typical flood monitoring and management program. The components and factors are to be connected from detection to reaction for an effective flood monitoring programme that constitutes an integrated flood forecast and flood information system.

Table 1: Flood management program

Structures	Activities	Dept. & Institutions	Key factors
DETECTION	Collection of meteorological data and weather forecasts Collection of hydrometric and hydrological data	Meteorological Dept, DID, other regional/local units	-Automated and telemetric data collection and transmission -Networks of data collection station -Satellite data ,weather radar

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Structures	Activities	Dept. & Institutions	Key factors
FORECASTING	Receiving and interpreting of data Flood modelling Flood forecasting Issuing of warnings	Flood forecasting agency DID flood unit, other regional/local units	-Operational flood forecasting system with R-R-model and water level -Efficient inter-agency and transboundary communication system
WARNING	Receiving of flood forecasts and warnings Interpretation and decision- making Dissemination of warnings Providing of information Co-operation of involved parties and media	Regional and local decision makers Flood committee and disaster prevention Civil protection (rescue service, police, fire brigade, etc.) Internet, print and electronic media	- Clear responsibilities for agencies - 24 – hour staffed offices - Fast and efficient communication - Long forecast lead time - Few false warnings -Targeted warnings -Efficient inter-agency and trans local authority co-operation
RESPONSE	Co-ordination of response activities/measures and participants Informing the public	Flood committee and disaster prevention Local government units Civil protection	good information system for the public with learning feedback
REACTION	Reduce vulnerability to damage by pre-cautionary measures, flood defence and evacuations	River user, companies, industry within flood prone areas Population at risk	-Response to information and warnings -Availability of assistance -Awareness of the situation prior flood experience

- **Application of SDSS in Flood Disaster Management**

Flood disaster management comprises detection, forecasting and warning component for which various decision-making criteria will be promoted by interest groups. Detection involves the collection of various data that include meteorological, weather forecasts, and hydrometric and hydrological data for analysis. The key decision-making criteria at this level will be the effectiveness of weather radar and meteorological data and quality of data received through automated telemetric data collection and transmission from the dense networks of data collection station.

Flood Forecasting involves the receiving and interpreting of data, flood modeling; flood forecasting and issuing of warnings. Priorities here are the efficiency of hydrological models, operational flood forecasting system with rainfall runoff modeling (Figure 2). Flood warning involves receiving flood forecasts and warnings in the form of maps that show possible inundated areas, interpreting it and making decisions. The priority will be the dissemination of warnings, providing of information, co-operation of involved parties and media.

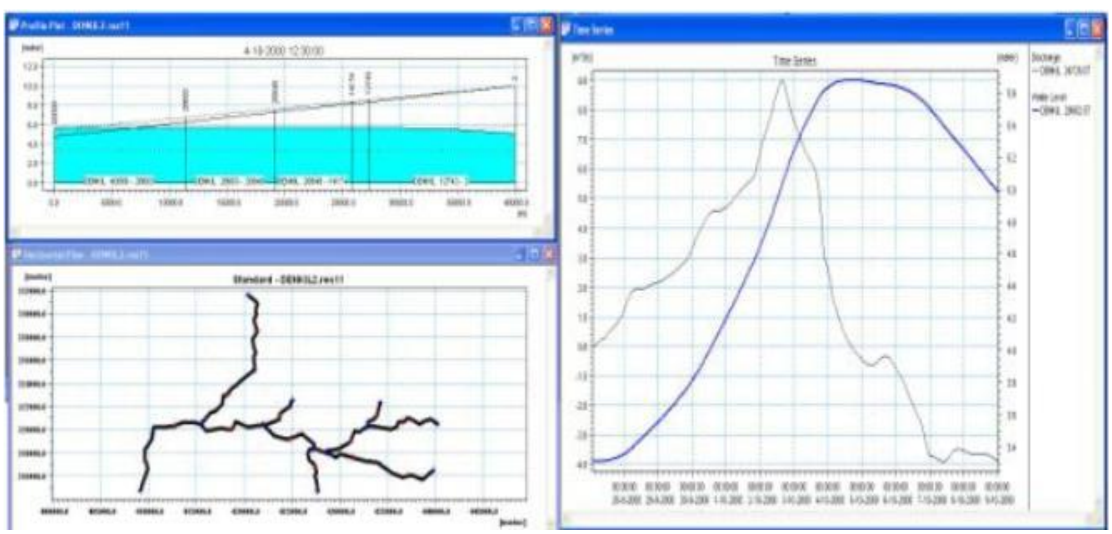

Figure 2: Water level and rainfall runoff modeling

The variously defined stages in this flood disaster management are integrated in an SDSS that will provide graphic and non-graphic information and have tools to retrieve data from the storage module, query and develop flood simulations. Resulting flood inundation maps provide the necessary visual information to aid decision making. Factors that may generally impact on decision-support from a SDSS comprise fast and efficient communication, long forecast lead-time, few false warnings and targeted warnings.

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OIL SPILL AND DECISION MAKING

Some of the information, e.g. geographical, ecological, legal, containment, clean-up equipment, and environmental sensor locations, can be acquired and organized in advance, typically through a GIS. Other types of information, e.g. winds, waves, currents, vessels traffic, and fishing fleet operations, must be dealt with in real time (Douligeries et. al, 1995). Decision Support System (DSS) serves a central role in all aspects of tactical operations. We tried to gather traditional methods of DSS, GIS, database systems and interface shells, to make a more intelligent Decision Support System which can help the environmental engineer to identify the optimal alternatives for pollution prevention and cleanup method selection processes and thereby help to reduce the costs for cleaning practices.

Considering the proposed contingency plan scheme in this project illustrates Decision Support System constitutes the central nucleon of this plan, which receives all information from different groups of contingency team. Decision Support System provides an easily understandable assistance for non-technical decision makers to be able to find the best managing method in shorter time.Comparing other various DSS models and studies indicates that most of them classify the user duties under these categories: defining the present condition of environment, identifying the conflicts or problems that environment face to them, and introducing the alternative solutions. According to this classification, the duty of DSS of oil spill management project also was considered as shown in figure. 3.

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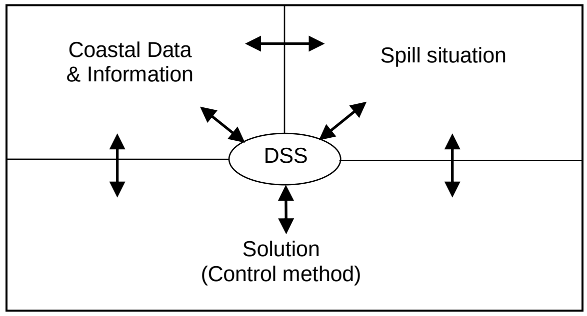

Figure 3: Three main domains of the oil spill management Decision Support

Table 2: Basic steps in making DSS engine for oil spill management

Existent Information	**Databases (queries)**	**Maps / Images (queries)**	**Models (Oil spill movement)**	**Appendices (tables, photos, clips, …)**
Knowledge	Sensitivity Criteria	Protection Priority	Clean-up Standards	Remarks
Conceptual Designing	If-based Rules	Inference Engine	Interface Visualization	User-friendly Relations
Evaluation System	Pilot Study Area	Expert Management (according to a sample spill)	DSS-based Management (according to a sample spill)	Comparing two combating groups
Developing Engine System	Corrections, System development for more comprehensive areas, Databases, Spill situations, Expert knowledge, Theory aspects & Practical computational			

It shows the general, simple idea suggested for in hand project of oil spill management (Pourvakhshouri and Mansor, 2003). Table 2 indicates the information used to establish the system. The coastal information was divided to three major parts of physical, biological and human use resources that was stored in system. Other stored information includes the required equipments, the maintenance ports/ agencies and access ways as well as explanatory documents like national regulations, criteria, exploitation sites, transportation routes, etc. Some part of data must enter the system as real time such as wind, current, oil spillage point, etc., through the interface. A part also was considered for validation of system by sample scenarios and historical cases (Figure 4).

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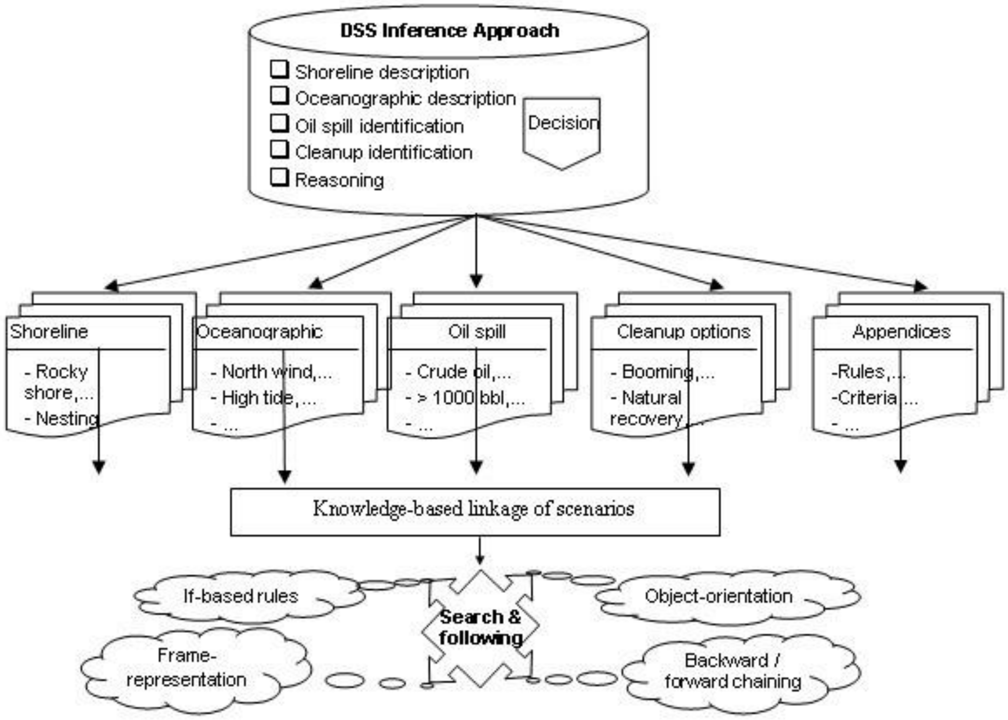

Figure 4: Detailed design of the proposed DSS for oil spill management

If the system is described simply, it can establish a linkage between spilled oil characteristics and location, shoreline sensitivity, and the different clean-up methods. Significant types of information are extracted through knowledge-based archive. And most linkages are based on expert system engineering methods like if-based rules, and backward/forward chaining, and frame representation. Knowledge engineering for constructing the decision support system on oil spill management involves three stages: knowledge acquisition, conceptual design, and system implementation. In the knowledge acquisition phase the objects and decision processes were clarified and determined. In the conceptual design stage, the knowledge was formalized and represented with various representation methods. Then the formalized knowledge was represented in produced rules in the knowledge base of the system.

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Regarding to the project's proposed aims, some criteria such as: - availability of more data with manageable volume, having the environmental sensitivity in both natural and human activity form, and exposure to oil related activities with pollution occurrence history, were considered for choosing the primary study area. Pilot study area has been selected at south east of the Straits of Malacca, from northern part of Port Dickson to south of Melaka town. Field validation was done by checking the coastal area, locating the various natural and man-made features, and GPS reading. These points and features were transferred to remotely sensed images and GIS-based maps as well as linking the related information and data bases, which obtained from Department of the Environment and Fisheries department, to establish an updated ESI map. User interface was developed using Visual Basic and Macromedia Dreamweaver.

Categorizing of important factors in shoreline area sensitivity was done via questionnaires and interviews among governmental and private sectors as well as public who are involving in coastal activities. Shoreline area was divided to three parts of major, medium and less in danger parts according to different factors like human economic disruption, wild life mortality, habitat availability, aesthetic degradation, etc. As well, some criteria affecting on choosing of oil response methods including of equipments, responding teams, environmental considerations, and cost were considered as base for knowledge acquisition from Malaysian Marine Department and Department of Environment, as the major responsible authorities in oil spill cases. The whole system is being designed based on experts' knowledge and experiences and validating some sample scenarios and selected historical cases.

CONCLUSION

The availability of GIS and digital data allows more reliable decisions both in pre-disaster and post-disaster activities to support all phases of disaster management. Oil spill management system aims to achieve a knowledge-based system which can choose the most suitable method of response in shorter time by analyzing the various sensitivity factors of coastal environment, affecting parameters on oil spill movement, environmental concerns in oil spill response, and consequent monitoring and clean-up measurements. SDSS is useful in speeding of response actions especially in the regions which still suffer from the shortage of enough experts for responding the disasters.

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