DECISION SUPPORT SYSTEM IN OIL SPILL MANAGEMENT

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Technical Commission II

Key Words: Oil Spill Management, Decision Support System, Knowledge Based System, Coastal Ranking, Coastal Prioritization, Malaysia

ABSTRACT:

Oil Spills can have severe and long-term biological, economic, political, cultural, and social impacts. While it is not possible to predict the impacts of an oil spill with any certainty, it is possible to evaluate the vulnerability of an area to a defined spill scenario based on the risk resources present in the area. One of the approaches is to assess environmental sensitivity to oil spills. This paper describes the design and development of the coastal prioritization index. The approach will take into account the vulnerability of natural and socio-economic resources, or more general societal values. Coastal area was categorized to different level of importance to perform management planning and strategies. 180 km shoreline of two states of Negeri Sembilan and Melaka, in west Malaysia was chosen as a pilot area. Knowledge extraction has been done via direct interview and questionnaire designing. Coastal data acquisition was based on Malaysian ESI maps from 1989-1992, which have been updated by remote sensing data as well as field check on June 2004. Coastal prioritization ranking has been done according to coastal sensitivities in physical and biological resources along with human usage and activities. A GIS-based DSS was developed where the decision maker can choose the most reasonable combating method for prevention, control, and/ or cleanup way against the oil spills pollution. It will be an advisory service to determine the priorities in emergency response conditions, according to the coastal sensitive areas. Provided computerized DSS with GIS-based produced maps and stand alone user interface was developed with VisualBasic6 program. Main achieved goal has been regarded to establishment of a “priority ranking scale” for the coastal area, assisting the decision making procedure for management of oil spill impacts on the coastal area resources. Although all the coastal areas will receive a code and number for ranking, they have been categorized finally in five main categories from very high to low priority, to be more sensible to all users to describe the category and refer to the management alternatives, which come up through the DSS management recommendations.

1. BACKGROUND

1.1 Introduction

Numerous examples of competition for space, over-exploitation of resources, degradation of natural habitats, pollution, and other user conflicts attest to increasing exhaustion of coastal space and resources (LMP, 1998). Multiple use of coastal space, the implications of coastal processes on human society, and the fragility of marine environment and its coastal fringe all require that rational, integrated and sustainable management strategies be developed. Coastal zone management is planning, implementing, and monitoring the sustainable use of coastal resources (Bartlett, 2000).

While it is not possible to predict the impacts of a specific event with any certainty, it is possible to evaluate the vulnerability of an area to a defined event scenario based on understanding the sensitivity of those resources to that event. Sensitivity index mapping was considered appropriate at the time for oil pollution, concerns have been raised subsequently that such an approach fails to take account of the actual sensitivity of coastal resources and values to management priority for a certain event in coastal areas (Robert and Crawford, 2004).

Including more than 4670 km coastal borders with valuable mangrove swamps, shrimp prawns, birds’ breed and nesting areas, turtles egg laying as well as recreation and tourist resorts, has formed Malaysia as a big and important part of coastal natural resources. This paper summarizes the factors would be considered as effective ones to establish a DSS for prioritization of Malaysian coastal area, based on the experts’ knowledge dealing with oil spills management in local organizations along with Malaysian existent ESI maps. With this prioritization approach, involved decision makers will be able to prioritize the actions needed to be done to protect the coastal sensitive resources.

1.2 Coastal Prioritization

Management of coastal systems has become the focus of many national and international projects. Coastal systems extend beyond jurisdictional boundaries and are affected by impacts of many local users and by decisions made by different levels of government.

Effective decision-making on the coast requires the decision-maker to have a genuine understanding of the morphological, biological and human-oriented processes likely to be encountered within the coastal system. This level of understanding will only be obtained if accurate, timely and appropriate information is available for consulting (Bartlett, 2000).

The Environmental Sensitivity Index (ESI) is a ranking of the relative sensitivities of various geomorphic coastal environments in terms of oil–sediment interactions. Traditional ESI mapping techniques involved the uses of already existing planimetric base maps and the subsequent identification of shoreline and biological sensitivity areas, as well as the locations of access – protection facilities (Getter et al., 1981). More recent work on ESI mapping has involved the use of remote sensing and GIS technology to make it a more effective and efficient tool (Jensen et al., 1990; Jensen et al., 1993).

There are many reasons to develop a prioritization system; one is to determine the points and problems which require the most attention, and to direct an approach for specific needed actions. Once the targeted areas identified, optimized management system can be used via implementation of various best management practice options, consequently (Bartholic et al., 1996).

1.3 Decision Support System

Decision making process uses a four element roadmap as a guide to the decision process. With this, any group can identify what it should work towards next and it can also assess where it has been. However, just as a roadmap is not the same as a set of directions to be followed, like a checklist. Rather it is a set of opportunities, in a logical flow, which leads to the development of a robust decision (Raiffa, 2003).

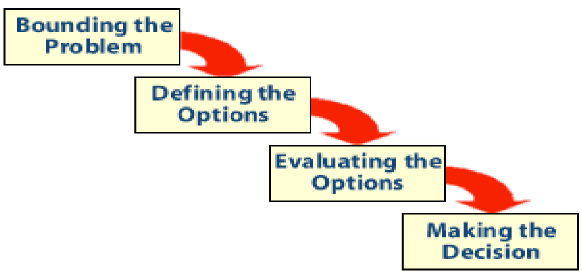

Figure 1. Four-element road to achieve a good decision making (Raiffa, 2003)

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). Earliest definition of Decision Support System, introduced by Scott Morton in 1978 (Neethi and Krishnamoorthy, 1988) was: "Interactive computerized systems that help decision makers utilize data and models to solve unstructured problems." A DSS also may be defined as an integrated, interactive and flexible computer system that supports all phases of decision-making with a user-friendly interface, data and expert knowledge (Fabbri, 1998).

There is a spectrum of definitions on DSS, which reflects the fact that heterogeneous groups viewed it differently. Most DSS designers refer to a developed man-machine interface between user and system. This has lead to a generalized perception of calling any computerized system, which helps decision making, in some way or other, as DSS.

While appreciating potential of technology, it may be noted that technology has not been received in totality by the decision makers and implementers, who are responsible for executing certain management plans in the field. Decision Support System offers the system, which captures knowledge of scientists / domain experts and acquirements of decision makers. In order to translate efforts of scientists / technologists in reality, the role of Decision Support System is enormous (Ravan, 2002).

Decision Support System (DSS) is a well-established area of information system applications, which assists the decision makers to derive an in-time, efficient solution. Decision Support System provides an easily understandable assistance for non-technical decision makers to be able to find the best managing method in the least time. In fact, DSS is software that establishes the required relations between the present condition and the needed management requirements.

2. METHODOLOGY

2.1 Designing Coastal Prioritization

The identification of coastal priority index required a sensitivity analysis in general, including environmental, social, cultural, and economic factors. The first step in this analysis process was to divide the coastline into "coastal cells", cells of enough coarse size to analyze as well sufficient resolution. The cells were chose based on the standard satellite image grids of area. Each cell is 10×10 km^2, which covered 180 km of coasts of study area by 16 squares.

Each coastal cell was ranked in terms of its environmental and human sensitivity, based on allocating experts' points for different criteria. The criteria were:

- Coastal physical characteristics;
- Biological and ecological resources;
- Human health and use;
- Significant sites.

Each category was ranked on a scale of 1–3 (for low to high sensitivity) of groups, with each category being awarded a knowledge-based significant weight (from 0–1), for relative significance in compare to other categories. For each cell, the sensitivity scale was multiplied with the respective weight for the category. Then, the weighted values summed to provide an index of priority.

2.2 Decision Support System Components

Almost all reviewed modells concentrated on three major distinct areas, under different titles. Comparing the various DSS models indicates they 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, DSS domains of this management project also were suggested in Figure 2 (Pourvakhshouri and Shattri, 2003).

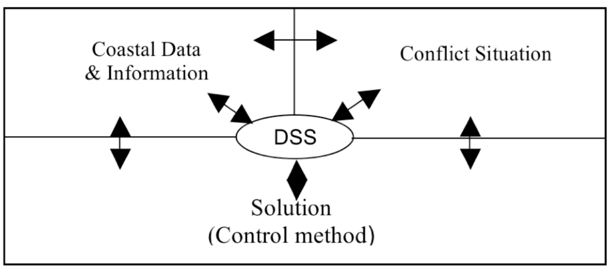

Figure 2. Three main domains of the established management Decision Support System

Considering the project proposed plan, DSS constitutes the central nucleus of this plan. This receives all information from different groups of contingency teams. Decision Support

System provides an easily understandable assistance for non-technical decision makers to be able to find the best management method in the least time.

DSS programming stage has been done using VisualBasic6 to make a stand alone system, including the following points:

- Friendly user interface;
- Knowledge-based information pack;
- GIS- based provided maps;
- Inference coding window.

2.3 Integrating DSS for coastal prioritization

The first type of required data layer has been updated in GIS-based database, focused on the Malaysian national ESI maps, which has been updated with remotely sensed images and field-based validation. Quantifying of this category of data has been knowledge-based according to local and non-local experts dealing with oil spills responses measures.

The second part has been established using if-based ruling, as it is mostly variable, semi-real data; can be composed and be effected when the spill is happened. So, most probable scenarios have been outlined in system engineering space, to be extracted in the case.

A prioritization matrix relates selection criteria to options by scoring the options. The scores are entered into the matrix and are summed, usually, to obtain final scores for each option. The prioritization element typically involves using weighting factors on the criteria (hence the prioritization).

2.4 Study area

Malaysia with a coastline of more than 4670 km coastal borders with valuable mangrove swamps, shrimp prawns, birds' breed and nesting areas, turtles egg laying as well as recreation and tourist resorts, has large and important coastal natural resources.

Study area has been selected in the Strait of Malacca from the North part of Port Dickson to South of Melaka, the estuary of Muar River. Field check trip has been done during 14-16 July 2004, to validate the existent data from the area, update the maps, and compare the extracted information from satellite images as well as GPS readings (Figure 3).

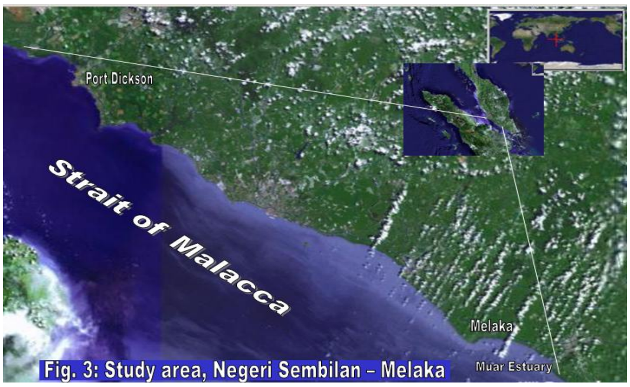

Fig. 3: Study area, Negeri Sembilan - Melaka

3. RESULTS AND DISCUSSION

Continuing the project, the main required criteria for classification of the coastal sensitivities against oil pollution were defined according to the experts' knowledge acquainted. For knowledge acquiring, some questionnaires were distributed between the private and governmental sectors as well as the interview with part of them. The questionnaires and interviews with about 20 local experts in both governmental and private sectors are being analyzed, while the other 20 international questionnaires have proceeded as the same. Along with local experts' knowledge, some of the standard texts both in national and international citations were searched to obtain the needed knowledge for completion of system designing.

System engineering has been constructed involving four main stages: knowledge acquisition, conceptual design, system implementation, and validation phase. 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 production rules in the knowledge base of the system (Table 1).

Existent Information	Databases (queries)	Maps / Images (queries)	Models (coastal situation)	Appendices (tables, photos, clips, …)
Knowledge	Sensitivity Criteria	Protection Priority	Management Standards	Remarks
Conceptual Designing	If-based Rules	Inference Engine	Interface Visualization	User-interface Relations
Evaluation System	Pilot Study Area	Expert Management (according to a sample event)	DSS-based Management (according to a sample event)	Adduction of two approaches
Developing Engine System	Corrections, System development for more comprehensive areas, Databases, Expert knowledge, Theory aspects & Practical computational			

Table 1. Basic steps in making DSS engine

The local data was updated by area visiting and field validation, and key points were located on the image and map from GPS readings. 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. The extracted information from image was transferred to GIS to obtain the vector maps for more analyses (Figure 4).

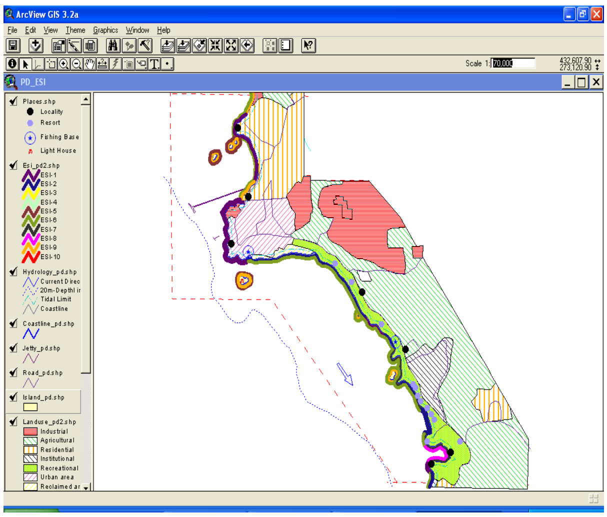

Figure 4. GIS-based updated ESI map for the study area

Then the rules for running the DSS of oil spill management are being prepared based on the local and non-local experts' knowledge. If-based rules of Visual Basic programming assist to develop a user friendly engine and interface.

Main achieved goal has been regarded to establishment of a "priority ranking scale" for the coastal area, assisting the decision making procedure for management of coastal threats. According to this ranking, any risk area will be categorized to different, important cases; whether the area is faced to direct impact on the human activities and life or not. The factors for direct impact have been defined and were discussed with people, involved officers, and responders. In the case of direct impact on the human activity, the coastal area will prioritize as the high priority for protection and management. If the area is not under the direct impact potential, it will go through the coding processing, to find the level in the priority ranking scale.

Although all the coastal areas will receive a code and number for ranking, they have been categorized finally in four main categories from very high to low priority. Then, it is simply understandable for all users to describe the category and refer to the management alternatives, which come up through the DSS management recommendations.

4. CONCLUSION

Study in the field of coastal zone management, oil pollution, and decision support system are among the attractive issues have the attention of many researchers. Building ease to decision making is one interesting case in this information-base century and this on going project aims to achieve this goal.

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.

Analysis and processing functions of digital images together with and GIS engine have been applied to develop a coastal priority ranking map to protect the vulnerable environmental and socioeconomic resources of the Malacca Straits, as a necessary part of oil spill control and cleanup program.

This study integrates the GIS, Landsat imagery, and visual basic programming language to achieve an assistance system for clarifying the priorities in protection and response activities against oil spills pollution in Malaysian marine-coastal environments, based on the stakeholders benefit and experts' knowledge and experiences.

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