UNIVERSITI PUTRA MALAYSIA

COASTAL PRIORITY RANKING IN OIL SPILL RESPONSE DECISION SUPPORT MECHANISM

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia
In Fulfilment of the Requirements for the Degree in Doctor of Philosophy

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DEDICATION

To My Family;

For their stream of Love, Faith and Encourage

And

To Whom Challenges for Supporting Humanity with Knowledge

Abstract of the thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree in Doctor of Philosophy

COASTAL PRIORITY RANKING IN OIL SPILL RESPONSES

DECISION SUPPORT MECHANISM

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Millions of tons of oil are produced in the world every year and over half of it is transported to the users by means of marine routes. Based on statistics, a best estimate of oil spill is more than 3 million tons per year. Oil spills cause disastrous impacts on the environment, ecology and socio-economic activities. The right decision has to be made in the event of an oil spill to facilitate prompt action, considering the priorities of protection, to prevent environmental damages. Interest in having modern, technological management system in semi-structured fields such as disastrous incidents is increasing rapidly. Response decision support is a mechanism utilizing a knowledge-based plan to choose the most suitable method of response by analyzing the various sensitivity factors, parameters affecting oil spill impacts, environmental concerns in oil spill response, and consequence monitoring and clean-up operations in the shortest time. Environmental sensitivity index (ESI), a traditional scale, is mostly a static scale for evaluation of coastal situation. It requires calibration along with oil nature and impact in each spill case to be able of priority displaying in action. This study aimed to develop a semi-automatic knowledge-based decision support mechanism to retrieve experts' knowledge for prioritization in responding to oil spill events. A tool was needed to classify information about knowledge and expertise in this field and follow the rational logic of master minds and could be transferable. The knowledge and expertise from knowledgeable participants were obtained through questionnaires and direct interviews as well as information from literatures. Three objectives were covered by the study including ranking of sensitivity-oil-response criteria, development of coastal priority ranking (CPR) scale, and establishment of a validated computer-based mechanism for oil spill response (OSR-DSM). Analyses of questions were conducted using Delphi method, Likert scaling, and repertory grid analysis. The evaluation of knowledge level provided the normalized weights (from 0.09 to 1.0) for respondents' knowledge and these weights were applied to criteria ranking. Considering two objects of environment and oil, priority ranking matrix was established and CPR scale was calculated based on the fact that various "low/ medium/ high" impacting scenarios of oil can affect the corresponding "low/ medium/ high" sensitive resources. One program was designed to visualize DSM with computation of ESI, coastal sensitivity, oil impact, and CPR values as well as reporting on response alternatives. The advantage of CPR scale method was its ability for a more dynamic quantitative evaluation of priorities in application time rather than only explaining sensitivity indices of area. The scale for CPR was evaluated ranging from 35 to 469 and the values were qualitatively categorized from low priority to medium, high, very high and extremely high priorities. Three major categories were renowned for responses alternatives - on-sea response or preventive activities, shoreline protective activities, and on-coast response or cleanup activities. Results were verified to present the inclusiveness, accuracy, and system algorithm. The verification activity involved exploring the knowledge base, coding of reasoning processes / inference engine, technical performance, ability for development, and interface. A total of 80 percent of users in the verification phase believed that development of such mechanism was a right approach for supporting the right decision in oil spill responses, either by increasing the speed and accuracy in evaluation or reducing the cost. Verification research could attain rates of over 50 percent in all five categories. General rates given to the mechanism by two groups of users were 82 and 85 percent with a $\pm$ 3.66 percent of uncertainty that was issued a high verification value. This study has resulted in two main products: - coastal priority ranking scale (CPR) and oil spill response decision supporting mechanism (OSR-DSM). It is intended to facilitate the oil spill response process while at the same time improves the decision-making quality by applying the effective knowledge and expertise in oil spill response procedures. Definition of knowledge criteria leading to classification of knowledgeable participants, as well as numerical verification frame for qualitative knowledge-base mechanism were two significant outputs of this study.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

RANK KEUTAMAAN PESISIRAN PANTAI DALAM MEKANISMA MENYOKONG PEMBUATAN KEPUTUSAN RESPON-RESPON TUMPUHAN MINYAK

Oleh

Seyedeh Zahra Pourvakhshouri

JULAI 2008

Beberapa juta ton minyak dapat dihasilkan dalam dunia setaip tahun dan lebih setengah hasil ini dapat diangkut kepada pengguna-pengguna melalui perjalanan-perjalanan marin**.** Berasaskan data statistik, anggaran tumpuhan minyak yang paling baik adalah melebihi 3 ton setahun. Tumpahan minyak dapat menyebabkan impak-impak yang sangat teruk terhadap alam sekitar, ekologi dan aktiviti-aktiviti socio-ekonomi. Keputusan yang betul dan mengambilkira keutamaan perlindungan, hendaklah di buat

sekiranya belaku tumpahan minyak supaya dapat bertindak dengan segera untuk mengcegah kerosakan alam sekitar. Keminatan untuk memperolehi sistem pengurusan menggunakan teknologi moden bagi tujuan bidang berstruktur separuh seperti kejadian bencana, kian maningkat. Respon penyokong keputusan adalah sesuatu mekanisma yang menggunakan pelan berasakan pengetahuan untuk memilih keadah respon yang paling sesuai melalui analisa pelbagai faktur-faktur kepekaan, parameter-parameter yang mempengaruhi impak tumpuhan minyak, kebimbangan alam sekitar terhadap respon tumpuhan minyak, pemantaun akibat dan operasi pembersihan dalam masa terpendek. Index kepekaaan alam sekitar (ESI), satu skala tradisional, merupakan skala yang statik bagi tujuan penilaian situasi persisiran pantai. Ia memerlukan kalibrasi mengikut sifat minyak dan impaknya setiap kes supaya dapat menunjukkan tindakan keutamaan. Kaijian ini bertujuan untuk membangunkan sesuatu mekanisma menyokong pembuatan keputusan berasaskan pengetahuan secara automatik separuh, agar ilmu daripada pakar-pakar dapat diperolehi untuk mengutamakan respon-respon terhadap peristiwa tumpahan minyak. Sesuatu peralatan adalah diperlukan untuk mengelaskan maklumat mengenai pengetahuan dan kepakaran dalam bidang ini dan mengikut logik pemikiran pintar dan boleh dipindahkan. Ilmu dan kepakaran daripada pakar-pakar yang berilmu luas telah diperolehi melalui siasatan soal-selidik dan temuduga-temudaga secara langsung termasuk juga maklumat yang di perolehi daripada soratan kajian. Tiga objektif telah diliputi dalam kajian ini. Ini adalah susunan rank sensitiviti kriteria-kriteria respon minyak, pembangunan skala rank keutamaan persisiran pantai (CPR) dan penubuhan mekanisma respon tumpahan minyak (OSR-DSM) berasaskan komputer. yang sah. Analisa maklumbalas soalsilidik telah dibuat dangan penggunaan keadah *Delphi, Likert Scaling* dan *Repertory Grid.* Penilaian paras pengetahuan telah menghasilkan *normalized weights* yang berubah daripada 0.09 ke 1.00 untuk setiap pengetahuan respon dan nilai keberatan ini dapat terus digunakan dalam susunan rank kriteria-kriteria. Matriks rank keutamaan telah dibuat mengambilkira dua objek ,iaitu, alam sekitar dan minyak; dan skala CPR diperkirakan berasaskan bahawa scenario impak-impak minyak rendah/sederhana/tinggi boleh mengesan sumber-sumber yang bersensitif rendah/sederhana/tinggi. Satu program dapat direkabentuk bagi tujuan memberi gambaran DSM dengan perkiraan ESI, kepekaan persisiran pantai, impak minyak dan nilai-nilai CPR, termasuk juga memberi laporan respon-respon alternatif. Kelebihan keadah skala CPR adalah dari segi kebolehannya memberi penilaian keutamaan kuantiti yang lebih dinamik dalam masa aplikasi berbanding dengan hanya memberi keterangan indeks sensitiviti kawasan yang berkenaan. Skala CPR yang telah dinilai berubah daripada 35 ke 469 dan nilai-nilai ini dapat dikumpulkan mengikut kelas keutamaan rendah, sederhana, tinggi, sangat tinggi dan terlalu tinggi. Tiga kategori utama yang terkenal bagi alternatif-alternatif respon adalah respon di laut atau aktiviti pencegahan, respon perlindungan aktiviti-aktiviti persisiran pantai, dan respon di atas pantai atau aktiviti-aktiviti pembersihan. Keputusan-keputusan telah diuji untuk memberikan kelengkapan, kejituan dan algorithma sistem. Aktiviti verifikasi ini melibatkan melayari landasan pengetahun, pembuatan kod proses rasional / enjin pengertian, kejayaan teknikal, kebolehan pembangunan dan antaramuka. Sejumlah 80% pengguna-penguna dalam fasa verikasi mempercayai bahawa pembangunan mekanisma ini merupakan pendekatan yang baik untuk menyokong pembuatan keputusan yang betul terhadap respon tumpuhan minyak dengan cara meningkatkan kelajuan dan kejituan penilaian atau penurunan kos. Penyelidikan verfikasi boleh mencapai kadar melibihi 50 peratus dalam kelima lima kumpulan. Kadar am yang diberikan pada mekanisma ini oleh dua kumpulan pengguna ialah 82 dan 85 peratus dengan ± 3.66 peratus ketidakpastian, yang dikeluarkan dengan nilai verifikasi yang tinggi. Kajian ini telah menghasilkan dua produk utama- skala rank keutamaan persisiran pantai (CPR) dan mekanisma penyokong pembuatan keputusan respon tumpahan minyak (OSR-DSM). Ia bertujuan untuk memudahkan proses respon tumpuhan minyak, sementera dalam masa serentak meningkatkan lagi kualiti pembuatan keputusan dengan menggunakan pengetahuan dan kepakaran yang berkesan dalam prosedur respon tumpuhan minyak. Definasi kriteria pengetahuan yang telah menghasilkan pengkelasan peserta-peserta yang berilmu, dan juga rekabentuk verifikasi berangka bagi tujuan mekanisma berkualitatif bersasaskan pengetahuan adalah dua hasil kajian yang penting.

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I certify that an Examination Committee has met on date of viva to conduct the final examination of Seyedeh Zahra Pourvakhshouri on her PhD thesis entitled "Coastal Priority Ranking (CPR) In Oil Spill Responses Decision Support Mechanism" in accordance with Universiti Putra Malaysia (Higher Degree) Act 1980 and Universiti Putra Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the Ph.D. degree. Members of the Examination Committee are as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Date: 15 January 2009

DECLARATION

I declare that this thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously and is not concurrently submitted for any other degree at UPM or at any other institution.

Seyedeh Zahra Pourvakhshouri

Date: 30 January 2009

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ASEAN	Association of Southeast Asian Nations
BC	British Columbia
CPR	Coastal Priority Ranking
DGEQ	Director General of Environmental Quality
DSS	Decision Support System
EDSS	Expert Decision Support System
EEZ	Exclusive Economical Zone
EQA	Environmental Quality Act
ESI	Environmental Sensitivity Index
GADS	Geo-data Analysis and Display System
GDSS	Group Decision Support System
GIS	Geographic Information System
GSS	Group Support System
IMO	International Maritime Organization
IS	Information System
ITOPF	International Tanker Owners Pollution Federation
JUPEM	Geodesy Section Department of Survey and Mapping Malaysia
KBS	Knowledge Base System
KS	Knowledge System
LS	Language System
MACRES	Malaysian Centre for Remote Sensing
NAS	National Academy of Science
NEB	Net Environmental Benefit
NOAA	National Oceanic and Atmospheric Administration
NOSCC	National Oil Spill Control Committee
OSPAR	Operational Strategic Planning and Research
PIMMAG	Petroleum Industry of Malaysia Mutual Aid Group
SDSS	Spatial Decision Support System
UNEP	United Nations Environment Program
USCG	United States Coast Guard

CHAPTER ONE

INTRODUCTION

1.1 Background

Among others, an imbalancement environmental issue for the coastal area is oil pollution and spillage, resulting from exploitation, extraction, transportation or disposal activities. An oil spill is the leaking of oil (generally, petroleum) into the natural environment. Oil means oil of any kind or in any form and includes crude oil, oil refuse, petroleum-related products or by-products, oil mixed in waste, oily ballast, and oily bilge water, which can cause plant or animal species to be endangered.

Worldwide, from 1978 to 1995, there were more than 4100 major oil spills of 10,000 gallons or more (Etkin & Welch, 1997). Several serious oil spill incidents have taken place since 1995; Notable example is Sea Empress from which some 5000 tons of oil reached the UK coastline (Li, 2001). These excluded the huge amounts of oil, which spilt towards marine resources during the wars.

An oil spill response includes all the measures to prevent or mitigate the impacts affecting the environment and human life. Response decision support is a mechanism utilizing a knowledge-based plan to choose the most suitable method of response in the shortest time by analyzing the various sensitivity factors, parameters affecting oil spill impacts, environmental concerns in oil spill response, and consequent monitoring and clean-up operations. 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 and introduce the priority for any action plan. Once the targeted areas are identified, as a priority, optimized response plan can be used via implementation of various best practice decision-making options (Ravan, 2002).

Taking into account the priorities both in measurements and in resources protection, it is necessary to provide a rational decision-making against the pollution. Locations of the environmental sensitive areas, spill points and their distances from the sensitive areas; kind and amounts of spilt oil; time of pollution occurrence; required response methods; and many more factors do influence the priorities (White, 2000).

Decision-maker requires a genuine understanding of the morphological, biological and human-oriented processes within the coastal system to approach an effective decision-making to manage the coastal zone. This level of understanding will only be achieved if accurate, timely and appropriate information is available for consultation (Bartlett, 2000). The semi-structured nature of spill management emphasizes on a need to enhance and improve the decision-making process, essentially recognition of the need to promote decision-support development. Decision Support System (DSS), focuses on specific decisions (semi- and/or unstructured decisions) and support rather than replace human decision-making processes. DSS offers the system that captures knowledge of scientists / domain experts and acquirements of decision makers and translate the efforts of scientists / technologists to reality (Ravan, 2002).

1.2 Problem Statement

Oil spills are serious environmental disasters, often leading to significant impacts on the environment, ecology and socio-economic activities of an area. Oil spills can cause short-term and / or long-term effects. Mortality and damage to marine life, disrupting the food chain, affecting the community health and many others are examples of these effects. Management of emergencies, resulting from natural or man-made disasters, requires enough information as well as experienced responders. The decision for a suitable method at a given site often requires expertise on both remediation technologies and site conditions (Hernandez & Serrano, 2001).

After an oil incident, quick and accurate decisions have to be made for combating primary target areas of oil and preventing long-term effects on the nature (Ihaksi, 2007). Improvement and strengthening of management and decision-making is the main goal in all disaster planning. However, making decision in many regions is still a traditional process, based on manual methods, old maps and certain people. It is becoming increasingly difficult to ignore that decision-making needs a practical method to look for priorities.

Existent Environmental Sensitivity Index (ESI) is a traditional scale for measuring sensitivity of environment since 1970s. Although ESI is an advantageous scale for coastal sensitivity but in practice, it does face some limitations in priority achievement (Roberts & Crawford, 2004). ESI is mostly static and requires being set along with oil potential impact in each spill case to be able displaying the priorities in action plans.