DEVELOPMENT OF INTEGRATED EMERGENCY MANAGEMENT MODEL FOR SHIPS IN DISTRESS

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ships in distress, DSS, GIS, multicriteria analysis

Abstract

The paper presents research in development of an integrated emergency management model as a support tool for National Maritime Rescue Coordination Centre (MRCC). MRCC manages all SAR situations within territorial sea of Republic of Croatia. Ever increasing number of tourist and commercial vessels, as well as frequent weather changes at Adriatic Sea cause ever more accidents that demand adequate efficient SAR management system. That was the reason why a project for developing effective Decision Support System (DSS) for emergency management system in case of maritime accidents has been initiated. Logically, development of such DSS leads to the implementation of a system that will support all decision in case of maritime accidents. The organization of that system is generally hierarchic; at each level decisions are made in accordance with the authority. Decisions' character is different at some levels and depends on the system organization; decision range at lower levels is in accordance with previously made strategic decisions. The DSS helps to structure and organize such a large quantity of information related to the emergency management system in case of maritime accidents, especially spatial data, in order to make it available to decision makers in a comprehensible and user-friendly way. Conceptualized DSS for tactical and operational level is divided in a number of segments (modules) that will be additionally built in the further phases. Basic module is GIS (Geographical Information System), for all levels of DSS, that comprise information sub-systems about spatial and other data and serves the other modules with data and information. GIS module is divided in several thematic layers with basic information about places of refuges, climate, maritime, hydrographic, ecological and biological characteristics, existing navigable waterways, maritime limits, boundaries of counties and cities, limits of territorial sea, continental shelf, military zones, topographic data, location emergency services, etc.

Introduction

Directive of the European Community 2002/59/EC is binding on all member states of the EU to establish (and communicate to the European Community) the places of refuge for ships in need of assistance off their coasts, or to develop techniques for providing assistance to such ships. Consequently, the Croatian Ministry of the Sea, Tourism, Transport and Development has initiated the procedure of harmonizing its working procedures and the respective

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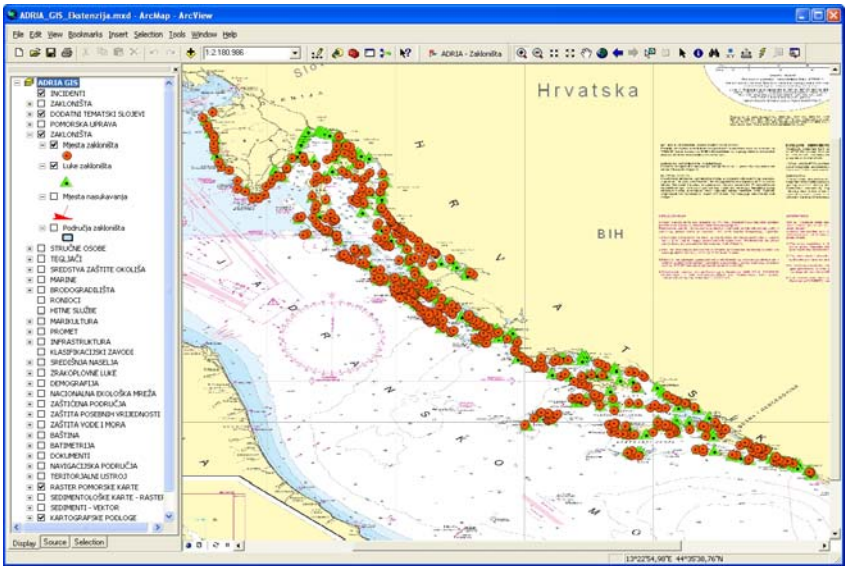
executive organization to meet the requirements provided for in the Directive. In this context, a project is launched aiming at development of working procedures for providing assistance to ships in distress in the area within jurisdiction of the Republic of Croatia. The first step was building of an integrated emergency management model for support decision process in case of maritime accidents.

First-year research on the project resulted in a study treating the issue of places of refuge (PoR) in a both scientific and professional manner. The GIS (Geographical Information System) application is developed containing integrated data about the 380 potential locations for PoR designated in the official navigational pilot book (Figure 1).

Figure 1: Layout of GIS application containing data about 380 PoR



The research within the project scope involves evaluation of natural, socio-economic and bio-ecological characteristics, maritime traffic situation and analysis of possible threats to the environment, and finally the principle of preliminary selection of places of refuge and their description. Relevant characteristics have been included in the GIS application called GIS ADRIA. An additional result achieved by this project is the drafting of the concept of a "Integrated emergency management model" for deciding on the requests for places of refuge. The main goal of the research is to significantly improve the decision-making processes in emergency situations at sea.

Two modules were conceived and built in the first stage of the project:

- GIS support with problem-oriented extensions, and over 30 thematic layers for subordinating characteristics of places of refuge, and
- MCA (Multicriteria analysis) for valuation of each potential shelter (PoR) according to the relevant criteria with direct interface towards GIS application.

Methodology

The decision process in emergency situations has same characteristics as any other decision process. Namely, the decision process is a generic process that can be applied on any kind of organized set of activities in order to meet objectives. Generally, there is no unique model of decision process, because it includes numerous variables, different levels of decisions (strategic, tactical, and operational), as well as different decision makers.

The usual perspective of emergency management at sea concerns minimising the environmental impact. Other research (Afshartous et al, 2009) is focused on facility improvements like study of the problem of suitably locating air stations to respond to emergency distress calls. Another perspective to deal with distress situation at sea is to provide mariners with a global communications and locating network alerting Search and Rescue (SAR) (Tetley and Calcutt, 2001). The main purpose of this research is to develop a system that manages emergencies at sea in comprehensive and integrated manner taking into account all criteria that should be concerned during rescue process.

Perceiving efficiency of the paradigm “data-dialog-models” which is basis for the Decision Support System (DSS) concept, same system architecture is used for the development of the “Integrated emergency management model”. The DSS helps to structure and organize such a large quantity of information related to the emergency management system in case of maritime accidents, especially spatial data, in order to make it available to decision makers in a comprehensible and user-friendly way. A systematic approach throughout the DSS provides very simple and comprehensible integrated information regarding the technological changes and in accordance with different emergency policies and management methods.

Herein, for the purposes of emergency management at sea, the main idea is to combine GIS with multicriteria analysis to make an effective DSS platform. The multicriteria character of ranking problems within emergency management suggests the need to implement this kind of analysis in this particular field.

The idea that combines GIS with decision-making procedures is not new because a significant number of problems from many fields can be characterised as spatial at the same time. Therefore, many authors have tried to combine decision-making process with GIS to help the involvement of many stakeholders in solving spatial decision problems (Jankowski et al, 1997). Interesting research (Jankowski et al, 2001) is an introduction of a new prototype of SDSS emphasizing the need for the improvement of the typically limited role of maps as support tool, to move toward the use of maps as a source of structuring in multiple criteria spatial decision-making. However, each viewpoint of combining decision-making processes and GIS, such as emergency management, has its own particular characteristics and problems.

Based on the authors’ experience, in this research, among various multicriteria methods (Guitouni and Martel 1998), the method PROMETHEE II is chosen (Brans and Mareschal 1991) and connected with GIS. PROMETHEE II method is well accepted by decision makers because it is comprehensive and has the ability to present visualized results as it is proven in the application of this method in other engineering problems (Mladineo et al. 1987, 1992, 1993, 2003, Vuk et al. 1991, Knezic and Mladineo 2006). For the purpose of this project GIS was implemented in ESRI software (ArcGis) and linked with output of PROMETHEE method. There is already an effort in literature (Marinoni, 2005) to integrate PROMETHEE in a GIS showing how the combination of a decision-support methodology with powerful spatial analysis and visualization capabilities can be applied to evaluating decision alternatives.

Generally, use of that knowledge and experience in the development of a “Integrated emergency management model“ for emergency management in case of maritime accidents logically leads to the implementation of a system that will support all decision levels (Mladineo et al., 2005). The organization of that system is generally hierarchic; at each level decisions are made in accordance with the political competences. Decision character is different at some levels and depends on the system organization; decision range at lower levels is in accordance with previously made strategic decisions.

Conceptualized DSS for tactical and operational level is divided in a number of segments (modules) that will be additionally built in the further phases, like: oil spill simulation, vessels trajectory simulation in case of fuel shortage taking into account sea currencies and wind direction, emergency units’ capacities and locations, such as fire brigades, medical emergency, technical squads, etc. The basic module is GIS, for all levels of DSS, that comprise information sub-systems about spatial and other data and serves the other modules with data and information. The GIS module is divided into several thematic layers with basic information about places of refuges, climatological and maritime characteristics, hydrographic characteristics, ecological and biological characteristics, existing navigable waterways, maritime limits, boundaries of counties and cities, limits of territorial sea, continental shelf, military zones, topographic data, location emergency services, etc. (Mladineo, N., Knezic, S., 2005).

Building integrated emergency management model for defining the places of refuge

Based on aforementioned methodology developed "Integrated emergency management model" contains a possibility of a combination of GIS analysis and a multicriteria method in order to enable effective emergency management, namely it would be used to establish worthiness of a place of refuge for each ship category, taking into account different kinds of accidents. GIS is outlined as a powerful tool for the generation of aggregated information used in multicriteria analysis (MCA), as is the link between hierarchic decision levels.

The function of Module MCA (multicriteria models) is the evaluation of the suitability of each of the 380 potential locations for PoR designated in the official navigational pilot book for each category of vessel and each type of maritime accident. For the suitability valuation of each PoR, relevant criteria are defined as well as their ranges and weights that define the importance of criteria. There are a total of 14 criteria for assessing each potential place of refuge (Table 1) (Grzetic et al, 2008).

Table 1: Criteria for multicriteria analysis

Criterion No.	Criterion Description	Criterion Weight
Cl	Swing room	9
C2	Navigational approach	8
C3	Bottom keeping	8
C4	Grounding suitability	7
C5	Booming ability	9
C6	Wind protected (preferential)	10
C7	Accessibility by road, train, and/or air	8
C8	Socio-economic acceptability	10
C9	Oil spill shoreline sensitivity	9
C10	Ecological sensitivity	10
C11	Repair facilities	6
C12	Tug response time	8
C13	Dispersants response time	8
C14	Tank barge response time	8

The multicriteria method PROMETHEE from Module MCA is adapted to the criteria values and connected to ADRIA GIS database performs selection or ranking of a certain number of places of refuge within a pre-defined radius around the position of a ship sending a request (Figures 2 and 3).

To facilitate and automate the process of decision making in an emergency, and consequently reduce the possibility of subjective error, the expert team develops "designated scenarios", as shown in Table 2, in which criteria weights are changed to adapt the decision-making process to the characteristics of an incident, e.g., ship damage (Grzetic et al, 2008). In the next phase a scenario generator will be developed. Possible scenarios will be generated automatically according to the following parameters: vessels length, vessels type (cargo, passenger, tanker, etc) and accident type (collision, explosion, oil spill, stranding, etc).

Figure 2: GIS + additional extension – Input of a ship position and starting the searching procedure in defined perimeter

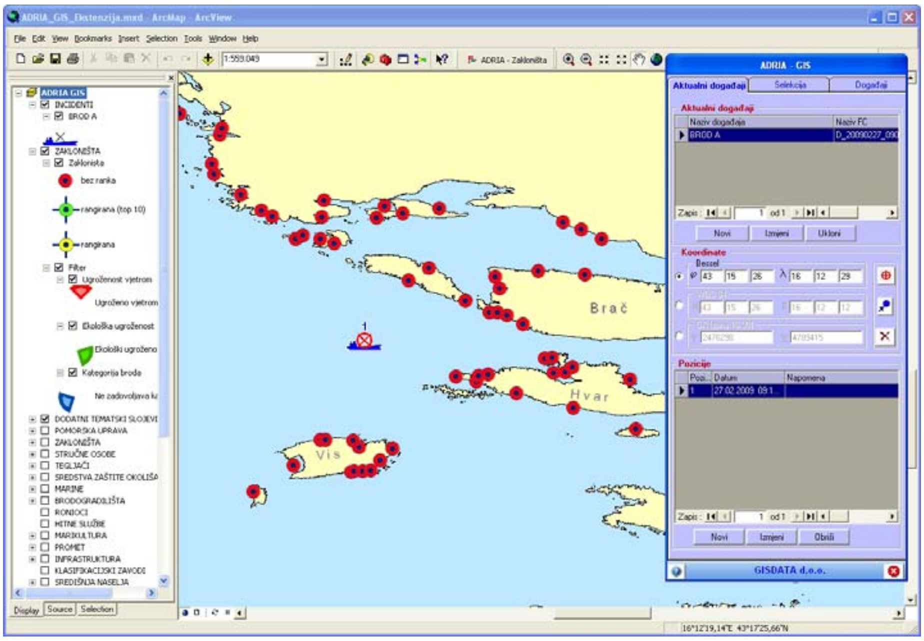
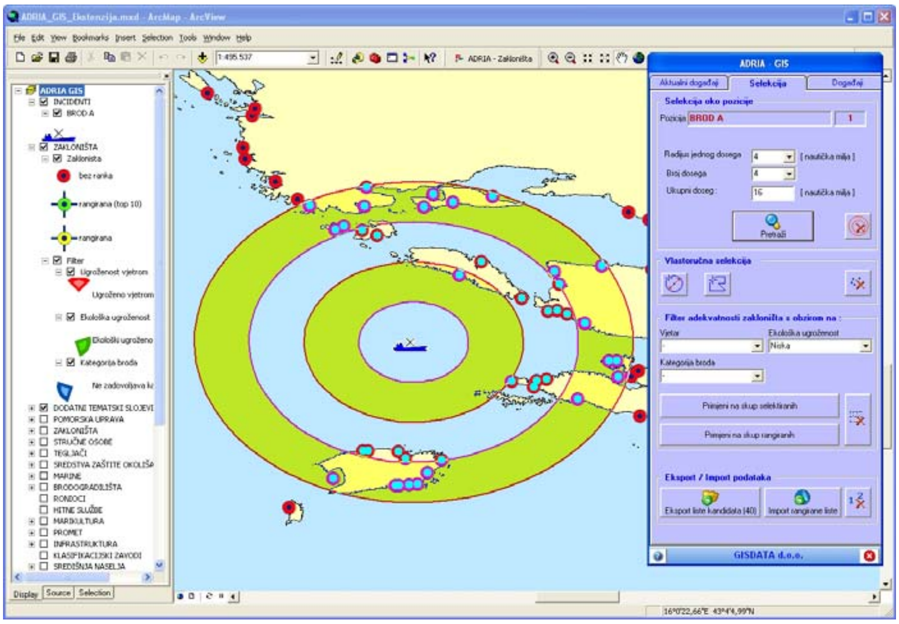


Figure 3. Selection of a certain number of PoR within a defined radius around the position of a ship

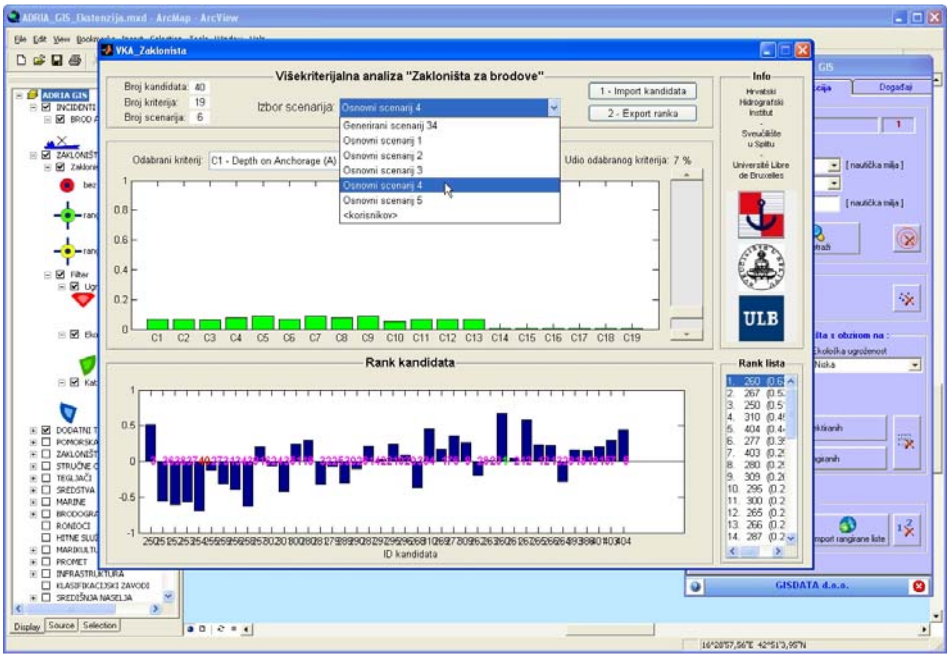


The presented DSS, based on GIS in conjunction with multicriteria analysis, is found to be a powerful tool for spatial decision-making. Figures 4 and 5 show calculated rank of potential places of refuge using MCA. Namely, to each selected PoR, according to calculated rank, a number is attached suggesting to an operator the suitability of each refuge place regarding defined criteria.

Table 2: Example of designated scenarios

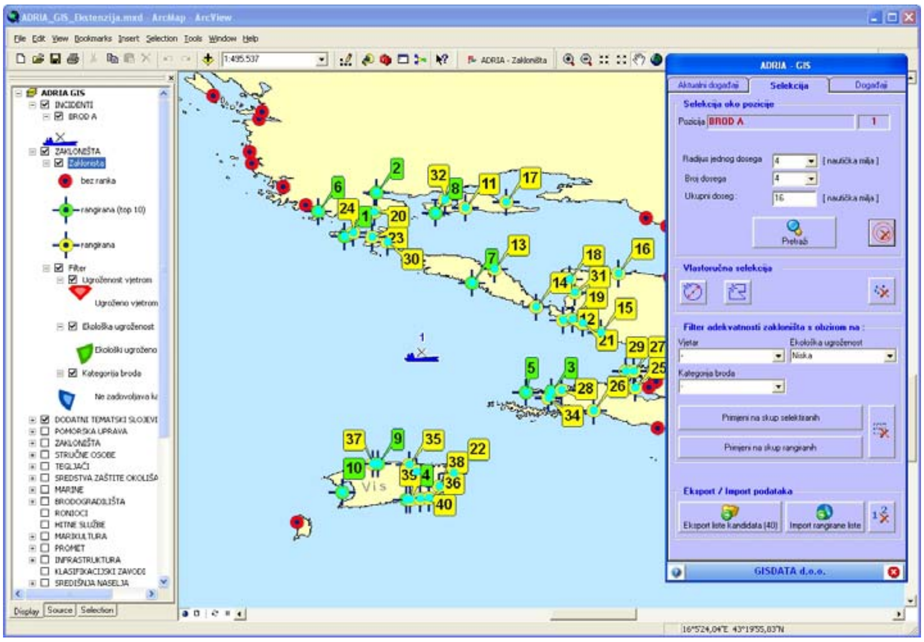
Scenario No.	Scenario Description
Scenario 1	General criteria weights - places of refuge with no specific purpose
Scenario 2	Ship category (large) - no risk of oil spill
Scenario 3	Ship category (large) - risk of sinking and oil spill
Scenario 4	Ship category (large) - risk of fire and many casualties
Scenario 5	Ship category (large) passenger - evacuation and care of many casualties needed
Scenario 6	Ship category (smaller) - no risk of oil spill
Scenario 7	Ship category (smaller) - risk of sinking and oil spill
Scenario 8	Ship category (smaller) - fire risk
Scenario 9	Ship category (smaller) passenger - evacuation and care of casualties needed
Scenario 10	………………………………………

Figure 4: MCA Software Support - Display of change of criterion weight scenario according to characteristics of incident (oil spill, fire, etc.)

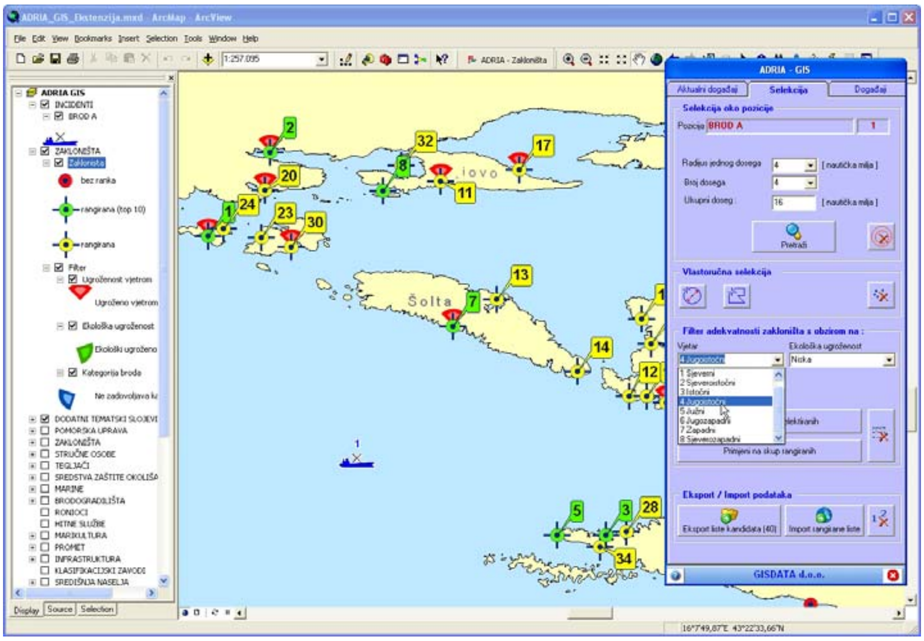


While developing the DSS it has been important to think about introduction of dynamic aspects of the system, such as wind which is very important during maritime accidents because it influences emergency management actions. The Figure 6 shows a layout of dynamic PoR elimination according to actual wind characteristics. For example, if meteorological report shows presence of strong south-east wind, using simple procedure (right side of the screen), it is possible to present elimination (red triangle, positioned upward) of all those PoR that have low protection of south-east wind. Figure 6 shows that both first and second ranked place of refuges are eliminated because of low wind protection.

<u>Figure 5: GIS + additional extension: Display of calculated rank of potential places of refuge using MCA</u>



<u>Figure 6: *GIS + additional extension:* Elimination (red triangle) of those PoR that have low protection from south-east wind</u>



The conceptualized DSS is divided in a number of segments (modules); some of them will be additionally built in later phases.

Very important support to the operator is surveillance of a ship position regarding the influence of winds and sea currents. Figure 7 displays surveillance of a ship position and elimination of those places of refuge that have high ecological vulnerability (green triangle, positioned rightward). Blue triangles, positioned leftward, show warning for places that are not suitable because of a ship size. Buffer around the islands in the bottom of the screen warns to very vulnerable sea bed, so a ship should be moved away from this area. The operator thus receives visual data about each PoR available as a shelter for a particular ship.

Figure 7: GIS + additional extension - Entering elimination criterion of wind protected condition for a place of refuge

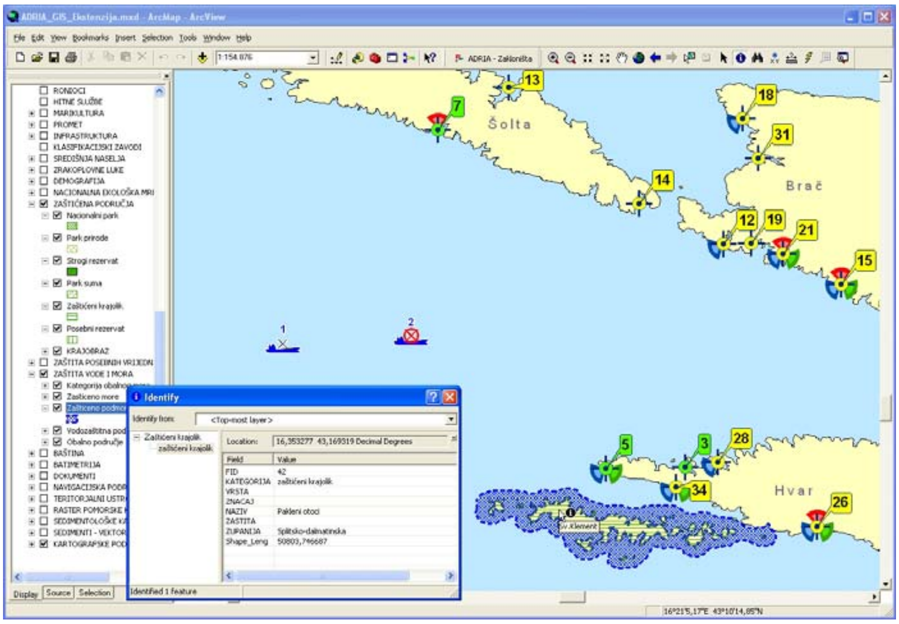
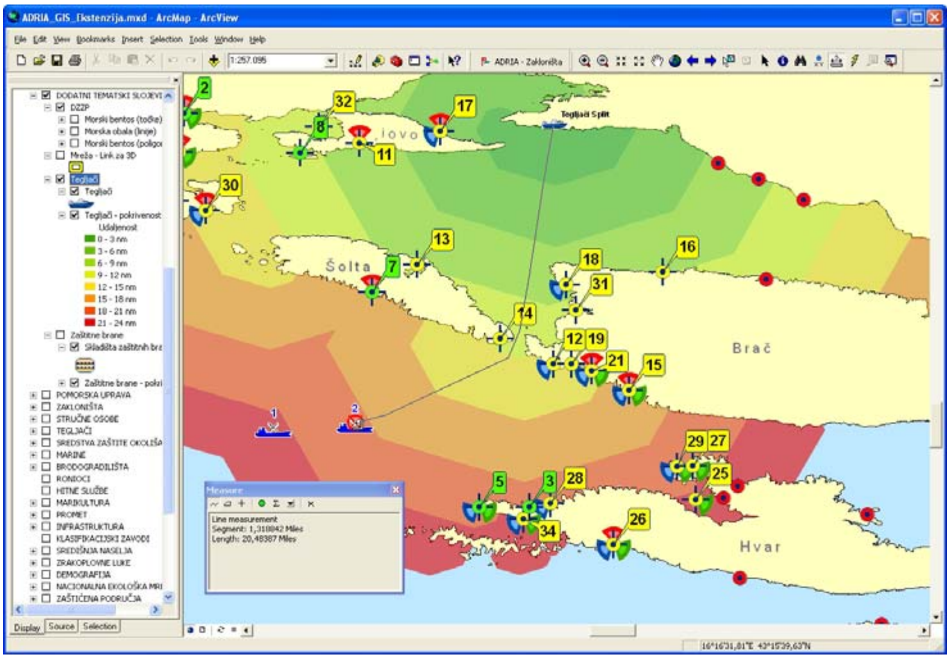


Figure 8: Display of tug response time from the nearest location with basic information about tug



Using GIS and other GIS-based tools the scope of the emergency services action is visualized. For example, it is possible to visualize a tug response time from the nearest location (Figure 8). This figure shows a colour ramp where every colour represents 3 nautical miles. This is used for a quick estimation of response time, taking into account that an average speed of tug is approximately 12 nautical miles per hour. At the same time, the characteristics of the tug, such as its dimensions, speed, pulling power, available counter-fire equipment, equipment for oil spill relief, etc., could be easily retrieved from the data base and displayed on the screen.

Conclusion

Supporting complex and sensitive decision-making processes such as selection of places of refuge for ships in distress cannot be achieved without using "Integrated emergency management model" principles of connection of appropriate methods and data. International regulations and guidelines for defining places of refuge for ships were a good starting point for considering such methodological approach and solution concept. The Decision Support System presented in this paper is a unique system for the safety of navigation at sea conceptualized as a conjunction of operational models and GIS spatial functions. Applied to the pilot counties it seems to function well. However, the system depends upon availability of relevant thematic layers (system parameters) in GIS, which calls for the defining, collecting and editing of data in a suitable format to be the basis for necessary analyses. This paper proposes the basic concept of the DSS which helps to establish efficient emergency management using GIS and its spatial analysis tools. After the analysis it should clear where the sea territories that cannot be reached in reasonable time are situated, and what emergency management strategy has to be undertaken. This model could be used for any other emergency management system where an object or a location on the sea that is in distress could be presented by a point and recovery methods are similar such as for: aircrafts, oil rigs, other types of vessels, etc. For other types of objects such as polygonal or circular with significant area, this model should be reconceptualised, accordingly. The DSS model could be also easily linked to the other emergency models as well as used for cross-border emergency activities.

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Abbreviations

DSS - Decision Support System
GIS - Geographical Information System
MCA - Multicriteria Analysis
MRCC - National Maritime Rescue Coordination Centre
PoR - Places of Refuge
SAR - Search and Rescue

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