Place of refuge selection for ships aiming at reduction of environmental hazards

Z. Bradaric[1], M. Srdelic[1], N. Mladineo[2] & S. Pavasovic[2]
[1]Hydrographic Institute of the Republic of Croatia, 21000 Split, Zrinsko-Frankopanska 161, Croatia
[2]University of Split, Faculty of Civil Engineering and Architecture, 21000 Split, Matice hrvatske 15, Croatia

Abstract

As a future member of the European Union (EU), Croatia has decided to implement Directive 2002/59/EC of the European Parliament and of the Council binding all of the EU member states to define places of refuge for ships in need of assistance off their coasts, or to develop techniques for providing assistance to such ships. Consequently, the Ministry of the Sea, Tourism, Transport and Development of the Republic of Croatia has initiated a project for developing an effective "Decision Support System (DSS) for defining the places of refuge for ships in distress at sea". Such a system would include a model support based upon the GIS and several operational research models, which would eventually result in establishing a single DSS. All levels of the DSS are based on a basic GIS-module that comprises information sub-systems with spatial and other data and provides the other modules with the data and information. The GIS module contains various thematic layers with the data on locations of refuges, climatological, maritime, hydrographic, ecological and biological characteristics, existing navigable waterways, maritime limits, administrative boundaries, limits of territorial sea, continental shelf, military zones, topographic data, location of the emergency services, etc. The analysis starts from the existing shipping corridors and 380 potential locations for places of refuge designated in the official navigational pilot book. Multicriteria analysis, with the GIS-generated input data, is used to establish "worthiness" of a place of refuge for each ship category, taking into account the nature of the accident. Tables of "available intervention resources" are produced, as well as the analysis of the resources' availability in respect of the response time as well as the quantitative and qualitative sufficiency.
Keywords: environmental hazard, emergency management, GIS, multicriterional analysis, DSS.

1   Introduction

A significant increase in both coastal area users and uses leads to intensive competition for coastal area resources. This competition often results in a sectoral approach to environmental hazards management, neglecting the integrated approach to the coastal area management as well as the increase of various kinds of environmental hazards. For these and other reasons, there is a strong need for tools based on integrated coastal area management, which would improve prevention (or reduce) of environmental hazards.

When defining its future development, the Republic of Croatia has decided on a gradual approach to the European Union. In this respect, it has assumed a commitment to harmonise its legal system with the legislation of the European Union. Therefore, it is necessary that, among other things, working procedures of the Ministry of the Sea, Tourism, Transport and Development and its respective services be harmonised with the provisions of certain directives of the European Community relating to the safety of maritime traffic. Therefore, Directive 2002/59/EC of the European Parliament and of the Council of 27 June 2002 establishing a Community vessel traffic monitoring and information system and repealing Council Directive 93/75/EEC, is binding on all member states of the European Community 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 (MMTPR) has initiated the procedure of harmonising its working procedures and the respective executive organisation to meet the requirements provided for in the Directive. In this context, the study has been initiated aiming to:

- examine the conditions of maritime traffic in the Adriatic, especially off its eastern coasts;
- show characteristics and assess the possibilities of action in case of maritime accidents or other emergency or threat to the safety of ships or environment in the area within jurisdiction of the Republic of Croatia;
- develop working procedures for providing assistance to ships in distress in the area within jurisdiction of the Republic of Croatia;
- make preliminary selection of the places of refuge, in accordance with the experience and established working procedures in the European Community countries;
- create a GIS database of the relevant layers for the places of refuge.

One-year work on the project resulted in a study treating the issue of places of refuge (PoR) in a scientific and professional manner. The Study involves evaluation of the natural, socio-economic and biological-ecological characteristics, the maritime traffic situation and the analysis of possible threats to the environment. Finally the Study proposes the model for the preliminary selection of places of refuge. Relevant characteristics have been included in the GIS-application called GIS ADRIA. Additional result achieved by this project is drafting the concept of a Decision Support System (DSS) for deciding on the requests for places of refuge, presented through the pilot project for the area of

the three coastal counties. The above concept is presented in this paper, and its development (as provided for project approved by the Ministry of the Sea, Tourism, Transport and Development) will significantly improve the decision-making processes in emergency situations at sea, as well as the integrated management of the Croatian coastal area.

　　Two modules of DSS were 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;
- MCA (Multicriteria analysis) with direct interface towards GIS application.

2   Methodological approach

The Decision Support System (DSS) helps to structure and organise such a large quantity of information (especially spatial data) related to the emergency management system in case of maritime accidents, in order to make it available to decision makers in a comprehensible and user-friendly way. A system 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. DSS is based on a combination of GIS analysis and a multicriteria method in order to enable efficient emergency management, namely it would be used to establish "worthiness" of each potential place of refuge for each ship category, taking into account possible kinds of the accident. GIS is outlined as a powerful tool for the generation of integrated information used in the multicriteria analysis, as is the link between hierarchic decision levels in the proposed DSS. Decision support system (DSS), can simply be explained as a system that consists of users/managers who use the system and its resources in order to solve tasks (problems) in organisational environment [18]. "Philosophy of DSS" is based on the paradigm "Data - Dialog - Models", meaning that the "user" communicates with the computer using his/her natural language (mainly through the GUI-organised menus), and additional interfaces enable the data base and the model
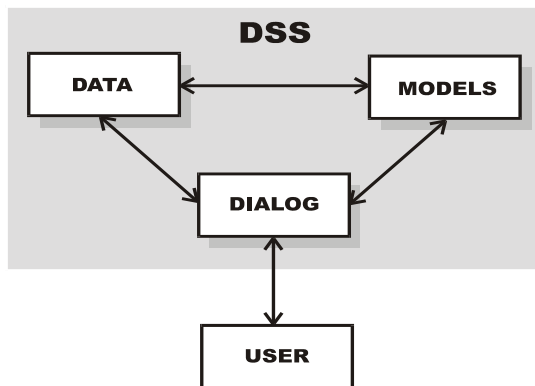

Figure 1:   Basic DSS concept.

management, that are able to communicate mutually as well (Figure 1). From the user's (manager's) point of view, a decision support system must support users at all levels and help the integration between levels whenever possible. Furthermore, the decision makers express the need for integration and co-ordination of the decision making process that includes several persons who participate in the process of solving a larger problem.

3 Concept of DSS for places of refuge

The design of DSS defines the relevant criteria as well as their ranges and weights. There are a total of 14 criteria for assessing each potential place of refuge. A mathematical programme for the MCA has been adapted to the criteria values and connected to the ADRIA GIS database in order to use the multicriteria analysis for the selection and ranking of the possible places of refuge within a pre-defined radius around the position of the ship sending request (Figure 2). Figure 3 shows a schematic procedure [16], starting with the GIS analysis, i.e. the integration and the evaluation of the relevant criteria presented as thematic layers. For those criteria that cannot be spatially presented using the GIS analysis, the input information based on the expert assessment is provided to the multicriteria analysis separately.

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", in which criteria weights are changed to adapt the **decision making process** to the characteristics of "incident", i.e. ship damage.
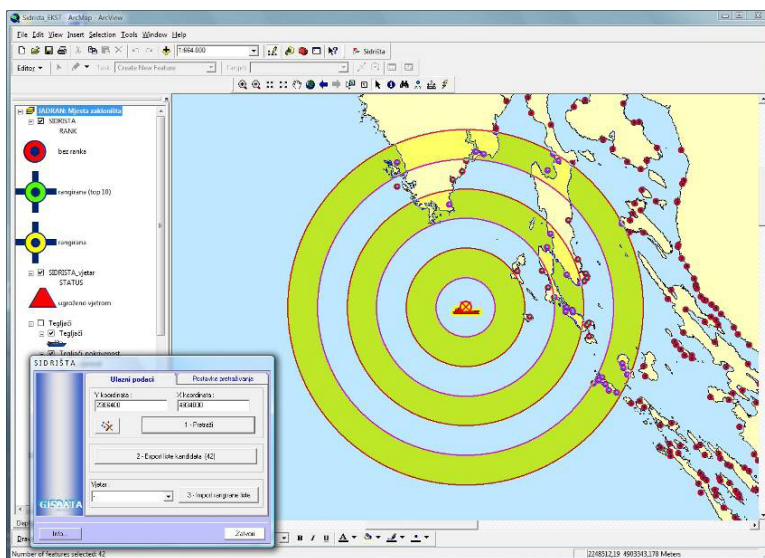

Figure 2:   GIS + additional extension – searching for the places of refuge within the specified radius.
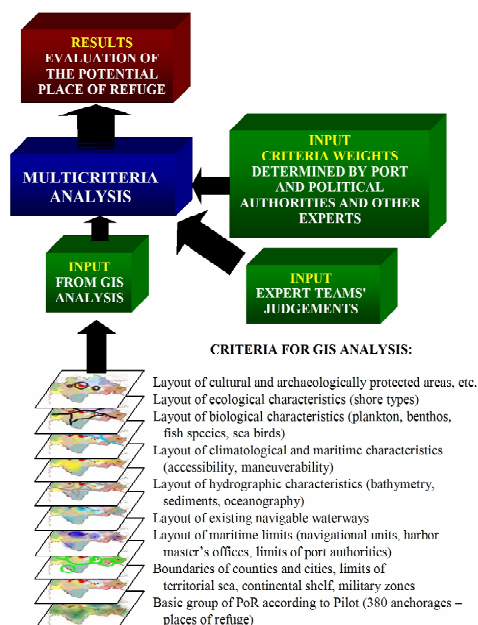
Figure 3:   Layout of the methodological procedure to define places of refuge for ships.

Table 1:   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	………………………………………

The presented DSS, based on GIS in conjunction with multicriteria analysis, is found to be a powerful tool for spatial decision-making. Figure 5 shows calculated rank of potential places of refuge using the MCA.
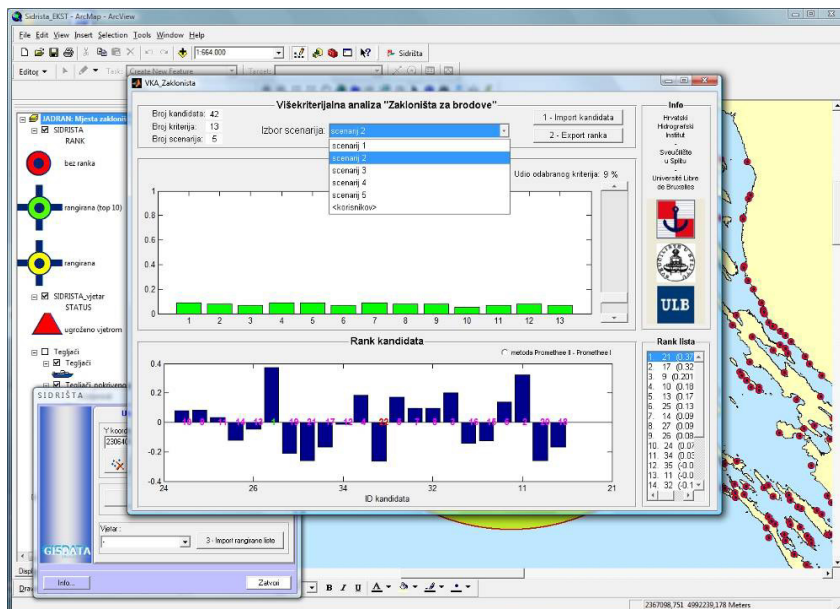
Figure 4:   MCA Software Support – display of change of criterion weight scenario according to characteristics of incident (oil spill, fire, etc.).
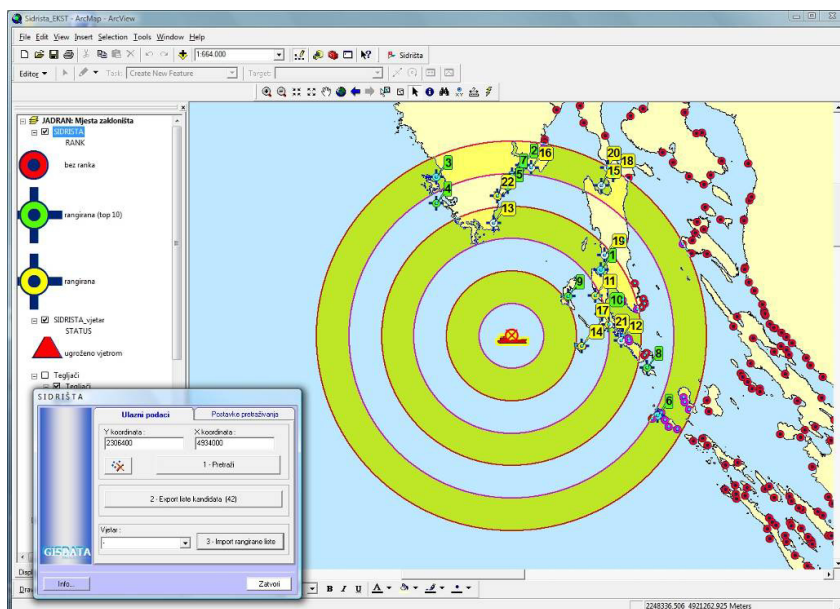

Figure 5:   GIS + additional extension – display of calculated rank of potential places of refuge using MCA.

Conceptualized DSS is divided in a number of segments (modules) that will be additionally built in the following phases. 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. DSS also supports the dynamic approach. For example, it is possible to enter data on present wind conditions and eliminate places of refuge that aren't adequately wind protected (Figure 6).
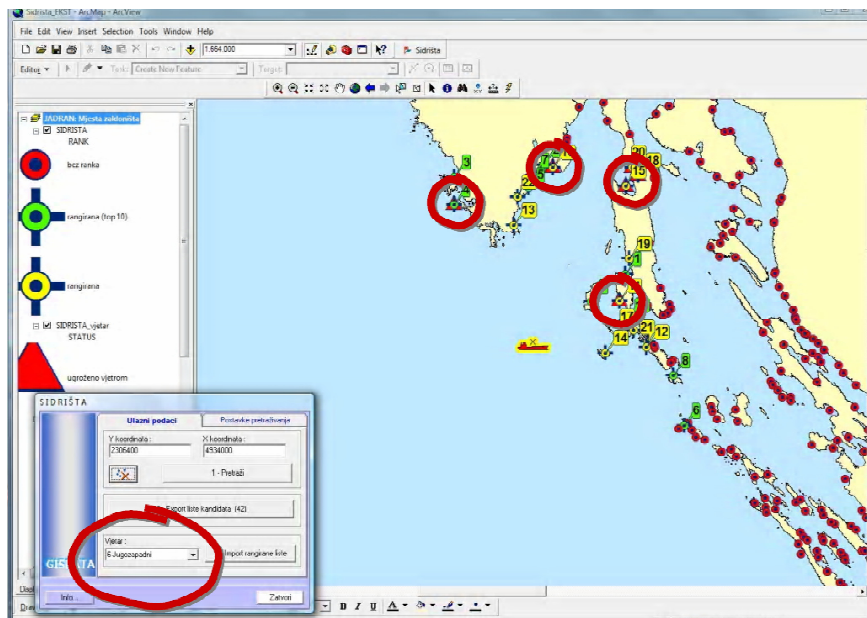

Figure 6:   GIS + additional extension – entering elimination criterion of wind protected condition for a place of refuge.

4   Conclusion

In resolving complex and sensitive problems such as selection of places of refuge for ships in distress, it is essential to offer solutions based upon the exact scientific and expert investigations, using the appropriate methodological and computer support. The existing international regulatory rules and guidelines for defining places of refuge for ships are a good starting point for considering the appropriate methodological approach and solution concept, as well as for offering solutions to the competent maritime administration.

Adoption and implementation of the methodology and decision support system presented in this paper into integral system of the safety of navigation at sea is a prerequisite for making the right decision in case of requests for places of refuge as well as in other emergencies at sea.

The system also depends upon availability of relevant thematic layers (parameters) in the GIS environment, which calls for defining, collecting and editing of data in suitable format and place to be the basis for necessary analyses.

The system can be extended into a more comprehensive DSS, which would use the same methodology and combine the existing data base with additional thematic layers for the integrated process of prevention/reduction and/or management of various kinds of environmental hazards. Having this in mind, it can be said that the system is a useful step towards the integrated coastal area management and sustainable development of the Croatian coastal area.

Acknowledgements

References

[1] Brans, J.P., Mareschal, B. and Vincke, P.H., 1984, PROMETHEE – a new family of outranking methods in multicriteria analysis. In Operational Research IFORS 84, J.P.

[2] Brans (Ed.), pp. 477–490 (Amsterdam: North Holland).

[3] Brans, J.P. and Mareschal, B., 1991, THE PROMCALC & GAIA Decision Support System for Multicriteria Decision Aid (Brussels: Centrum voor Statistiek en Operationeel Onderzoek, Vrije Universitet).

[4] Brans, J.P. and Mareschal, B., 1994, PROMCALC & GAIA: a new decision support system for multicriteria decision aid. Decision Support Systems, 12, pp. 297–210.

[5] Chang, N.-B., Wei, Y.L., Tseng, C.C. and Kao, C.-Y.J., 1997, The design of a GIS-based decision support system for chemical emergency preparedness and response in an urban environment. Computers, Environment and Urban Systems, 21, pp. 67–94.

[6] Hill, M.J., Braaten, R., Veitch, S.M., Lees, B.G. and Sharma, S., 2005, Multi-criteria decision analysis in spatial decision support: the ASSESS analytic hierarchy process and the role of quantitative methods and spatially explicit analysis. Environmental Modelling & Software, 20, pp. 955–976.

[7] Jankowski, P., 1995, Integrating geographical information systems and multiple criteria decision-making methods. International Journal of Geographic Information Systems, 9, pp. 251–273.

[8] Jankowski, P., Nyerges, T.L., Smith, A., Moore, T.J. and Horvath, E., 1997, Spatial group choice: a SDSS tool for collaborative spatial decision-making. International Journal of Geographical Information Science, 11, pp. 577–602.

[9] Joerin, F. and Musy, A., 2000, Land management with GIS and multicriteria analysis. International Transactions in Operational Research, 7, pp. 67–68.

[10] Marinoni, O., 2005, A stochastic spatial decision support system based on PROMETHEE. International Journal of Geographic Information Science, 19, pp. 51–68.

[11] Milicic, J. and Mladineo, N., 1985, Application of multicriteria analysis to the problem of reinforcement improvements in concrete works. European Journal of Operational Research, 21, pp. 339–346.

[12] Mladineo, N., Margeta, J., Brans, J.P. and Mareschal, B., 1987, Multicriteria ranking of alternative locations for small scale hydro plants. European Journal of Operational Research, 31, pp. 215–222.

[13] Mladineo, N., Lozic, I., Stosic, S., Mlinaric, D. and Radica, T., 1992, An evaluation of multicriteria analysis for DSS in public policy decision. European Journal of Operational Research, 61, pp. 219–229.

[14] Mladineo, N., Knezic, S., Pavasovic, S. and Simunovic, I., 1993, Development of 'Land rent model' using multicriteria analysis and geographical information systems. Journal of Computing and Information Technology, 1, pp. 243–251.

[15] Mladineo, N., Knezic, S. and Gorseta, D., 2003, Hierarchic approach to mine action in Croatia. Journal of Mine Action, 7(2), pp. 41–45.

[16] Ribarovic, Z. and Mladineo, N., 1987, Application of multicriterion analysis to the ranking and evaluation of the investment programmes in the ready mixed concrete industry. Engineering Costs & Production Economics, 12, pp. 367–374.

[17] Sprague, R.H. and Carlson, E.D., 1982, Building Effective Decision support System (Englewood Cliffs, NJ: Prentice Hall).

[18] Uran, O. and Janssen, R., 2003, Why are spatial decision support systems not used? Some experiences from the Netherlands. Computers, Environment and Urban Systems, 27, pp. 511–526.

[19] Vuk, D., Kozelj, B. and Mladineo, N., 1991, Application of multicriterial analysis on the selection of the location for disposal of communal waste. European Journal of Operational Research, 55, pp. 211–217.

[20] www.visualdecision.com/PROMETHEE