**Scientific Journals**
**of the Maritime University of Szczecin**

**Zeszyty Naukowe**
**Akademii Morskiej w Szczecinie**

**2016, 45 (117), 191–195**
**ISSN 1733-8670 (Printed)**
**ISSN 2392-0378 (Online)**
**DOI: 10.17402/105**

*Received: 31.08.2015*
*Accepted: 23.02.2016*
*Published: 25.03.2016*

# Decision support systems in search, rescue and salvage operations at sea

**Marzena Małyszko, Mirosław Wielgosz**

Maritime University of Szczecin, Faculty of Navigation, Institute of Navigation
1–2 Wały Chrobrego St., 70-500 Szczecin, Poland
e-mails: {m.malyszko; m.wielgosz}@am.szczecin.pl, corresponding author

**Key words:** decision support, search and rescue, salvage operations, environment protection, working procedures, simplified algorithm

**Abstract**

This article presents the concept of a decision support system for maritime search, rescue and salvage operations. It describes the main ideas for systems in three areas of maritime rescue – search and rescue (saving lives), salvage (saving property at sea), and environment protection operations. It contains an analysis of the factors influencing the decisions of both marine navigators and shore-based centres. The general ideas of the systems are presented in the form of flow charts. An analysis was made of input data, working procedures, and the decisions based on these data and procedures. The simplified algorithm of the system is described. The principles of system utilisation are explained, developmental trends are described, and conclusions are drawn.

## Introduction

Saving lives and property at sea, and minimising possibility of pollution of the marine environment, are not routine activities for people working in the shipping industry. The diversity and wide range of possible rescue operations constitute major obstacles to the development and widespread use of comprehensive emergency procedures at the core of Search and Rescue (SAR) plans and manuals. Conducting a SAR operation, especially when assuming the role of a SAR Mission Coordinator or On Scene Coordinator, is a stressful activity. The designated coordinator must rapidly process and analyse vast amounts of data and information. Coordination with disparate team members requires careful data selection and planning, all done under tremendous time pressure. The actual search operation that follows initial planning entails unique operations based on rapid and sometimes irreversible decisions.

Once prepared, the initial plan and its implementation may require a re-analysis of data and the consideration of different assumptions, scenarios and tactics (IMO/ICAO, 2013b). Such an adjustment of approach is especially likely when the initial stages are not successful. Because the scope of the analysis is usually very wide, requiring specialised analysis of huge digital databases, computer- based Decision Support Systems (DSSs) are perfect tools for a ship's crew or the staff of a Maritime Rescue Coordination Centre (MRCC). Such systems are already used in the shipping industry to reduce the likelihood of collisions, to provide navigational information to pilots, and as a required method of dealing with emergency situations on passenger ships (Pietrzykowski, Borkowski & Wołejsza, 2012).

The main advantages of such computer systems include their speed and accuracy in analysing huge databases, as well as their ability to produce a clear and flawless interpretation of the procedures assigned to them. A final advantage of such computerised systems is their ability to present a solution as well as an alternative solution simultaneously.

The disadvantage of such systems is the impossibility of developing algorithms for all possible SAR operations. This impossibility can be uderstood by considering the fact that SAR operations differ in such factors as:

- the number of units in distress;
- the number of people in distress;
- the kind of threat;
- the quantity and completeness of the relevant information;
- the nearness or remoteness of the accident site from SAR units;
- hydrometeorological conditions, and so on.

This paper conducted a preliminary analysis of the range of input data, as well as the required output decisions and instructions, for newly designed decision support systems in SAR operations at sea. The analysed systems were designed for both seagoing ships and MRCCs. The main tasks for such systems have already been identified, and the principal features of the architecture of the supporting software have already been described.

## SAR incident

Construction of a DSS for SAR operations requires a preliminary analysis concerning the range of input data as well as the range of expected output decisions and instructions. To survey the adequacy of different appropaches to achieving this function, the authors analysed existing systems, and reviewed the policies of institutions and other parties involved in SAR incidents and associated rescue, salvage, and marine environment protection operations.

Each SAR incident and its following SAR action has six components (Figure 1). Some of them are advanced computer-operated digital systems that are required to broadcast SAR operational information continously, regularly, or upon request. Some of them require operator action to manually input necessary information into the system.

These six systems and institutions are described in greater detail in Table 1.

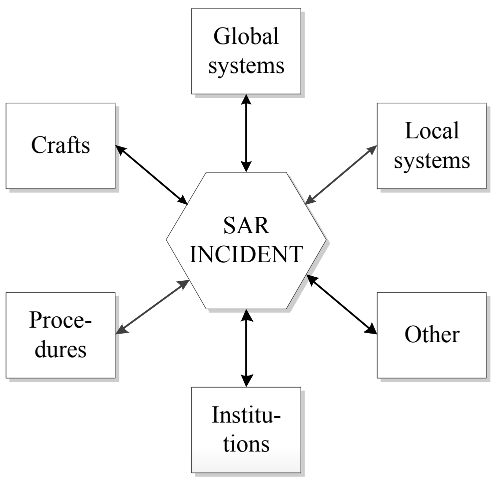


**Figure 1. The six aspects of a SAR incident**

## The need of decision support and the quality of the support obtained

The variety of accidents at sea and the variety of expected assistance mean that MRCCs must prepare in advance (usually by creating flowcharts) for procedures and scenarios covering a wide range of rescue scenarios. These scenario plans should be part of the general SAR plans for individual states (IMO, 2006). Some examples of the threats to a vessel or aircraft at sea are listed below. Conducting a SAR operation requires the use of different scenarios, manpower and resources, but there is always a need for immediate access to detailed, previously prepared procedures (Burciu, 2011).

Examples of threats to a vessel requiring advanced SAR operations include:

- missing ship, with a need to search and rescue survivors;
- sinking ship, or a ship at risk of sinking:
  - position known, vessel sunk, rescue survivors;
  - position known, ship in distress but afloat, need to evacuate passengers and crew;
- ship is disabled but not sinking:
  - assistance to crew and passengers;
  - fire;
  - prevention of environmental pollution;
  - salvage (technical assistance – e.g. towing, pumping of flooded compartments, and so on).

The complexity of SAR operations and the need to change the scenario if a missing vessel or aircraft is

**Table 1. Systems, institutions and third parties involved in SAR incidents and associated operations**

| Global systems | Local systems | Crafts | Procedures | Institutions | Other |
|---|---|---|---|---|---|
| GMDSS incl. Cospass-Sarsat | VTS | Conventional ships | IAMSAR | MRCC | Accidental witnesses |
| GNSS, Gallileo | Local reporting systems | Small crafts | ISM | Ship owner | GSM and other commercial communication systems |
| AMVER | Shore stations | Naval ships | SAR Plans | Charterers | |
| AIS, LRIT | THETIS; in Poland: SSN, SWIBŻ, PHICS | Aircrafts | | Weather Routing | |

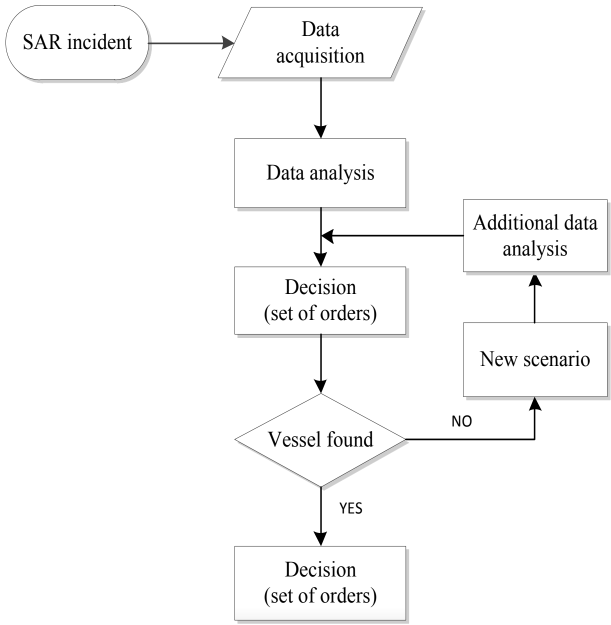


**Figure 2. SAR incident – missing ship**

not found is shown in Figure 2. Decisions in the context of a SAR operation become particularly stressful at the moment when the scenario is reinterpreted, especially when the ultimate decision is made to terminate the action. The SAR DSS may be particularly useful in such a situation (IMO/ICAO, 2013a; 2013b; MSPiR, 2014).

## Tasks and requirements for SAR DSS

The predefined range of tasks and requirements has not yet been completely specified. Plans have been made to collect additional data from experiments and from questionnaires. This new data is intended to result in new SAR DSS systems that are capable of the following tasks:

- main tasks:
  - increasing the reliability and the effectiveness of SAR operation;
  - shortening the time required for analysis and the SAR operation itself;
  - automatic and accurate application of the procedures mandated by the SAR Plan and Volumes 2 and 3 of the IAMSAR Manual;
  - suggesting alternative solutions;
- additional tasks:
  - optimising SAR operations;
  - reducing the risk of marine environment pollution;
  - minimising the cost of a SAR operation;
  - re-estimating the values of various coefficients in SAR theory, and presenting the user with the option of using such revised values.

The SAR DSS has a modular design (architecture) similar to existing decision support systems. It allows automatic data acquisition and exchange with external sources, as well as exchange of data on demand. Although no performance standards have yet been set for such systems, it seems obvious that SAR software should conform to certain obligatory standards. The establishment of such performance standards should, however, be preceded by expert research targeting the full range of information concerning computerised SAR systems, the institutions participating in SAR operations, and other factors impacting the efficacy of the entire system in implementation.

The SAR system generates both strategic and operational decisions covering the full range of possible SAR actions at every level of coordination and decision making. Proper substantiation is also essential for the officer in charge to be to double check his decisions and to avoid sending wrong or incomplete orders.

### DSS on board ship

The DSS on board a ship should have a simple and clear interface which complies with the provisions of international conventions and other regulations. It should also make use of standard procedures recommended by manuals and plans (Figure 3). When activated, the system should present the operator with a choice of specific SAR actions in order to reduce the time spent developing alternatives. The predetermined SAR options should include the following measures as options for the operator to pursue:

- actions related to person overboard;
- search operation planning;
- rescue of survivors;
- response to receipt of distress message;
- medical evacuation by helicopter; collision;
- grounding;
- hull perforation;
- fire on board;
- flooding;
- sinking;
- pirate or terrorist attack;
- other.

Some of the data needed by a SAR DSS should be collected automatically from devices already installed and used on the ship (Figure 3). Doing so would significantly reduce the time of data collection. Information and data from systems typically used on board conventional ships include:

- GNSS;

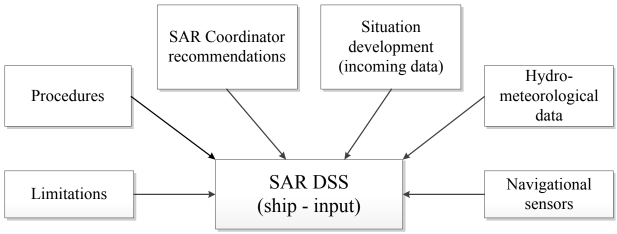


**Figure 3. DSS ship – input**

- AIS;
- speed (log);
- course (gyrocompass);
- RADAR/ARPA;
- anemometer;
- GMDSS (Inmarsat, Navtex, DSC).

Other data will have to be manually entered by the operator. To avoid wasting time, only truly important data, identified by a proper template or digital assistant, should be hand-entered. Moreover, the system should be able to import data relating to weather forecasts, tides, and currents from digital databases typically found on board. The operator has to be aware of the fact the situation is continuously changing as a function of changes in the weather changes, new orders from the SAR Mission Coordinator or On Scene Coordinator, and so on. It should be possible for the operator to reanalyse / recalculate a situation by simply flipping the appropriate switch – for example, a "New operation" or "Action reset" switch.

The system should be programmed to take into account routine constraints and limitations on a specific vessel. Such constraints and limits include:

- wind force and sea state;
- radio equipment (range of communication);
- load lines;
- icing (ships, sea surface);
- legal issues (certificates);
- stores (fuel oil, fresh water, and so on).

The output data should contain sets of decisions supplied by substantiations and detailed instructions (Figure 4). In the case of performing the OSC function, the system must be able to generate instructions for other ships at the scene.

The range of decisions and recommendations in the output shall contain (but not to be limited to) the following:

- for own ship:
  - sequence of tasks;
  - search parameters;
  - route details (parameters);
  - engine and helm orders;
  - ship manoeuvres;

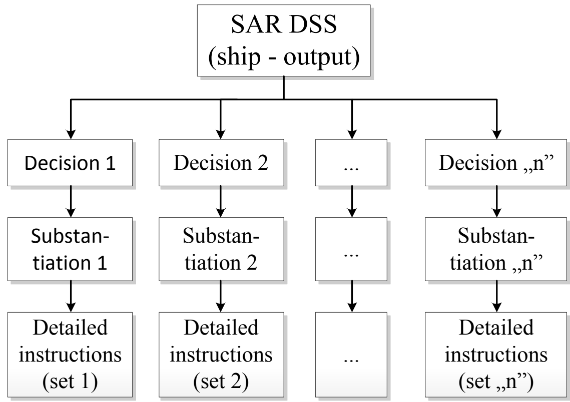


**Figure 4. SAR DSS output schematic**

  - communication procedures;
  - crew subdivision into sections;
  - prioritised tasks;
  - stability analysis;
  - selection of refloating method after grounding;
  - selection of firefighting methods and equipment;
  - closing of watertight compartments;
  - ballast operations;
- for other ships:
  - areas to be searched;
  - track details (course, speed, spacing, and so on).

### DSS for Maritime Rescue Coordination Centre

The problem of making the correct decision in the context of a SAR operation weighs heavily on the personnel working in Maritime Rescue Coordination Centres. The risk of incorrect decisions makes the process of decision-making stressful even for experienced operators. A well-programmed DSS will reduce the time required for decision making, eliminate the possibility of incorrect or wrong decisions, and complement the MRCC's other activities.

With some significant differences, a DSS for a MRCC has similar tasks as a DSS for a seagoing vessel. Some of these differences and similarities are shown in Figure 5, which summarises the input data for a MRCC DSS.

A significant difference between an on-board system and a system in a MRCC is the variety of decisions, the scope of orders, and especially the variety and nature of the recipients of the decisions and orders. In a ship's system, the output generally concerns the vessel carrying the system, and the orders and decisions are executed on board (Figure 4), unless the vessel is acting as an OSC. The decisions produced by a DSS for a MRCC are usually addressed to recipients in four groups (Figure 6), whose numbers may reach upwards to several dozen.

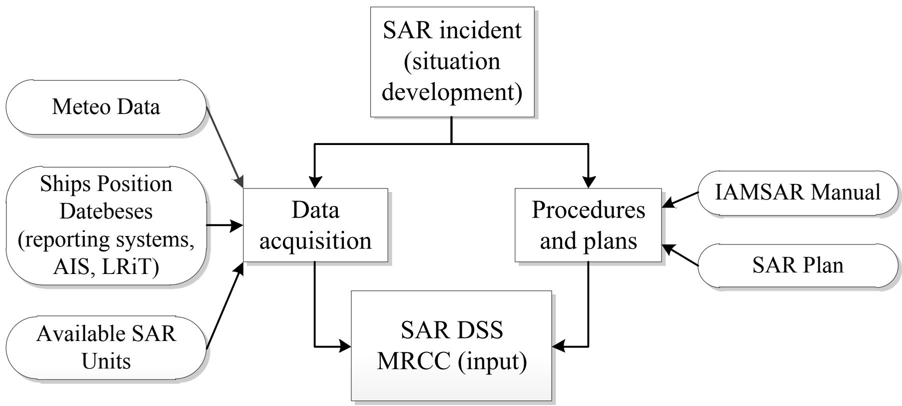


**Figure 5. SAR DSS MRCC – input**

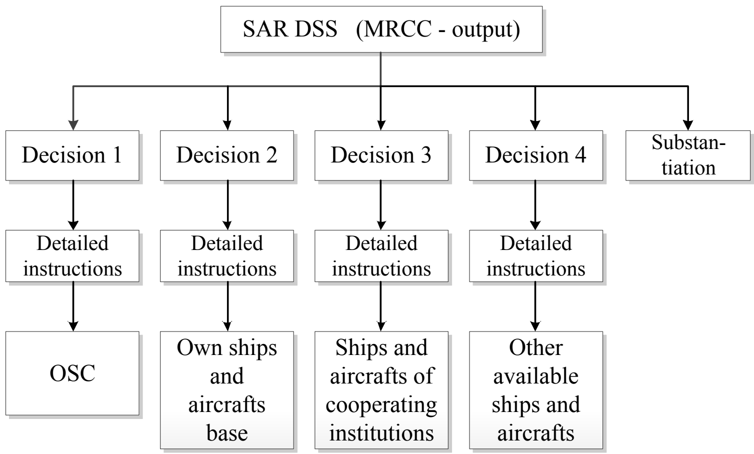


**Figure 6. SAR DSS MRCC – output**

## Conclusions

Decision support systems currently are incorporated into various spheres of life. Although all DSSs have a similar modular design, they differ fundamentally in the operation of their input module (data collection system) and output module (decision making system).

Installation and use of a computer-based SAR DSS will result in the following advantages:
- advanced computer software will quickly and faultlessly analyse large digital databases;
- an additional advantage is the relatively low cost of a standard PC;
- a SAR DSS can make use of existing systems with no additional cost.

Usage of digital data in a DSS gives system the ability to integrate with navigation systems, making use of their navigational charts (ECS, ECDIS), and using some of the same systems and databases already connected to them. There is also a possibility of integrating DSSs with Integrated Bridge Systems in the future.

Implementation of SAR DSSs in maritime rescue centres and on board ships will provide the following benefits:
- shortening of the process of SAR operation planning;
- increase in the efficiency and reliability of SAR operation;
- shortening of search time and a reduction of costs by using advanced optimisation algorithms.

## References

1. Burciu, Z. (2011) *Bezpieczeństwo w transporcie morskim i zarządzanie w akcji ratowniczej*. Gdynia: Wydawnictwo Akademii Morskiej w Gdyni.
2. IMO/ICAO (2013a) *International Aeronautical and Maritime Search and Rescue Manual. Vol. 2. Mission Coordination*. Montreal
3. IMO/ICAO (2013b) *International Aeronautical and Maritime Search and Rescue Manual. Vol. 3. Mobile Facilities*. Montreal.
4. IMO (2006) SAR Convention. London: IMO.
5. Pietrzykowski, Z., Borkowski, P. & Wołejsza, P. (2012) NAVDEC – navigational decision support system on a sea-going vessel. *Scientific Journals of the Maritime University of Szczecin* 30 (102). pp. 102–108.
6. MSPiR (2014) *Plan akcji poszukiwawczych i ratowniczych*. Gdynia.