Comparative Analysis of Renowned Softwares for Search and Rescue Operations

Komparativna analiza poznatih softvera za operacije traganja i spašavanja

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DOI 10.17818/NM/2016/2.6
UDK 004.42:627.7
627.7:656.61
Review / *Pregledni rad*
Paper accepted / *Rukopis primljen:* 17. 11. 2015.

Summary

Search and rescue computer programs have been developed in order to increase the efficiency of search and rescue (SAR) operations and to help operators to determine search areas, estimate resources required, calculate search patterns, and make decisions efficiently. The paper analyses renowned SAR software systems, including SARPlan, SARIS, SAROPS, SARMAP and TRANSAS. They have been used by a number of prominent search and rescue maritime authorities all over the world. A qualitative SWOT analysis allows an insight into their advantages, shortcomings, opportunities and threats. The comparative analysis has produced results that show characteristics of application of the individual programs with regard to search areas and material and human resources.

KEY WORDS

search and rescue
search and rescue software
probability of search area
search and rescue resources

Sažetak

Računalni programi za operacije traganja i spašavanja razvijeni su kako bi se povećala učinkovitost operacija traganja i spašavanja (SAR) te kako bi se pomoglo pri određivanju područja traganja, procjeni potrebnih sredstava, izračunu sheme traganja i učinkovitom donošenju odluka. U radu se analiziraju poznati SAR softverski sustavi SARPlan, SARIS, SAROPS, SARMAP i TRANSAS. Njima se koriste istaknute pomorske službe za traganje i spašavanje diljem svijeta. Kvalitativna SWOT analiza sustava omogućuje uvid u njihove prednosti, nedostatke, mogućnosti i prijetnje. Komparativna analiza dala je rezultate koji pokazuju karakteristike primjene pojedinih programa s obzirom na područja traganja, kao i na sredstva i ljudske resurse.

KLJUČNE RIJEČI

traganje i spašavanje
softver za traganje i spašavanje
vjerojatnost područja traganja
sredstva za traganje i spašavanje

1. INTRODUCTION / *Uvod*

Search and rescue operations at sea involve a number of complex actions that require material and human resources. Searching is an action aimed at identifying and locating persons in distress who are not able to return to a safe location without external assistance. Rescuing involves approach, stabilisation and evacuation of persons in distress using currently available resources. In addition to transfering to safe locations, the act of rescue includes rendering medical and nursing care to survivors. [1] [2] [3]

Search and rescue computer programs have been created to increase the probability of detection of persons in distress at sea, and to provide them a timely and adequate assistance. They are of great help to the teams taking part in search and rescue (SAR) operations. Utilisation of software systems in these operations has increased the efficiency of missions. For instance, compared to CSAD[1], SARPlan has increased the SAR operation efficiency by 30-50%. Moreover, the efficiency of SAR resources has become higher, while the duration of actions has become shorter and the operational costs lower.

Here are some explanations that may help in understanding the effects of computer programs [4]:

- *POA – Probability of Area* or *POC - Probability of Containment*
- *POD – Probability of Detection*
- *POS – Probability of Success*
- *Effort*
- *Effective sweep width*

POA – Probability of Area or *POC – Probability of Containment* is the likelihood that the search object is contained within the geographic area where the search and rescue operation is being carried out; it is expressed as percentage.

POD – Probability of Detection is the likelihood of finding or detecting the object that is being searched over the geographic area, assuming that the search object is really contained there.

[1] CSAD – Canadian Search Area Definition (non-computerised method of defining the search area)

POS – Probability of Success is expressed as the product of the above probabilities:

$$POS = POA * POD \quad (1)$$

In other words, it is the likelihood that the operation of searching a target object within the boundaries of some geographic area will be successful.

Effort represents the consumption of the available search resources and may be defined as the distance run by searchers over a specific segment of search area, that is, over a geographic area allocated to a search tool and to a searcher or a search team inside the total search area.

Effective sweep width – the quotient of the average number of located objects per unit of time and the density of objects (average number of objects per unit of space) is called the *effective search* or *sweep rate*. The *effective sweep rate* is expressed in a unit of space divided by the elapsed time (e.g. km²/h). The quotient of the *effective sweep rate* and the sensor's motion speed results in the *effective sweep width* that is expressed in distance units.

$$\text{Effective sweep width} = \frac{\text{number of located objects per unit of time}}{\text{(number of objects per unit of space) x (search speed)}} \quad (2)$$

Coastguards and other maritime authorities use various SAR software systems that reduce the duration of operations and increase the probability of detecting the object that is being searched. Computer programs allow the users to enhance rescue planning and allocation of material and human resources at reduced costs. [5] [6]

All software systems developed for search and rescue operations have their strengths and weaknesses, as well as their areas of application (high seas, coastal waters and land). Besides the price, they differ in their way of operation, databases, calculation speed and handling complexity. A comparative analysis of individual features of these programs provides an insight into their advantages and shortcomings.

2. METHODOLOGY / *Metodologija*

This paper analyses the features of renowned search and rescue softwares, including:

- SARPlan
- SARIS
- SAROPS
- SARMap, and
- Transas.

These programs have different support tools and use different databases. Some of them require manual input of additional data. Moreover, they have different areas of application (land, coastal waters, high seas). The qualitative SWOT matrix has been used to analyse and compare the *Strengths, Weaknesses, Opportunities and Threats* of these software systems.

3. ANALYSIS / *Analiza*

3.1. Search and Rescue Plan – SARPlan / *Plan traganja i spašavanja – SARPlan*

SARPlan is the software developed as a search and rescue (SAR) support system for Canadian Coast Guard. It allows for the optimisation of SAR resources aimed at maximum probability of successful missions. Optimisation modules are based on the search theory that may considerably enhance and accelerate SAR operation planning.

SARPlan has been developed to assist search and rescue coordinators in using optimal resources. SARPlan runs on a Windows platform featuring client-server architecture. It provides the search planners with fast, intuitive, easily applicable tools and methods for designing optimal search plans (Fig. 1). SARPlan enables the user to define the search possibility area.

The SARPlan's main structure for representing data consists of a data distribution grid. It is displayed as a raster graphic image, i.e. as a set of identical squares that are generated over the area of search possibility. The grid template (Fig. 2) is automatically generated for the defined area of the defined possibility area. SARPlan can automatically fill in the *sweep width* grids, the so-called *theme* grids, with information on the searched object and SAR units. The user can manually design a network by creating zones, i.e. quadrants having approximately identical features such as, for example, the same topography. The user then assigns certain values to the zones.

SARPlan contains four main modules (Fig. 3):

1. Case management module,
2. Possibility area module,
3. Theme grids creation and edition module, and
4. Search operations module.

Initially, SARPlan was designed to assist in search operations after aircraft crashes but soon it proved to be a

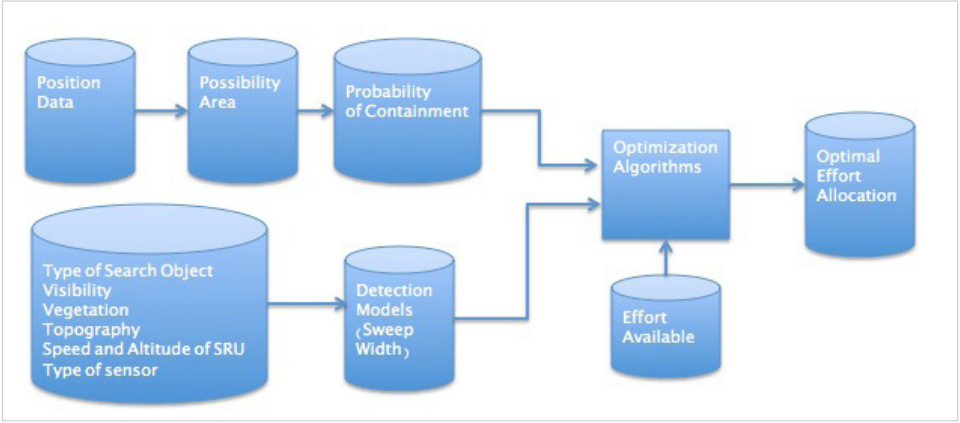

Figure 1 Information content and data flow in SARPlan
Slika 1. Sadržaj informacije i protok podataka u SARPlanu

Source: [7]

valuable asset in sea and land SAR missions as well. It enables efficient distribution and allocation of SAR resources and increases the probability of success by 30-50% compared to the non-computerised methods of Canadian Search Area Definition (CSAD).

By increasing the efficiency of search operations, SARPlan provides multiple benefits:

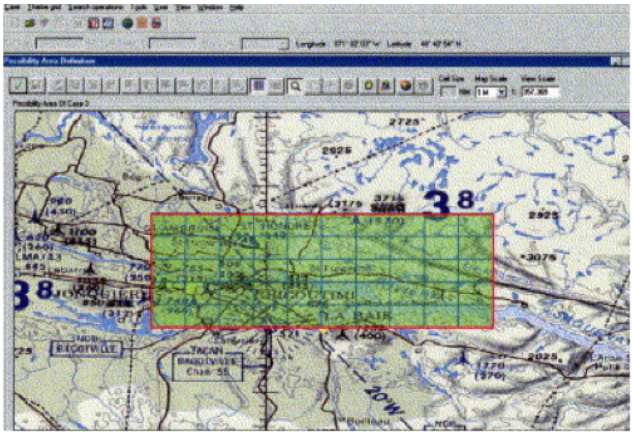

Figure 2 Automatic grid of the possibility area in SARPlan
Slika 2. Automatska mreža područja mogućnosti u SARPlanu
Source: [7]

- More lives saved by locating persons in distress in a faster and more efficient way
- Reduced search and rescue costs due to more accurate search methods
- Reduced risk to search crews due to reduced search time

Evaluation of the current SAR tactics and development of new, improved tactics aimed at higher efficiency in future SAR operations (development of the *survivability* models, i.e. maximisation of a possibility to locate persons in distress with regard to the possibility of survival in a defined area – areas with shorter survival possibility time are the first to be searched). [7]

3.2. Search and Rescue Information System – SARIS / *Informacijski sustav traganja i spašavanja – SARIS*

SARIS is the latest generation of information technology for search and rescue operations. It is used internationally, by a number of coastguards, navies and port authorities, including UK Maritime and Coastguard Agency (MCA), German Sea Rescue Service and German Navy, British Royal Navy, US Air Force, The Netherlands Coastguard, Hellenic Coastguard (Greece), Danish Royal Navy, Ukrainian Navy, Maritime Rescue Coordination Centre – Torshavn (Faroe Islands), Maritime Rescue Coordination Centre Hong Kong, and Guernsey Harbour

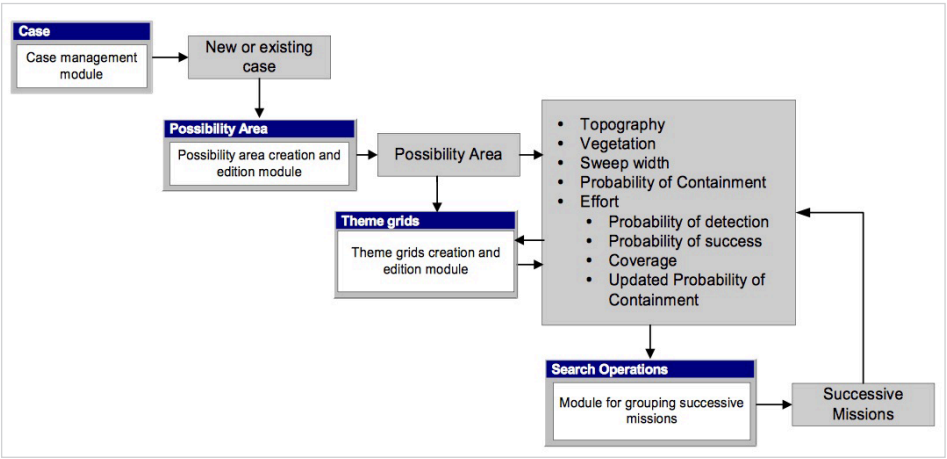

Figure 3 SARPlan main modules
Slika 3. Glavni moduli SARPlana

Source: [7]

Table 1 SWOT analysis of the SARPlan
Tablica 1. SWOT analiza SARPlana

Strengths	Weaknesses
1. Fast locating of the persons in distress, more lives saved. 2. Reduced costs of SAR operations. 3. Reduced risk to search crews. 4. Predicting the drift of search targets. 5. Usage in missing aircraft searches.	1. Potential error in assessing wind force and wave height may lead to poor search results. 2. Poor results may arise if search crew are insufficiently familiarised with the software package. 3. All users have to complete a program usage course. 4. Difficulties in using the program. 5. Imperfection of the method.
Opportunities	**Threats**
1. Upgrade of the survivability model. 2. Development of optimisation algorithms (taking into consideration SAR tools, their capabilities, and costs). 3. Supplementary training of rescue teams. 4. Supplementary training of program package users. 5. Development of software for usage in other situations (movement of oil slick after pollution).	1. Inaccurate data about the location of a SAR object and inaccurate time of the very event. 2. Insufficient familiarisation with the program features. 3. Extreme weather conditions during SAR operation. 4. Incorrectly entered data about the search object. 5. Equipment faults.

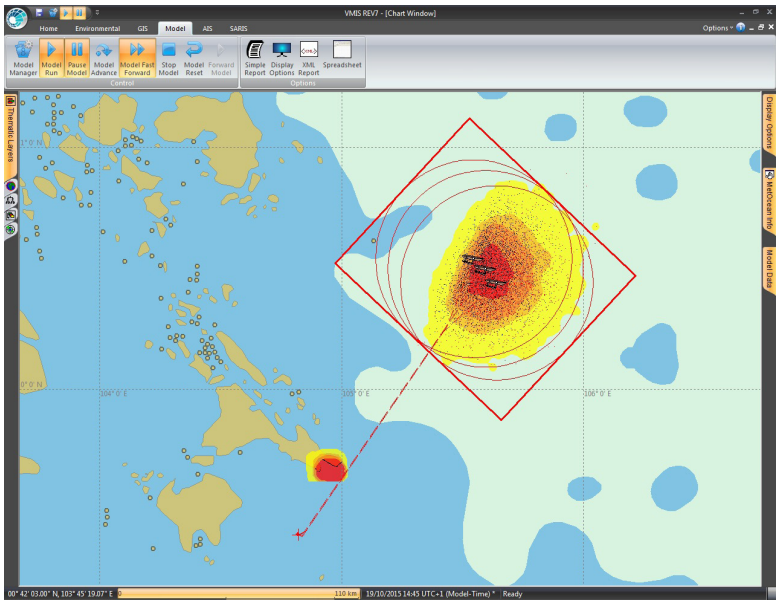

Figure 4 Defining the probability and search area using SARIS
Slika 4. Definiranje vjerojatnosti područja traganja koristeći se SARIS-om

Source: [13]

Authority. SARIS uses in-built oceanographic databases (of tidal and ocean current data) and electronic charts. The software is adaptable and can be applied by any search and rescue authority in the world. It is compatible with other search and rescue systems such as AIS. [8], [9], [10], [11], [12].

Some of the SARIS features include:

- Clear, step-by-step interface system that allows fast set-up during emergency operations by all personnel
- Database of the search target types
- Electronic charts
- Chart-based display of the target trajectory and the most probable search area
- Chart-based display of prevailing currents and winds in the SAR area
- Results output to reports, external files and printers
- Settings of universal technical tracer for any region in the world
- Completely flexible *drag and drop* feature for defining search areas by SAR units
- Automatic calculation of track spacing, sweep width and Probability of Detection (POD).

Defining a search area is one of crucial factors in SAR operations as it predicts the motion of targets by combining the effects of winds, currents and tidal streams. The software uses the methodologies developed by the British Coastguard in a way that the system establishes the most probable search area taking into account a range of probabilities, statistical deviations and errors. SARIS has in-built databases of tides and tidal streams, sea currents, search target drifts, navigational errors and other configuration parameters for rapid model set-up.

SARIS provides users with a range of tools for the configuration and employment of SAR units in searching targets. Enhanced graphics allows rapid planning and use of SAR resources. In addition to the ability of using pre-configured databases, SARIS can import gridded meteorological and oceanographic data in the NetCDF format automatically. [12], [14].

Table 2 SWOT analysis of SARIS software
Tablica 2. SWOT analiza softvera SARIS

Strengths	Weaknesses
1. Fast locating of the persons in distress, more lives saved. 2. Reduced costs of SAR operations. 3. Reduced risk to search crews. 4. Use of the methodology approved by IAMSAR. 5. Databases of the drifts of certain SAR targets.	1. Potential error in assessing wind force and wave height may lead to poor search results. The latter may arise if search crew members are insufficiently familiarised with the software package. 2. All users have to complete a program usage course. 3. Difficulties in search planning in the event of incomplete familiarisation with the SAR target environment. 4. Difficulties in using the program. 5. Imperfection of the method.
Opportunities	**Threats**
1. Ability of interaction with AIS and IMS with the purpose of additional optimisation of search and rescue teams. 2. Supplementary training of rescue teams. 3. Development of additional methodologies. 4. Enhancing the calculations of the SAR target drift. 5. Development of software for usage in other situations (removal of oil slick after pollution).	1. Inaccurate data about the location of a SAR object and inaccurate time of the very event due to insufficient familiarisation with the program features. 2. Reduced available staff due to selection of the ones who have completed a program usage course. 3. Insufficient familiarisation with the IAMSAR methodology. 4. Equipment faults. 5. Extreme weather conditions during SAR operation.

3.3. Search And Rescue Optimal Planning System – SAROPS / *Optimalan sustav planiranja traganja i spašavanja – SAROPS*

SAROPS is a comprehensive search and rescue planning system used by the US Coast Guard in coastal and offshore environment. The software has three main components:

- Graphical User Interface,
- Environmental Data Server, and
- Simulator.

The Graphical User Interface uses the Geographic Information System (ArcGIS) designed by the Environmental Systems Research Institute (ESRI), including specific US Coast Guard applications (SAR Tools Extension and SAROPS Extension). The display is able to present vector and raster electronic charts, search plans, search patterns, and probability maps. The Environmental Data Server gathers and stores all environmental data for use within SAROPS. Finally, the Graphical User Interface provides reports on all SAR operations.

Local SAROPS servers around the United States request environmental information from the Environmental Data Server based upon the area of interest. Different environmental products are catalogued on the server ranging from observational systems to modelling products. Observations include sea surface temperature, air temperature, visibility, wave height, tides and currents, etc. High-resolution model output from operational forecast models like the hybrid coordinate ocean model (HYCOM) and Global NRL Coastal Ocean (GNCOM) provides temporally and spatially varying wind and current information. Furthermore, the Environmental Data Server is capable of providing objective analysis tools and aggregation. The probability of detection (POD) is calculated with the aid of Monte-Carlo method. This is a stochastic simulation method that predicts the behaviour of complex mathematical systems using algorithms with random and quasi-random numbers and a large number of calculations and repetitions. The list of available products is always changing as researchers in the Navy, local universities and research centres continually improve the accuracy and reliability of products and make them available on a consistent basis (Fig. 5).

The simulator is provided with the ability to access global and regional wind and current data sets, making SAROPS the most comprehensive and powerful tool available for maritime SAR planners. SAROPS was used in SAR operation following the explosion on the oil rig "Deepwater Horizon" and assisted in the ultimate recovery of 115 persons. [15], [16], [17], [18].

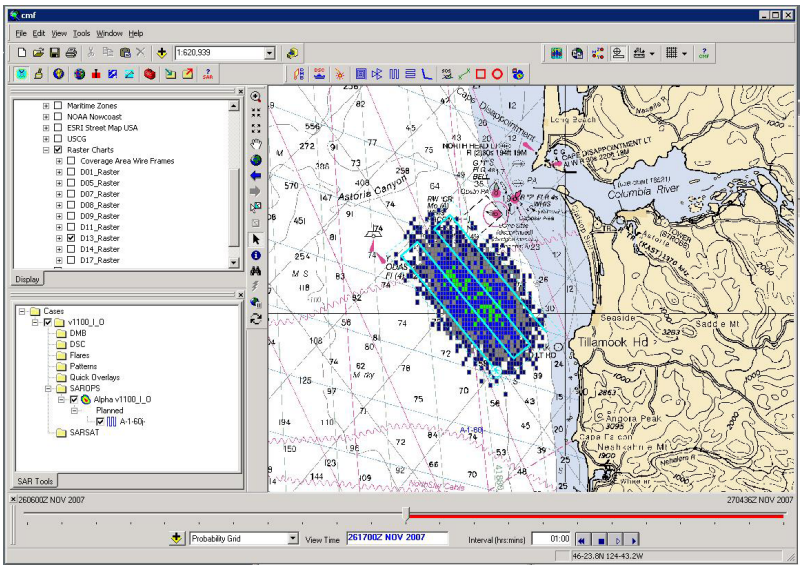

Figure 5 Output data in SAROPS
Slika 5. Izlazni podaci u SAROPS-u

Source: [15]

Table 3 SWOT analysis of SAROPS
Tablica 3. SWOT analiza SAROPS-a

Strengths	Weaknesses
1. Rapid detection of distress situation, more lives saved. 2. Reduced costs of SAR operations. 3. Reduced risk to search crews. 4. Use of Monte-Carlo method. . 5. Databases of the drifts of certain SAR targets.	1. Potential error in assessing wind force and wave height may lead to poor search results. 2. Poor results may arise if search crew are insufficiently familiarised with the software package. 3. All users have to complete a program usage course. 4. Imperfection of the method. 5. Difficulties in using the program.
Opportunities	**Threats**
1. Can be extended and applied to other situations, e.g. expansion of oil slicks after pollution. 2. Development of optimisation tools. 3. Additional training of rescue teams. 4. Constant improvement of analysis tools. 5. Enhancing the calculations of the SAR target drift.	1. Inaccurate data about the location of a SAR object and inaccurate time of the very event. 2. Insufficient familiarisation of users with the program features. 3. Extreme weather conditions during SAR operation. 4. Undesired search results due to the method's imperfection. 5. Equipment faults.

3.4. SARMAP – Search and Rescue Model and Response System / *SARMAP – Model traganja i spašavanja i sustav odgovora*

SARMAP provides fast predictions of the movement of drifting objects and missing persons at sea. The software includes the ability to deploy SAR units with search patterns, and to calculate the probability of containment (POC), probability of detection (POD), and probability of success (POS).

SARMAP is applied in:

- Defining the search area for missing persons, vessels, or containers at sea
- Identification of the probable location of an accident site or lost object
- Storing home base locations of all available search and rescue units
- Deployment of the SAR units and search pattern management
- Contraband tracking at sea
- Reverse calculations of the lost object's trajectory.

The features of SARMAP include:

- A database of drift behaviour, affected by winds, tides and currents, for a variety of objects based on the latest US Coast Guard data
- Easy interpretation of the search area on visual display over time
- Real-time data links, integrated with the COASTMAP Environmental Data Server
- Directly linked online web maps and meteorological and oceanographic data services
- Links floating debris to find a lost object or an accident site
- Supports commercial nautical electronic charts
- SARMAP Wizard quickly leads users through all the steps required to calculate a search area.

SARMAP clients include Irish Coast Guard, Singapore Civil Aviation, Singapore Port Authority, Argentina Coast Guard, US Navy, Spanish SAR Authority (Sasemar) and New Zealand Maritime Authority. SARMAP gathers environmental input data and integrates them for accurate SAR predictions. Since the quality of model predictions depends on the quality of the environmental data, a set of program tools allow the user to manage environmental data efficiently. Specifically, SARMAP integrates meteorological and oceanographic information (winds and surface currents) for accurate SAR predictions. SARMAP allows the user to make a prediction in a few minutes without having to enter data manually (Fig. 6). [19], [20].

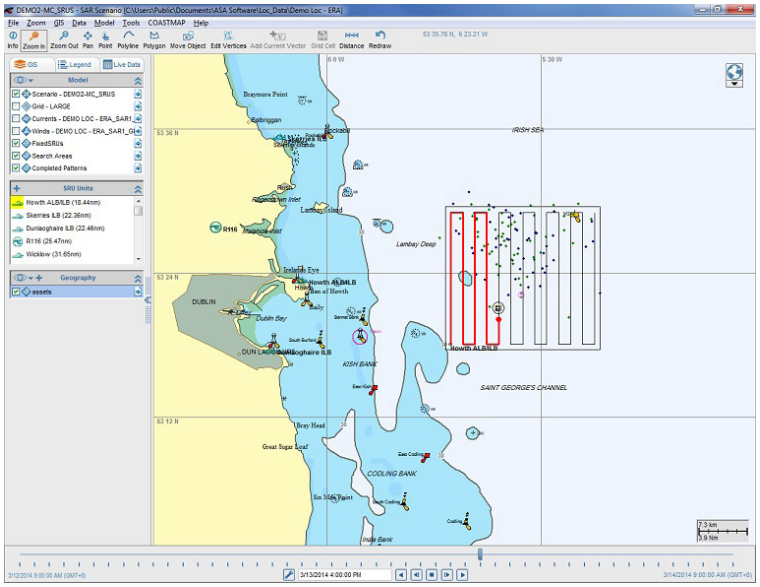

Figure 6 SARMAP model interface.
Slika 6. Sučelje modela SARMAP

Source: [21]

Table 4 SWOT analysis of SARMAP
Tablica 4. SWOT analiza SARMAP-a

Strengths	Weaknesses
1. Rapid detection of distress situation, more lives saved. 2. Reduced costs of SAR operations. 3. Reduced risk to search crews. 4. Use of Monte-Carlo method. 5. Automatic input of meteorological-oceanographic data.	1. Potential error in assessing wind force and wave height may lead to poor search results. 2. Poor results may arise if search crew are insufficiently familiarised with the software package. 3. All users have to complete a program usage course. 4. Imperfection of the method. 5. Estimated starting search position may be inaccurate.
Opportunities	**Threats**
1. Development of new search tactics. 2. Development of optimisation tools. 3. Additional training of rescue teams. 4. Development of additional methods. 5. Clients may request a subscription service to COASTMAP Environmental Data Server for different data products from different sources or providers, public or private.	1. Inaccurate data about the location of a SAR object and inaccurate time of the very event. 2. Insufficient familiarisation of users with the program features. 3. Extreme weather conditions during SAR operation. 4. Undesired search results due to the method's imperfection. 5. Equipment faults.

3.5. Transas / *Transas*

Transas' search and rescue software allows straightforward control of SAR missions and SAR resources. The Transas SAR module helps operators to efficiently determine search areas, estimate resources required, and calculate search patterns. The benefits of this software include:

- SAR data are displayed as a separate layer, together with real-time vessel positions, navigational charts, radar images and data from other sensors
- Fast allocation of search area with consideration of all available data
- Estimation of required resources
- Easy alteration of search parameters
- Switching of any search/operation in the chart window
- Automatic SAR reporting.

Search planning calculates the probability of success, and generates an SAR report describing search areas for each resource.

In the case of unsuccessful searches, the operator can plan a new search based on the previous data. The Transas SAR module (Fig. 7) also enables all SAR information to be archived for future debriefing, analysis and quality control. [22]

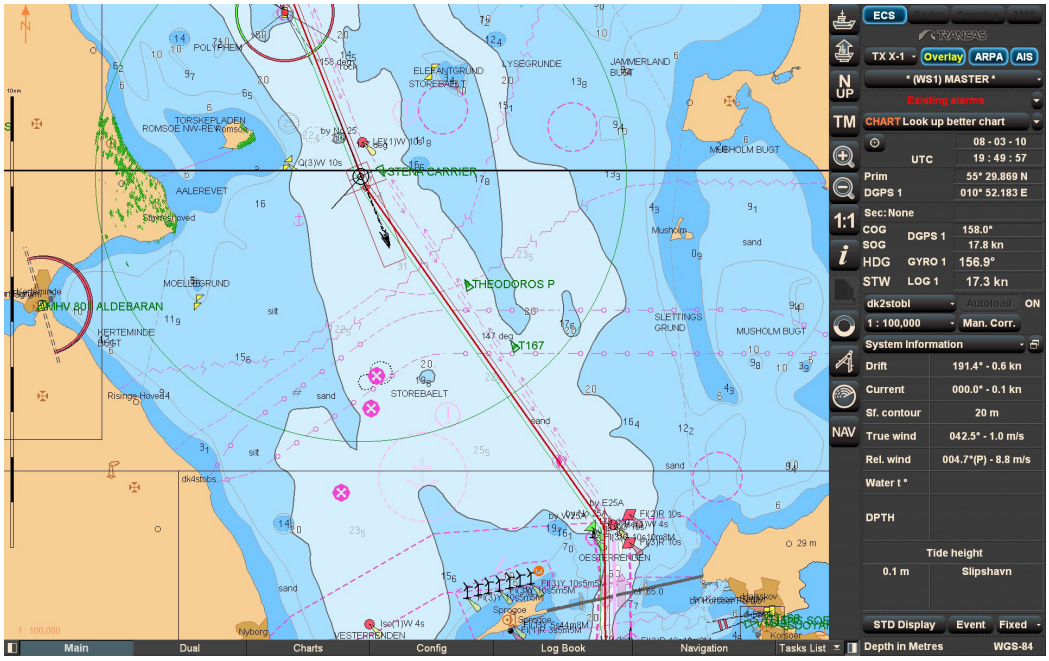

Figure 7 Display of Transas' SAR software
Slika 7. Zaslon Transas SAR softvera

Source: [23]

Table 5 SWOT analysis of Transas search and rescue software
Tablica 5. SWOT analiza Transas softvera za traganje i spašavanje

Strengths	Weaknesses
1. Rapid detection of distress situation, more lives saved. 2. Reduced costs of SAR operations. 3. Reduced risk to search crews. 4. Use of the methodology approved by IAMSAR. 5. Calculating the drift of search targets.	1. Potential error in assessing wind force and wave height may lead to poor search results. 2. Poor results may arise if search crew are insufficiently familiarised with the software package. 3. All users have to complete a program usage course. 4. Difficulties in search planning in the event of incomplete familiarisation with the SAR target environment. 5. Imperfection of the method.
Opportunities	**Threats**
1. Development of new search tactics. 2. Upgrade of SAR optimisation. 3. Additional training of rescue teams. 4. Development of additional methods. 5. Development of software for usage in other situations (removal of oil slick after pollution).	1. Inaccurate data about the location of a SAR object and inaccurate time of the very event. 2. Insufficient familiarisation of users with the program features. 3. Extreme weather conditions during SAR operation. 4. Insufficient familiarisation of users with the IAMSAR methodology. 5. Equipment faults.

Table 6 Comparison of SAR computer programs
Tablica 6. Usporedba SAR računalnih programa

	Database of drift behaviour of certain SAR targets	Monte-Carlo method	Automatic input of meteorological and oceanographic data
SARPlan	Yes	No	No
SARIS	Yes	Yes	Yes
SAROPS	Yes	Yes	Yes
SARMAP	Yes	Yes	Yes
TRANSAS	No	No	No

4. RESULTS / *Rezultati*

Tables 1-5 provide SWOT analyses of some of the most renowned computer programs for search and rescue operations. The analysed programs do not provide identical results for all SAR areas (land, coastal waters, high seas). They differ in time needed for data processing that depends on calculation methodology, software support and hardware. Although all these programs are available on market at similar price, the cost of their individual application may be increased depending on the database used by the software. It is important to point out that all programs use IAMSAR methodology and allow timely SAR planning and use of SAR material and human resources. The differences are shown in Table 6.

An important feature of all the above discussed programs is their ability to archive all data about the performed SAR operations for future use, analysis and quality control (personal experience of a SAR coordinator is not essential any more as the software uses necessary data for a specific operation from the database and calculates an optimal response).

Automatic input of meteorological and oceanographic data gives an advantage to SARIS, SAROPS and SARMAP since it increases system accuracy and enables faster and cheaper SAR operations.

CONCLUSION / *Zaključak*

Search and rescue computer programs have considerably increased the efficiency of search and rescue (SAR) operations. By helping SAR operators in determining search areas, estimating resources required, calculating search patterns, and making decisions, these software systems have maximised the efficiency of material and human resources. The paper has presented an analysis of renowned SAR software systems used by a number of prominent search and rescue authorities all over the world.

Although the analysed programs differ in price, application area (land, coastal waters, high seas), time needed for data processing, calculation methodology, software support and hardware, they have some essential common features. The simplicity of operation, IAMSAR methodology and integrated environmental data about weather conditions, tides and currents over the search area, enable the users to efficiently deploy available SAR resources, increase the probability of target detection and reduce the duration of action.

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