SAFE
MARINE RISK ANALYSIS SYSTEM
FEASIBILITY STUDY &
USER REQUIREMENTS

prepared for

Director, Marine Occurrence Programs
Transport Canada
344 Slater Street, Room 1256
Ottawa, Ontario
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The contents of this report reflect the views of the author and not necessarily the official views or opinions of Transport Canada.

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At the time of contract award, the Canadian Coast Guard (CCG) was an integral part of Transport Canada. On April 1st, 1995, most functions of the CCG were transferred to the Department of Fisheries and Oceans. For the purpose of this contract, Transport Canada (Marine) will continue to administer the contract. The office responsible is that of:

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I. INTRODUCTION

Project Scope and Objectives

The objectives of the project were established in the proposal and workplan as: to conduct a study to assess the user requirements for, and feasibility of developing a marine safety risk analysis tool on a PC platform to identify trends, causes of ship accidents and incidents and effectiveness of regulations and marine safety policy. The system is known as SAFE *or Safety Analysis and Functional Evaluation.* The specific requirements were designed through on-going interaction with Marine Occurrences Programs and other potential users of SAFE and risk analysis.

In general, system requirements were to include the ability to access relevant databases and conduct analysis by location, time, vessel or occupational accident type etc. These are key attributes of a Geographic Information System (GIS). The system would enable the integration of a variety of data including vessel casualty data, vessel movements, port calls, Vessel Traffic Service history files, port state controls inspections, and environmental data. System output requirements were to include the ability to identify a need to change or create regulations that would improve safety and respond to deficiencies and to measure the performance and contribution of programs, regulations and procedures through the use of safety indicators. The principal goals of this initiative were to:

Identify user requirements through interviews with MARINE OCCURRENCES personnel and interaction with the INSTITUTE FOR RISK RESEARCH (IRR)

- Identify and prioritize analysis and output requirements;
- Identify existing database information and method of access to meet analysis requirements;
- Identify priority analog information that should be converted into database, or digital format;

Identify all practicable options for successfully resolving the problems or taking advantage of the opportunities identified in the analysis of user requirements

- Identify software alternatives and recommend a preferred system;
- Through discussions with Transport Canada personnel, develop a demonstration tool which provides a demonstration user interface and examples of specific application functions and output; and

Provide a Class B estimate detailing the development plan, the costs of system development and implementation including operator requirements and software support

- Detail the management plan and costs to develop and install a fully functional system and provide software support to head office.

Summary of User Requirements and Feasibility Study

This document comprises the User Requirements and Feasibility Study to create and implement the SAFE risk analysis system and risk management strategy. ***Part One*** (page 7) summarizes the findings of user requirements, database inquiries, and software alternatives, and provides an overview of the SAFE prototype software interface. ***Part Two*** (page 78) outlines where the SAFE Risk Analysis Module (RAM) fits into risk analysis work in government, explains the risk management strategy, and gives an overview of the preliminary functional specifications that were developed over the duration of Phase I of the project.

Note: A Class B estimate of the costs to implement SAFE in Phase II of the project forms a separate document.

Overall Findings

Summary User Requirements for SAFE

(See Part One, Page 7)

User Interface

A well designed and user friendly interface was of high priority. This means that the system should be sophisticated enough yet simple for analytical and managerial use.

Analytical Requirements

Analytical requirements included the need for the system to be multifaceted to allow analysis, querying of data, and basic mapping, data exchange and report presentation capabilities. Among the high priority functions which SAFE provides are the capabilities to manipulate tabular and spatial (mapped) data, as well as historical data, for the purposes of projections and forecasts. SAFE's geographical base allows users to calculate, measure and associate different data with respect to space-time-distance attributes—an important function when evaluating the distribution of phenomena and underlying causal factors. Key attributes of SAFE's analytical capabilities include:

- spatial and tabular data handling
- multiple presentation formats
- geographic display, and spatial analysis
- statistical, historic and economic analysis

Software Compatibility

Software compatibility in terms of being able to communicate and simultaneously work with other software, and work with existing and planned networks is an important requirement. SAFE's prototype MapInfo Windows software is also fully compatible to other software, including Windows spreadsheets, databases, and statistical packages. This is a key advantage of SAFE. Because it can interface with more complex packages and use their complex functions, it can maintain a relative sophistication and simplicity as a stand-alone analysis tool. SAFE is the only system in Transport Canada which outputs data in most standard data and presentation formats including maps, charts and tables. Key software compatibility attributes include:

- integrated with MS Excel, and other Windows products
- sophisticated compatibility
- robust as a stand-alone interface

Data Accuracy

Since data accuracy, scale and details were high priority requirements for consistent and repeatable risk analysis, SAFE is superior with respect to maintaining data accuracy and scale especially in the presentation of map details.

Data Access and Conversion

(See Part One, Page 22)

Access to most of the data required for a fully functional SAFE marine risk analysis system is fairly open and involves minimal costs. Because most of the data are public domain, there are almost no direct fees for accessing the data, although in some cases data processing costs would be passed on because of the volume of data, and resources required to download and convert the data

Many of the marine databases and other sources of data are fragmented according to the level of geography, time period, sampling, consistency, and coverage. A significant portion of the data from the available sources would need to be standardized to some level of geography and coverage, and be converted to a proper digital form to be used in SAFE.

It should be expected that formal written statements will need to be prepared for each data request, in order to ensure from the supplier's side that the data be used only for the stated project and referenced accordingly.

Recommendations for GIS software purchase

(See Part One, Page 40)

Among the implementation options for GIS, we recommend buying one of the many available popular or leading GIS software packages available in the marketplace. We support our recommendation with the following comparative advantages.

- Relatively Low Costs of System Implementation
- Relatively Low Costs of Components and Staff
- Relatively Low Labour Costs Over Time
- Comparatively Better Technical and Software Support
- Relatively Low Resource Requirements (e.g., labour, staffing)
- Comparatively Lower Level of Dependence and Uncertainty
- Comparatively Better System Functionality and Customization

The most important considerations in the selection of GIS software are the main GIS capabilities and mapping functionality required by SAFE, in order for it to be an effective and fully functional analysis tool. The package recommended will therefore be able to perform all of the necessary spatial analysis and mapping tasks required by SAFE, and provide the best combination of user interface, geographic analysis capabilities, map analysis tools, reports, data management, vendor support, customization, and overall practicality. It is important to highlight that as the longer-term demands for SAFE and complexity of SAFE change, it may be necessary to modify the overall software implementation strategy.

A recommended option would be to use MapInfo 3.0. Of the systems evaluated, MapInfo 3.0 appeared to be the most practical option given the present requirements for SAFE and type of users. MapInfo's greatest strengths are its flexibility, user friendliness, and open applications development environment. It ranked very well amongst its competitors and full-blown GIS systems with good and excellent ratings on many of the important criteria, such as user interface, input/output, analytical functionality, and mapping.

As well, MapInfo provides comparable GIS capabilities needed by SAFE, without added technical sophistication of operation typical of the other GIS software and systems. Overall, MapInfo's functionality is compatible to the scope of SAFE, the low level of technical knowledge required to use it, and relatively low cost and short period of time of fully implementing MapInfo.

SAFE Prototype

(See Part One, Page 62)

A significant accomplishment of this project was the creation of a customized, off-the-shelf, GIS software prototype over two months of development. The development team worked from a very draft set of functional requirements supplemented by in-house expertise in the field of marine navigation safety and risk analysis, GIS, software development, and risk management. The result was a software prototype which surpassed the capability of a “demo system” as it provided demonstrations of some key built-in functions. The prototype fairly closely demonstrates the concepts developed by Canarctic and the Institute for Risk Research in Parts One and Two to this feasibility study.

An overview of the SAFE prototype software is provided in Part One, Page 62. A discussion of the methods and functional concepts for SAFE is provided in Part Two. These products are a major step towards the creation of a fully developed and documented software development plan and functional specifications document in the next phase. The next phase would enable greater flexibility in statistical analysis, data management, trend analysis, modeling, reporting and decision-making.

Overall Goals and Objectives for SAFE

(See Part Two, Page 78)

The overall objectives for SAFE are to:

- Build on existing “best practice” within Transport Canada for the analysis of safety measures
- Automate and enhance existing risk analysis methods so that people can do their job faster and better
- Conform to government information management plans
- Follow government and marine standard terminology
- Be maintainable within a rapidly changing working environment
- Proceed in a practical step by step implementation to ensure continuous improvement in the SAFE function within Transport Canada.

Accountability of government

The SAFE system will assist Transport Canada (Marine) to develop “safety indicators”. Safety indicators can be used to demonstrate accountability by determining how well programs and regulations are working. Safety indicators are consistent with the on-going move towards a “risk-based” approach for the allocation of funds to new and existing programs.

Consistent approach to policy evaluation

The Risk Analysis Module (RAM) of SAFE forces the user to take a systematic, structured approach to policy evaluation. This structure imposed by RAM ensures that the numbers and methods used to calculate risks, develop trends, and analyze relationships between cause and effect are clearly displayed so that stakeholders and others can review the analysis and evaluate their validity. This structure is compatible with the CSA Q850 standard for risk management.

Integration of data, tools, techniques and expertise

By using the latest in computer technology (including a geographic information system (GIS), the SAFE marine risk analysis system links historical data on accidents and incidents, exposure, weather, geography, infractions & inspections etc. with state of the art analysis techniques to provide a basis for continuous and incremental improvement to policy evaluation within Transport Canada. The SAFE system is designed to be fully integrated and user-friendly in terms of its ability to store, analyze and display safety information.

PART ONE

II. IDENTIFY USER REQUIREMENTS & DESIGN CRITERIA

Introduction

The first step in the project was to assess the user requirements for developing a marine occurrence analysis tool. This requires on-going interaction with Marine Occurrences Programs and the Institute for Risk Research (IRR). In general, system requirements should include the ability to access relevant databases and conduct analysis by location, time, vessel or occupational accident type etc. System output requirements would include the ability to identify a need to change or create regulations that would improve safety and respond to deficiencies and to measure the performance and contribution of programs, regulations and procedures through the use of safety indicators. The principal goals of Task 2 were to: Identify and prioritize analysis and output requirements.

Canarctic was tasked primarily with the identification of software requirements while the IRR focused on the functional requirements for SAFE. Therefore, this report is organized into two parts summarizing the findings of Canarctic and IRR. Through interviews and extensive discussions with Coast Guard and Transport Canada personnel identified by Marine Occurrences and through advisory input IRR to review Transport Canada's near term needs for risk management information and analysis tools, key analysis and functional capabilities were identified and software requirements were prioritized. These ideas were integrated to produce a set of design criteria to be used to develop a prototype system.

The combination of input from Transport Canada, Canarctic, and IRR were integrated to produce a set of design criteria from which a prototype system can be developed. These findings are summarized in two sections: the first dealing with software requirements and the second describing the analysis and output requirements. Work to date has shown that these criteria will likely be updated as more information becomes available.

Methodology

Consultations

Canarctic held meetings and interviews with all Transport Canada and CCG divisions involved with marine risk reduction and safety improvement programs. In addition, two meetings were held with the steering committee and one workshop was held with the working group. The objectives of these meetings and consultations were to:

- Understand specific risk and safety analysis requirements;
- Ensure SAFE platform is compatible with information systems used by Transport Canada;
- Evaluate case study examples, research literature, and existing systems being used; and
- Formulate specific analysis requirements for Transport Canada and other stakeholders.

Literature examination/case studies

The suggested use of case studies has undergone a minor evolution since the fall of 1994. In order to help identify the basic risk analysis requirements and provide an example of a marine traffic problem to demonstrate the analysis tool described in Task 5, it was proposed to use a single test case. It was intended that the case study be used to help identify the types of queries, functions and outputs that a risk analysis tool would be required to perform

The use of a case study to analyze the risk of a tanker casualty in the St. Lawrence River was suggested as an example, however, consultation with the Institute for Risk Research led to the suggested use of several existing examples to help illustrate different type of problems that could be addressed by SAFE. Several examples of the use of the prototype software MapInfo were demonstrated to Transport Canada and other federal government departments, and three examples were suggested to Marine Occurrences and IRR. Furthermore, IRR suggested that the choice of case studies would be better defined **after** input from those interviewed in Task 2, and the potential to involve the Transport Canada working group would be enhanced. The examination of Case Studies can be found in Part II.

Contact Groups

Canarctic developed a list of valuable contacts with various expertise in marine research, analysis and safety. The list was established from an initial steering committee list and expanded through direct consultation with members from the steering committee.

Table 1 provides a list of all contact group members with whom we have had or plan to have discussions with. A meeting was scheduled with at least one or more key members from each group. All of the steering and working group divisions were represented, with the exception of the Ship Inspection Directorate and Marine Regulatory Directorate. These two bodies have only recently emerged. We plan to contact and hold discussions with key representatives once official functions and mandates for these directorates have been formally announced, and steering and working group representatives have been selected.

The formation of this contact group list is an on-going process. We anticipate that the list will grow as more Transport Canada personnel become familiar with the SAFE system and find areas of application for SAFE. Further, we plan to utilize the contact group on a continuing basis to guide us through the development of a prototype.

Table 1. Contact Groups

MARINE COMMUNICATIONS & TRAFFIC SERVICES	CONTACTED	DISCUSSIONS
GABRIELLE JOE	*Yes*	*Yes*
FORBES FRED	*Yes*	
KENNSETT RICHARD	*Yes*	*Teleconference*
ENGINEERING & TECHNICAL SUPPORT SERVICES		
CLAVELLE JACQUES		
ANDERSON WILLIAM	*Yes*	*Yes*
RADICAN JOHN	*Yes*	
RESCUE & ENVIRONMENTAL RESPONSE		
GADULA CHARLES	*Yes*	
DALY SUE	*Yes*	
VANDENBERG PAUL	*Yes*	
KATSUMI NAOMI		
MELHUISH TERRY	*Yes*	
CIMON MICHELE	*Yes*	
INFORMATION RESOURCE MANAGEMENT		
LAWLOR MICHEAL	*Yes*	
FORGIE KIM	*Yes*	*Yes*
PRIEUR SCOTT	*Yes*	
MARINE OCCURRENCES PROGRAMS		
PREST BARBARA	*Yes*	*Yes*
WOODBURY JACK	*Yes*	*Yes*
BROCK JIM		
NAVIGATION SERVICES		
KINGSTON R.	*New Contact*	
BARKER LEA	*Yes*	
JACKSON DAVID	*Yes*	*Yes*
VAN DYKE HANK	*Yes*	
MARINE REGULATORY DIRECTORATE		
HUBBARD M.J.	*Yes*	
MORRIS TOM	*Yes*	*Yes*
SHIP POLICY & PLANNING		
GAREAU GILLES	*Yes*	
JENKINS DAVID	*Yes*	*Yes*
LAWSON JIM	*Yes*	
MCARTHUR FRANK	*Yes*	
WADE HARVEY	*Yes*	
SCOTT BILL	*Yes*	
SHIP INSPECTION DIRECTORATE		
REJEAN LANTEIGNE	*Yes*	
TRANSPORTATION SAFETY BOARD		
LAVOIE SERGE	*Yes*	*Yes*
SNOW ERIC	*Yes*	*Yes*
LEMIEUX LISE	*Yes*	*Yes*
TRANSPORT CANADA: SFC & MARINE DATA/STATS		
TULIPAN GARRY	*Yes*	*Yes*
KOCHHER PAUL	*Yes*	*Yes*
NATIONAL SEARCH & RESCUE SECRETARIAT		
MCDONALD AMANDA	*Yes*	*Yes*

Evaluation criteria

As part of the interview and discussion process, Canarctic developed a list of standard criteria in order to evaluate specific user and system requirements. These criteria can be divided into four important groups.

A. User interface

The front-end software linking the user to a system's functions. It allows users to efficiently access, manage, and analyze data through a series of menu selections and commands.

B. Outputs

System outputs include capabilities to transfer and present data in a variety of ways including spreadsheets, charts, tables, files, summaries, and maps.

C. Analytical functions

Analytical functions are built-in or customized operations which allow the user to associate, calculate and manipulate a variety of data for more sophisticated analyses such as risk analysis, cause/effect, optimal location, routes analysis, and so on.

D. Data management

Data management includes system capabilities to facilitate efficient records management and storage, and compatibility with different file formats, systems and software.

A Glossary of Terms (see page 56) includes a detailed list of attributes describing each one of these groups. The attributes chosen reflect standard items and functions frequently identified in marine risk and safety analysis case study examples, research studies, and analysis systems.

These are important aspects of a system which need to be further considered in the development of the risk analysis system. A brief questionnaire was also distributed to contact group members to supplement our discussions, especially in cases where we may not have addressed all of our evaluation criteria or where the representative was asked to pass on the questionnaire to personnel having the required specialization to comment on user requirements.

Documentation

The evaluation criteria were used to systematically document all of our discussions and reviews. By applying the same criteria to all stakeholders, we were able to effectively summarize our information into key words and separate spreadsheet tables.

We then developed a comparative profile of the stakeholders and the relative importance of the key attributes of SAFE based upon discussions and an examination of the literature produced within Transport Canada. Based on individual spreadsheet tables produced for each stakeholder, we were able to map into a summary figure the relative importance of the evaluation criteria attributes. Each attribute was weighted as a high or low priority with respect to its importance as a requirement for the stakeholders to effectively perform marine safety and analysis functions. This allowed us to identify some of the more important user and system functionality potential users of SAFE required (Figure 1).

Figure 2 was developed to compare present work activities related to safety analysis within Transport Canada (including methods or systems) and the potential use of SAFE if it utilized a leading GIS./Desktop Mapping software product. This helped to identify software requirements. We required a benchmark to properly measure the relative comparability of the systems in providing the necessary functionality potential users required. The same attributes as above were used to measure SAFE's relative comparability to systems and methods presently being used by stakeholders. We did this by rating how well SAFE could provide the necessary functionality. Adopting SAFE as a benchmark, we rated presently used systems within the Transportation Safety Board and Transport Canada.

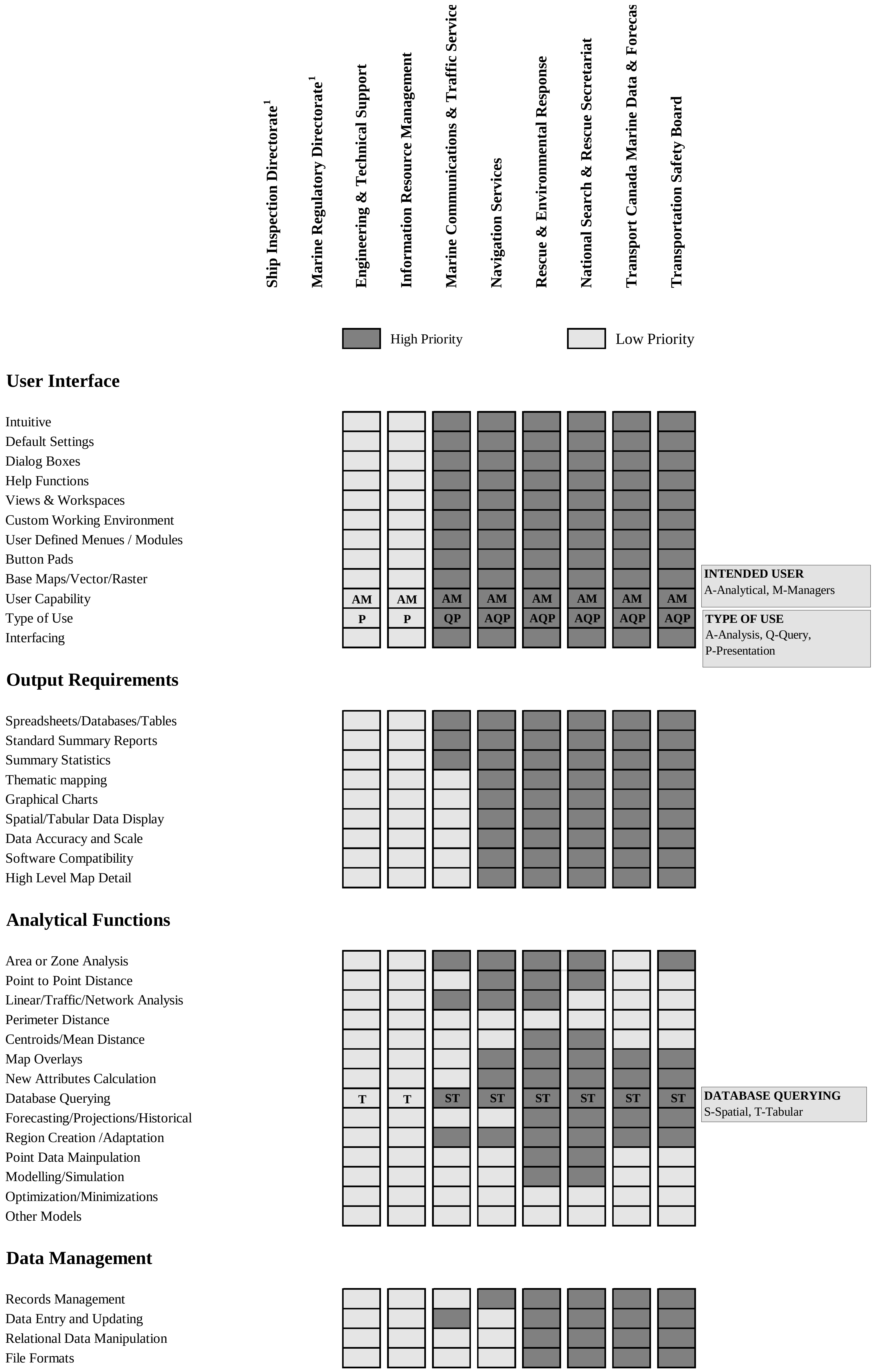

Figure 1. Key Attributes and Potential Users

NOTES:

1 These Transport Canada and CCG divisions were only recently split into separate directorates. User requirements for these directorates will be addressed once appropriate representatives and responsibilities have been formally defined.

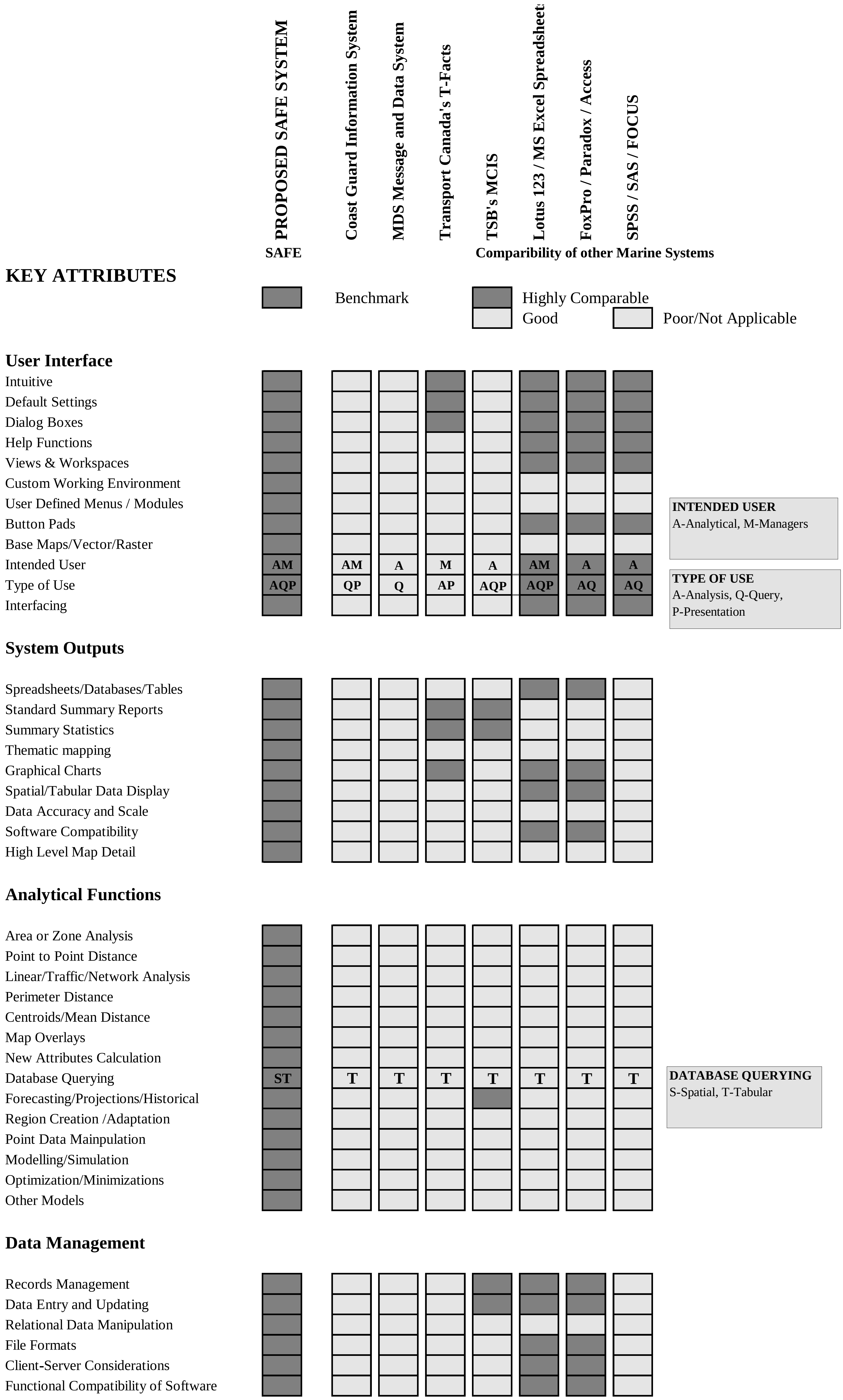

Figure 2. Present Marine Data Analysis Systems

Findings

Contact groups and the role of SAFE

Some of the contact groups with which we held discussions with have since then been renamed or merged with other departments, as part of a larger Federal government restructuring process. We have summarized below some of the major findings of our meetings with the contact groups.

Marine Communications & Traffic Services

The main functions of this division are to maintain and facilitate communication information between marine traffic regulators and vessels at sea. The division has experienced a recent amalgamation of the marine traffic regulation and CCG radio operations formerly called the Telecommunications and Electronics Directorate. A major thrust of present work involves the development of a PC-based information system called INNAV (Information System on Marine Navigation).

The division presently uses an outdated PC-based software for information management and analysis. It is called MDS (Messages and Data System) and it contains a limited vessel information database based on the radio logs between vessels and VTS stations. Most information is maintained in summary Lotus files and contains vessel traffic particulars from the VTS centres. SAFE could assist in better management of the data and visual display.

Engineering & Technical Support Services

This division is responsible for the development and maintenance of all electrical and engineering information systems. They consider themselves as developers of systems rather than users. However, it is likely that certain personnel would use SAFE for map presentation.

Among their main work, they are involved in the development of Differential GPS, server-based FAX tracks electronic maintenance systems to monitor the health of buoys and navigational aids, and VTS/radio station interfaces. Based on interaction with users, the division foresees SAFE as a supportive tool for many projects where geographically-based data and analysis is required.

Rescue & Environmental Response

Their responsibilities are to ensure overall rescue and environmental response resources are capable of handling all marine emergencies. Their work involves the establishment of guidelines for emergency response schedules, allocation of resources and response capabilities. They are likely to be important SAFE users because of their need for detailed geographical data and risk analysis.

The division is described as under-staffed and lacks a database. SAFE could play an important role in adding efficiency to work functions and in the development of a database. They are involved in a prototype project using some GIS functions in the Laurentian Region.

Information Resources Management

This division is responsible for the maintenance of Transport Canada (Marine) database information systems.
A major project underway is the Information Systems Management Plan which will introduce future information systems, data models, and processes to Transport Canada. They do not see themselves as key users of SAFE. However, they certainly endorse a tool such as SAFE and would appreciate access to such a tool whenever needed.

They provided some interesting insight into database technologies which may be useful in later stages of SAFE's development. It was agreed that MapInfo may be ideal as an initial system for mapping applications development, because of its low cost, ease to setup, and ease to use. They suggest that as applications became more complex and system demands change, it will be easier to translate MapInfo's functionality to a higher end GIS if required.

Navigation Services

Their functions involve establishing guidelines for aids to navigation for vessels. They are involved in all kinds of analyses of weather, operations, user needs, threat rating, design, and risk analysis. It was agreed that SAFE would provide invaluable capabilities not available at Transport Canada, and introduce advanced methods of querying data to access and analyze geographically-based information.

Special data and analysis needs where identified. A definite need was expressed to integrate daily work applications with PC-based Windows analysis tools such as SAFE.

Ship Policy & Planning

Their function deals mainly with the regulation and inspection of ships. This involves a broad range of applications including the planning of routing systems, electronic charting standards, monitoring the carriage of dangerous goods, regulatory issues, vessel inspection, and small vessel safety. They believe SAFE will be an important source of historical data for many of their decision-making processes relating to marine regulation and policy.

Presently, the division is not a major user of any analysis software, other than traditional word processing and spreadsheet packages. They are comfortable with Microsoft products and also use E-mail and CGIS. An introduction to SAFE would be welcomed because of its compatibility to present software and ease of use.

Transportation Safety Board of Canada

The role of TSB is to advance safety in the marine, commodity pipelines, rail and air modes of transport. As applied to marine safety, they conduct independent investigations and studies into marine incidents, identifying transportation safety deficiencies, and making recommendations designed to eliminate or reduce these deficiencies.

They manage the MCIS (Marine Causality and Investigation System) mainframe database and are developing its follow-up "MARSIS" using an Oracle database system. TSB's work in marine analysis involves a detailed level of analysis (e.g., point or area of marine occurrence), because of special interest in identifying and evaluating causal factors associated with each unique marine occurrence. Among data requirements, they foresee a need for detailed level information such as ocean depth contours, and to interface with ECDIS (Electronic Charting and Display Information Systems). They definitely would use a system like SAFE if made available to them.

Transport Canada Economic Analysis Directorate

They are responsible for monitoring trends in historical and forecasted traffic and commodity flow data across different types of marine and surface modes. The division, in addition to providing analysis functions, works as part of Transport Canada's Policy and Coordination Office. They showed a keen interest in risk analysis and identified a dated consultant report demonstrating previous work. They are a good source of data on historical marine traffic and commodity flows, including aggregate forecasts.

Most analyses done by this group involve changes in aggregate statistics over time. They also expressed a need for macro regional breakdowns of this information. They recommended that SAFE should be designed for both analytical and general users.

National Search & Rescue Secretariat

This group has a mandate to monitor trends in a broad range of search and rescue situations, including marine, air,, avalanches, etc. However, the group has dedicated a significant effort to monitor search and rescue incidents in marine transportation. They have a particular interest in geographical applications which allow analysis of spatial distributions, calculation of distances, measurements, resource allocation, time-distance relations, and simulations.

They have extensive experience with marine databases and have prepared several important publications evaluating available datasets. The group is a user of MapInfo and would certainly be an eager user of a more customized marine tool such as SAFE .

User Interface

- Well designed and user friendly interface was of high priority
- Design, help options, logic, and customization are all important factors to encourage usage
- System should be sophisticated enough yet simple for analytical and managerial use
- Multifaceted to allow analysis, querying of data, and basic presentation capabilities
- Infrequent users such as Engineering & Technical Services and Information Resources Management envision themselves as infrequent users with occasional needs to display simple thematic maps

System Outputs

- Output information in a variety of formats for exchange, analysis and presentation is important to stakeholders

Analytical Functions

- Among the high priority functions are the capabilities to manipulate tabular and spatial data
- There is a strong desire to add value to their data through calculations, measurements, overlays, and manipulation of data sets
- As well, there is a need to manipulate historical data for the purposes of projections and forecasts
- Some stakeholders such as Navigation Services, Rescue & Environmental Response, and National Search & Rescue have put a relatively high priority on the ability to model or simulate certain events such as oil spills, allocation of emergency resources, and prediction of accidents
- Thematic mapping was an important requirement for all stakeholders, mainly because mapping capabilities in software are either nonexistent or very limited
- Software compatibility in terms of being able to communicate and simultaneously work with other software was also important
- Data accuracy, scale and details were high priority requirements among stakeholders involved in emergency, rescue, spill, accidents analysis

Data Management

- Client-server considerations and software compatibility are high priorities for all of the stakeholders
- Consensus for integrated and accessible information systems
- Needs to manage both tabular and spatial data sets
- Capability to work with different database formats

System Requirements for SAFE

User Interface

- SAFE provides much of the user functionality required and identified by the stakeholders
- A number of the spreadsheet, database, and statistics packages are comparable with respect to the interface
- However, they are restrictive and difficult to customize to the specific marine and geographical requirements
- As well, the packages are mostly targeted for analytical users or advanced analysis, querying and statistical applications
- One key advantage of SAFE is that it can interface with these more complex packages and use of their complex functions, while maintaining a relative sophistication and simplicity as a standalone analysis tool

System Outputs

- SAFE is the only system of presently used systems which outputs data in most standard data formats
- A major advantage of SAFE over other systems is its capability to output any one or a combination of display and report formats, including maps, charts, and tables.
- Other systems are typically comparable in only one or two of the display and report formats such as charts and tables
- As well, SAFE is superior with respect to maintaining data accuracy and scale especially in the presentation of map details
- In contrast, other systems evaluated do not require accuracy or scale, or any level of detail
- SAFE’s prototype MapInfo Windows software is also fully compatible to other software, including Windows spreadsheets, databases, and statistical packages

Analytical Functions

- SAFE demonstrates its superiority in analytical functions particular to marine and geographical analyses
- Its main advantage is that it can manipulate and analyze both spatial and tabular data
- Other systems are strictly based on tabular data
- SAFE because of its geographical base allows users to calculate, measure and associate different data with respect to space-time-distance attributes
- These have been identified by the stakeholders as important functions, when evaluating the distribution of phenomena and underlying causal factors

Data Management

- SAFE has an important advantage over other systems pertaining to data management capabilities
- SAFE is far ahead of other systems with respect to relational data manipulation because it manipulates and combines data based on tabular and/or geographical relations
- This is powerful because it allows users to examine data in other dimensions such as space, time, distance, and direction

This section of the report identified the main user and system requirements for SAFE. These requirements shall be applied and considered in the subsequent stages of the report, and used to establish design criteria and requirements for the development of a prototype (discussed later in the report).

The next section of the report identifies essential database information sources required by SAFE to meet analysis requirements.

III. IDENTIFY ESSENTIAL EXISTING DATABASE INFORMATION

Introduction

The purpose of this section is to provide a summary of relevant database sources and to identify important parameters such as contents of databases, priority of variables, downloading requirements, accessibility, conversion, digitizing, and costs.

A list of some of the main marine parameters required for SAFE implementation was developed based on marine safety and risk requirements obtained from discussions with contact group members (Figure 3).

In addition, a database of marine-related sources was created and records over 40 databases and nearly 300 variables. Included in the database are the following parameters:

- variables
- source
- time period
- data storage medium
- outputs format
- restrictions
- database name
- main contact(s) phone number & address
- costs to retrieve
- data management system
- update frequency

In order to prioritize which marine data was of highest importance, we developed a matrix which matched major categories of marine data to common regulations enforced by marine regulatory bodies, such as Transport Canada, and Fisheries and Oceans, etc. Figure 3 provides definitions of marine categories of data. In Figure 4the use of the data are assessed in terms of relevance and applicability to marine safety regulations and the SAFE system.

Maintain Emergency Response Standards

Regulations designed to maintain effective rescue and environmental response capabilities and allocation of resources to handle all marine and vessel emergencies, related to search and rescue and vessel assistance.

Promote Smaller Craft Safety

Regulations aimed to reduce hazards and incidents of marine accidents associated with small recreational crafts and fishing vessels, through licensing, navigation aids, vessel inspection, and operating standards.

Promote Vessel Seaworthiness

Regulations aimed at preventing accidents which threaten the entire ship such as foundering, sinkings, capsizing, fires, explosions, or ice damage, and are due to various structural defects or deficiencies on the ship, poor containment of cargo, or poor compliance to inspection and operating procedures.

Protect the Environment

Regulations associated with reducing the risk of air and water pollution and general environmental degradation related to vessel movements, traffic, operation and technology.

Minimize the Consequences of Accidents

Regulations aimed at minimizing the consequences of accidents once they occur, including overall property damage, loss of life and injuries.

Promote Safe Navigation Practices

Regulations aimed to preventing marine accidents such as collisions, groundings, strikings, and contacts due to errors in navigation, communications or manning, or defects in navigation or communications equipment.

Prevent Accidents or Illness on Board

Regulations designed to prevent a wide range of accidents involving injury or death to the crew, at preventing illness among crew members and preventing damage to the ship due to problems in the design of the ship, poor handling, bad working practices, or inadequate health or fitness of crew.

Optimize Vessel Traffic Systems

Optimize navigation systems and equipment aimed to reduce the risk of marine occurrences or incidents resulting from vessel traffic densities, speeds, traffic schemes, and movements in the open sea, seaways, ports, harbours, and so on.

Reduce the Risk of Vessel Breakdown

Regulations designed to reduce the risk of vessel breakdown as related to vessel engine reliability, engineering, and operating procedures, and indirectly minimize the hazard vessel breakdowns pose to marine safety.

Figure 3. Definitions of Categories of Marine Safety Data and Regulations

Categories of Marine Safety Regulations

Marine Parameters	Parameter Descriptions	Maintain Emergency Response Standards	Promote Smaller Craft Safety	Promote Vessel Seaworthiness	Protect the Environment	Minimize the Consequences of Accidents	Promote Safe Navigation Practices	Prevent Accidents or Illness on Board	Optimize Vessel Traffic Systems	Reduce the Risk of Vessel Breakdown
Accidents and Incidents	Human Injuries & Fatalities	X	X	X		X		X	X	
	Ship Occurrences & Incidents	X	X	X	X	X	X	X	X	X
	Search and Rescue Incidents	X	X	X	X					
	Fishing Injuries & Fatalities	X	X	X		X				
	Pollution Incidents	X		X	X	X				
	Dangerous Goods	X		X	X	X				
Environmental Conditions	Ice Conditions	X	X	X	X	X	X	X		X
	Weather Conditions	X	X	X	X	X	X	X		X
	Sea Conditions	X	X	X	X	X	X	X		X
	Environmental Sensitivity	X		X	X	X				
Vessel Characteristics	Vessel Design, Structure & Engineering			X	X	X	X	X		X
	Cargo Containment & Cargo Handling			X	X	X	X	X		X
	Mariner Qualifications, Crew & Operating Procedures			X	X	X	X	X		X
	Ship Types & Work Capabilities	X		X	X	X	X			X
	Prevention, Life Saving, Medical Aids	X	X			X		X		
Navigation Factors	Navigational Aids/Communications	X	X	X	X	X	X	X	X	
	Local Sailing Directions	X	X	X	X	X	X			
	Notice to Mariners	X	X	X	X	X	X			
	Compliance	X	X	X	X	X	X			
Vessel Traffic	Number of Vessels	X	X	X	X	X	X		X	
	Ship Traffic/Movements	X	X	X	X	X	X		X	
	Pleasure and Small Crafts Traffic	X	X	X		X	X		X	
	Fishing Vessels Traffic	X	X	X		X	X		X	
	Commodity Types & Flow s	X		X					X	
Geographic	Marine Regions (e.g., CCG, VTS, Ports, Risk)	X	X	X	X	X	X		X	
	Coastal and Land Typologies	X	X	X	X	X	X			
	Emergency Response Resources	X	X	X	X	X				
Costs	Operational	X	X	X	X	X	X			
	Vessel Damage	X	X	X	X	X	X			
	Loss of Life and Injury	X	X	X	X	X	X			
	Release of Pollutants and Spills	X	X	X	X	X	X			

Note

The use of marine parameters as presented in the table is an approximation based on the perceived use of each marine parameter in Coast Guard safety regulations.

The table is intended to show what marine parameters as a minimum would be required for SAFE and where each parameter would be used in Coast Guard safety regulations.

Figure 4. Categories of Marine Data by Marine Safety Regulations

Sources of Database Information

We have summarized below most of the important sources of marine database information by major marine data categories, source(s), geographic and time coverage. Also included are comments, where appropriate, about data limitations, coverage problems, and other issues.

Accidents and Incidents

<u>*Boating Injuries & Fatalities*</u>:

Data Sources: *Provincial and Local Police Authorities, RCMP, Provincial Coroner Reports (Fatalities), Local & City Hospital Registries (Injuries)*

Geographic Coverage: Geographic coverage ranges from approximate locations of boating fatalities and injuries by water body or region, to regional and provincial counts.

Time Covered: Available for at least 5 years and more. Also varies by source.

Comments: *Data is highly fragmented among many local sources and methods of data management among provincial jurisdictions varies from good to poor. A lot of the data are stored in paper files.*

<u>*Ship Occurrences & Incidents*</u>:

Data Sources: *Marine Casualty Investigation System (MCIS) (Transport Safety Board) Search & Rescue Information System (SARS) (National Search and Rescue Secretariat)*

Geographic Coverage: All Canadian Waterways

Time Covered: MCIS (annual from 1986), SARS (annual 1988 to 1991)

Comments: *Both data sources have significant missing values for some cause factors*

Accidents and Incidents (Continued)

Search and Rescue Incidents:

Data Sources: Search & Rescue Information System (SARS) (National Search and Rescue Secretariat)

Geographic Coverage: All Canadian Waterways

Time Covered: SARS (annual 1988 to 1991)

Comments: Contains good SAR data such as response agency, severity, survival results, timeline, weather conditions, persons involved, identification, and injury status

Fishing Injuries & Fatalities:

Data Sources: Canadian Coast Guard Ship Safety (Regions)

Geographic Coverage: Coast Guard Regions

Time Covered: Varies by Region

Comments: Contains each incident's latitude and longitude. Much of the cause factors are missing or must be determined from condensed comments.

Accidents and Incidents (Continued)

<u>*Pollution Incidents:*</u>

Data Sources: *1. Pollution Incident Reporting System (Canadian Coast Guard)*
2. Dangerous Goods Accident Information System (Transport Dangerous Goods Directorate)
3. Potential Pollutants Monitoring System (Statistics Canada, Transport Canada)
4. National Analysis of Trends in Emergencies Systems (NATES) (Environment Canada)

Geographic Coverage: Ranges from individual pollution and spill locations to broad Canadian Coastal regions

Time Covered: 1. 1979 - present, 2. 1985 - present, 3. 1987-1989, 4. 1968 - present

Comments: *Work is needed to combine databases to ensure correspondence and ensure data integrity.*

<u>*Dangerous Goods*</u>*:*

Data Sources: *Dangerous Goods Accident Information System (Transport Dangerous Goods Directorate)*
National Analysis of Trends in Emergencies Systems (NATES) (Environment Canada)
Emergency Incident Reports (Canadian Coast Guard)

Geographic Coverage: Actual locations of accidents

Time Covered: Federal government databases are from 1985 to present, while Environment Canada's database is from 1968 to present.

Comments: *Uncertain whether individual vessel information is provided to determine compliance to regulations.*

Environmental Conditions

Ice Conditions:

Data Sources: *1. Arctic/Hudson Bay/Eastern Seaboard/Great Lakes (Environment Canada)*
2. Ice Thickness Point Data (Environment Canada)
3. Mass Balance of Four Arctic Ice Caps and Glaciers (Energy, Mines & Resources)
4. National Archive (CLIMATE) (Canadian Climate Centre)

Geographic Coverage: Ranges from point data, grid cells, to individual monitoring stations for most northerly water regions and some southern Canadian seaways and lakes.

Time Covered: 1.. Up to 1983, 2. 1947 - present, 3. 1959 - present, 4. 1840 - present

Comments: *The quality, storage and availability of data varies. Some data are based on on-going field work while other data are obtained from periodic evaluations from satellite, ship, or shore observations.*

Weather Conditions:

Data Sources: 1. National Archive (Marine Climate) (Environment Canada)
2. Atmospheric Environment Services (Environment Canada)

Geographic Coverage: Most national waters based on individual monitoring stations

Time Covered: 1840 - present including by-the-hour, daily and monthly readings

Comments: *Some of the data are presented on maps. This would require that some maps of interest be scanned in order to be used in mapping software.*

Environmental Conditions (Continued)

<u>*Sea Conditions*</u>:

Data Sources: 1. *Canadian Hydrographic Services (Department of Fisheries and Oceans)*
2. Arctic Marine Biological Oceanographic Database (Department of Fisheries and Oceans)
3. Atlantic Satellite Imagery Database (Bedford Institute of Oceanography) (Department of Fisheries and Oceans)
4. Ocean Current Database (Bedford Institute of Oceanography) (Department of Fisheries and Oceans)

Geographic Coverage: Latitude and longitude including user-defined regions of coverage. Coverage includes 35-90 lat - 40-180 long as well as Arctic region.

Time Covered: For the most part, data are available from mid-1940's to present. Source 2 data are up to 1990.

Comments: *Data are available on tapes and include recordings of monthly conditions.*

<u>*Environmental Sensitivity*</u>:

Data Sources: *1. Canadian Great Lakes Coastal Zone Database (Water Planning and Management Branch) (Environment Canada)*
2. Coastal Waterfowl Survey (Wildlife Conservation and Environmental Quality) (Environment Canada)
3. Fundy, Gulf of Maine, Georges Bank Resource and Environmental Database (Marine Assessment Division) (Environment Canada)
4. Inventory of Sensitive Areas in the St. Lawrence River (Environmental Protection) (Environment Canada)
5. Oceanography Data Inventory System (Institute of Ocean Science) (Department of Fisheries and Oceans)

Geographic Coverage: Varies from sampling points, grid areas to major coastal Regions.

Environmental Conditions (Continued)

Time Covered: 1. 1970's - present, 2. 1966 - present, 3. 1988 - present (maps only) 4. 1987 - present, 5. 1981 - present

Comments: *Some of the sources have digitized their data, while others have not or are presently in the process of automation.*

Vessel Characteristics

Vessel Design, Structure & Engineering:

Data Sources: *Ship Registry Information System (Canadian Coast Guard) Ship Inspection Reporting System (SIRS) (Canadian Coast Guard) Lloyd's Registry of Ships*

Geographic Coverage: All Canadian Ships (Coast Guard), International (Lloyd's)

Time Covered: Mid-1980's to present with on-going updates, including archived information (for Lloyd's).

Comments: *Only the Coast Guard's Ship Registry Database has an on-line link to MCIS.*

Cargo Containment & Cargo Handling:

Data Sources: *Ship Registry Information System (Canadian Coast Guard)*
Ship Inspection Reporting System (SIRS) (Canadian Coast Guard)
Marine Casualty Investigation System (MCIS) (Transport Safety Board)
Search & Rescue Information System (SARS) (National Search and Rescue Secretariat)

Geographic Coverage: All Canadian Ships

Time Covered: Mid-1980's to present with on-going updates. SARS (1988-1991)

Comments: *Relevant information could be obtained from Coast Guard databases as part of inspections. MCIS source lists cargo information as causal factors.*

Vessel Characteristics (Continued)

Mariner Qualifications, Crew & Operating Procedures:

Data Sources: *Ship Registry Information System (Canadian Coast Guard)*
Ship Inspection Reporting System (SIRS) (Canadian Coast Guard)
Marine Casualty Investigation System (MCIS) (Transport Safety Board)

Geographic Coverage: All Canadian Ships

Time Covered: Mid-1980's to present with on-going updates

Comments: *Relevant information could be obtained from Coast Guard databases as part of inspections. MCIS source lists crew and operating data as cause factors of marine occurrences and incidents.*

Ship Types & Work Capabilities:

Data Sources: *Ship Registry Information System (Canadian Coast Guard)*
Ship Inspection Reporting System (SIRS) (Canadian Coast Guard)
Canadian Ship Database (*National Transportation Agency of Canada)*

Geographic Coverage: All Canadian Ships

Time Covered: Mid-1980's to present with on-going updates

Comments: *National Transportation Agency database in not linked on-line to Coast Guard's database, and only contains data on ship's classification of work.*

Vessel Characteristics (Continued)

<u>Prevention, Life Saving, Medical Aids</u>:

Data Sources: *Ship Inspection Reporting System (SIRS) (Canadian Coast Guard)*
Marine Casualty Investigation System (MCIS) (Transport Safety Board)

Geographic Coverage: All Canadian Ships

Time Covered: Mid-1980's to present with on-going updates

Comments: *SIRS and MCIS have no on-line link. Some work will be required to merge relevant information from each database.*

Navigation Factors

<u>Navigational Aids/Communications</u>:

Data Sources: *Head and Regional Vessel Traffic Services (Canadian Coast Guard)*
Marine Data and Communication System (MDS) (Canadian Coast Guard)

Geographic Coverage: All Canadian and International Ships and Canadian Waters.

Time Covered: Varies by type of information required.

Comments: *Required information include the status and effectiveness of navigational aids, distribution of physical aids, and data relevant to marine occurrences captured by communication systems.*

<u>Local Sailing Directions</u>:

Data Sources: *Canadian Sailing Directions (Department of Fisheries and Oceans - Canadian Hydrographic Services)*

Geographic Coverage: All major Canadian Waters and Seaways

Navigation Factors (Continued)

Time Covered: Up-to-date charts including archived charts dating 5-10 years

Comments: *May require digitizing or scanning of older charts.*

<u>Notice to Mariners</u>:

Data Sources: *Notices to Mariners: Annual Edition (Navigation Services Canadian Coast Guard)*

Geographic Coverage: All major Canadian Waters and Seaways

Time Covered: Issued annually including archived information.

Comments: *May require digitizing or scanning of older charts.*

<u>Compliance</u>:

Data Sources: *Ship Registry Information System (Canadian Coast Guard)*
Ship Inspection Reporting System (Canadian Coast Guard)
Lloyd's Registry of Ships

Geographic Coverage: All Canadian and International Registered Ships

Time Covered: Mid-1980's to present

Comments: *It is uncertain whether International ships fall under the same classes of regulations as Canadian ships.*

Vessel Traffic

Number of Vessels:

Data Sources: *Ship Registry Information System (Canadian Coast Guard)*
Ship Inspection Reporting System (Canadian Coast Guard)
Vessel Traffic Services (VTS) under ECAREG, WESTREG, and NORDREG (for Foreign Vessels)
Statistics Canada for Foreign Vessels based on Canadian Customs data

Geographic Coverage: All Canadian Waterways

Time Covered: Ranges from on-going updates in the case of registry and inspection reports to annual data produced by VTS and Statistics Canada.

Comments: *Automation process and methods of data storage vary among sources.*

Ship Traffic/Movements:

Data Sources: *Shipping in Canada Database (Statistics Canada)*
Marine Traffic Distance Module (Transport Canada)
Ship Movements Forecasting System (Transport Canada)
Some Vessel Traffic Services (VTS) Centres (Canadian Coast Guard)
Ports Canada Corporation
St. Lawrence Seaway Authority

Geographic Coverage: Ranges for selected ports and seaways to several hundred ports (as reported by Statistics Canada and Transport Canada)

Time Covered: Statistics Canada and Transport Canada cover from at least the 1970's to present. For other sources, data storage is shorter term requiring archive searches or data entry from paper files.

Comments: *There significant differences in the methodologies used by the different sources in recording or estimating total vessel activity.*

Vessel Traffic (Continued)

Pleasure and Small Crafts Traffic:

Data Sources: *Provincial Police*
Registration Records (Provincial Ministries of Transportation)
Regional, Provincial and National Boating Associations

Geographic Coverage: Mostly regional and national summary counts.

Time Covered: Varies

Comments: *Information is highly scattered among many sources.*

Fishing Vessels Traffic:

Data Sources: *Fisheries Licensing Database (Department of Fisheries and Oceans)*
Central and Arctic Region Fishery Statistics (Department of Fisheries and Oceans)
Fisheries Catch and Effort Statistics (Department of Fisheries and Oceans)
Fisheries Database on Persons, Boats and Permits (Department of Fisheries and Oceans)
Some Vessel Traffic Services (VTS) Centres

Geographic Coverage: Ranges from regional summary databases to details of fishing locations

Time Covered: Department of Fisheries and Ocean's databases cover from 1960's to present. Coast Guard data goes back 5 - 10 years.

Comments: *Fishing vessel information is based on differing levels of geography and aggregation.*

Vessel Traffic (Continued)

<u>*Commodity Types & Flows*</u>*:*

Data Sources: *Shipping in Canada (Statistics Canada)*
Ship Movements Forecasting System (Transport Canada)

Geographic Coverage: Several hundred Canadian Ports (including movement and commodity flows between ports)

Time Covered: Statistics Canada covers from the 1970's to present. Transport Canada also develops forecasts from Statistics Canada.

Comments: *There is good correspondence between the two sources.*

Geographic

<u>*Marine Regions (e.g., CCG, VTS, Ports, High Risk):*</u>

Data Sources: *Digitized maps from the Canadian Coast Guard*
Publications, maps, research reports

Geographic Coverage: Varies

Time Covered: Varies

Comments: *Most maps of relevant regions will likely have to be either digitized or scanned.*

<u>*Coastal and Land Typologies*</u>*:*

Data Sources: *Digital Chart of World*
Canadian Hydrographic Services (CHS)

Geographic Coverage: The Digital Chart of World includes coastal and land typology for the entire world. CHS covers most Canadian coastal and land typology.

Geographic (Continued)

Time Covered: Most up-to-date

Comments: *Both sources of information may not perfectly match once displayed on maps, due to varying digitizing discrepancies.*

Emergency Response Resources:

Data Sources: *Emergency Response (Canadian Coast Guard)*
Search & Rescue (National Search and Rescue Secretariat)

Geographic Coverage: All Canadian potential coastal and land emergency response resources available by location and coverage areas.

Time Covered: Most up-to-date

Comments: *This information would have to digitized in order to display on maps.*

Costs

Operational:

Data Sources: *Canadian Coast Guard Operations*
Canadian Coast Guard Research Studies

Geographic Coverage: Operation costs by regions, purpose and vessels (e.g., tug escorts).

Time Covered: Historical trend is required.

Comments: n/a.

Vessel Damage:

Data Sources: *Vessel Manufactures*
Ship Yards
Case studies of a sample of damaged vessels by type of damage

Geographic Coverage: n/a.

Costs (Continued)

Time Covered: Historical trend is required (at least in terms of costs to rebuild or repair damages).

Comments: n/a.

<u>*Loss of Life and Injury*</u>*:*

Data Sources: *Worker's Compensation Board*
Average Earnings and Salaries (Statistics Canada)
Accidents in Canada (Statistics Canada)
Research literature on the human costs of vessel accidents

Geographic Coverage: n/a.

Time Covered: Historical trend is required.

Comments: n/a.

<u>*Release of Pollutants, Spills, Clean-up*</u>*:*

Data Sources: *Research literature on the costs of pollution and spills*
Case studies of actual clean-up costs (by government departments, labour, equipment, and time)
Canadian and International Spill Data (e.g., SSOPF, IOPCF, ITOPF, MMS)

Geographic Coverage: Canada and other countries.

Time Covered: Most up-to-date

Comments: n/a.

Data Access and Conversion

Access to most of the data identified above is fairly open and involves minimal costs. Because most of the data are public domain, there are almost no direct fees for accessing the data, although in some cases data processing costs would be passed on because of the volume of data, and resources required to download and convert the data. It should be expected that formal written statements will need to be prepared for each data request, in order to ensure from the supplier's side that the data be used only for the stated project and referenced accordingly.

As shown in the list of the database sources, many of the marine databases and other sources of data are fragmented according to the level of geography, time period, sampling, consistency, and coverage. A significant portion of the data from the available sources would need to be standardized to some level of geography and coverage, and be converted to a proper digital form to be used in SAFE.

IV. IDENTIFY SOFTWARE ALTERNATIVES

Introduction

The purpose of this section is to recommend a PC-based GIS software product that offers the best combination of technical, operational, and economic feasibility, and which will allow Marine Occurrences Programs and the Transport Canada to meet all of its objectives and responsibilities associated with SAFE.

Methodology

The method of evaluating prospective GIS/Desktop Mapping Systems was based on comparative performance, compatibility, and costs of prospective GIS systems, focusing on the main pros and cons of practical options. Each GIS system was evaluated along standards and user requirements established from the User and System Requirements section (developed as part of Task 2 and Milestone 1 Report).

A comprehensive list of low to high-end GIS systems was developed and reviewed as part of the evaluation process. Considerable effort was spent to identify and retrieve information on most leading GIS systems currently available on the market. This was done through a review of all popular GIS magazines and articles, GIS textbooks, through conversation with leading GIS users in the federal government and universities, and through dialogue with well established vendors about GIS systems. The following sources were reviewed to establish relevant criteria and standards for GIS systems and desktop mapping software.

1. Literature from GIS and Desktop Mapping Vendors
2. User Manuals and references from GIS and Desktop Mapping Software Packages
3. General Articles and Publications on GIS
4. Current Users of GIS and Desktop Mapping Software
5. Magazines (GIS World, Business Geographics, GIS World Report/Canada)
6. Newsletters (Federal GEOMATICS Bulletin, Federal GEOMATICS Special Reports)
7. Internet and Compuserve Forums on GIS / Mapping

As part of the selection and evaluation of GIS systems, detailed system specifications, manuals and demo diskettes were requested from vendors, upon which very detailed comparisons of each system were done. In cases where material received from vendors was not clear or demos were not available, additional conversations were held with vendor's sales or technical personnel to obtain required information. Additional discussions were held with selected GIS users in the Federal government, universities, and private consultants about their knowledge and experience with specific GIS systems.

The main features as well as the advantages and disadvantages of each system were examined. As well, each GIS was evaluated for performance areas of standard GIS functionality, such as capability to handle vector and raster data, compatibility with external sources of data such as the Digital Chart of the World, and various forms of data necessary for SAFE (e.g., ice grid points, ocean contours, geocoding of raster images, etc.).

Defining a GIS for SAFE

Types of Users

In order to determine whether a particular GIS is practical and appropriate, it was essential to define how an organization uses or is likely to use a GIS. We adopted Burrough's (1986, pp. 167-168) initial classification of organizations as GIS users, and added several more relevant considerations to understand the type of user Marine Occurrences and Transport Canada would likely be. These important organization considerations are as follows:

- Definition of Organization's Task(s) and Mandates
- Organization's Scope of Applications
- Technical Skill Requirement
- Research Skill Requirement
- Sophistication of GIS Software and Hardware Required

Such considerations proved to be important in positioning Marine Occurrences and Transport Canada (Marine) into one of three categories of GIS users (see Figure 5).

	TYPE OF GIS USERS		
ORGANIZATION CONSIDERATIONS	(A) Applied	(B) Technical	(C) Research
Definition of Task(s) and mandate(s)	Well Defined	Partly Defined	Not Defined
Scope of applications	Defined	Broad	Broad
Technical skill requirement	Low	High	Moderate
Research skill requirement	Low	Moderate	High
Sophistication of GIS software / hardware	Customized	High Level	High Level

Figure 5. Defining a GIS for SAFE

Type A User : Applied

These users have well defined uses of a GIS. The GIS is used primarily for the automation of existing procedures and tasks (some of which may be manual or semi-automated). The procedure of data gathering, analysis, presentation, and decision-making is central and already established, although it may not be necessarily efficient or even automated.

The scope of the GIS applications is mainly to make these processes systematic, organized and efficient. The type of GIS requires low technical and research skills, mainly because the organization has a blend of administrative, managerial and analytical personnel. As well, the requirements of sophisticated GIS software and hardware is low, with an emphasis on purchasing and customizing GIS software to their particular needs.

Type B User : Technical

These users have variable demands on GIS use. In contrast to Applied users, these users are data-rich organizations and are in the business of data gathering, management, and distribution (e.g., environmental and hydrographic mapping agencies).

The scope of applications is very broad and varies, and constantly change with government mandates and initiatives, data users, and technological trends. There is a need for highly technical skills (e.g., programmers, GIS technicians, analysts) to operate advanced GIS software and hardware components, such as networks, digitizers, data conversion facilities, plotters, database systems, etc. Usually highly sophisticated GIS software and hardware are required, with operation on very large mainframe computer terminals or UNIX workstations.

Type C User : Research

Type C users are typically large university or research organizations. Demands on GIS are usually unknown and use is mainly analytical and frequently changing with new research funding, projects and research needs.

The scope of applications for these users is also broad. Unlike Type B Technical Users, Type C users have a strong focus on specialized database development, methodologies, and analytical aspects of GIS. They have a special need for highly skilled personnel, trained in social, physical, theoretical and quantitative research. There is less emphasis on technical skills. The level of GIS sophistication is also high, mainly because of the advanced nature of applications developed.

Guidelines for SAFE

Type of User

The use of GIS by Marine Occurrences and Transport Canada (Marine) is well defined corresponding to the Type (A) Applied user. Users have fairly exact and well-defined tasks and mandates. GIS applications for SAFE will not require any major changes in the procedures of data gathering, analysis, presentations, or decision-making already taking place. The focus will be on automating the process of marine risk analysis and Transport Canada evaluation of current and proposed marine regulations and policies, through GIS capabilities.

Scope of SAFE

The scope and applications of SAFE can be summarized as follows:

I. Develop a GIS planning tool to evaluate long-term Transport Canada policies and regulations
II. Customize and automate a Risk Analysis Module for analysis, evaluation, and quantification of marine risk, consequences, and comparative solutions
III. Automate data and spatial querying methods and capabilities to determine and analyze risk and safety indicators
IV. Customize menu items and dialogs to allow a standard and systematic process of risk analysis and management (e.g., 9 Step Process to Risk Analysis)
V. Provide reports to display the results of risk analysis and management

It is presently out of SAFE's scope, at least in the short-term, to develop or purchase data gathering, management and analytical GIS facilities to the level of Type (B) and (C) users. Most of this functionality and capabilities are supported by data suppliers and users, both those internal and external to Transport Canada (e.g., Information Management Systems, Geomatics Canada, Marine Interest Groups, Private Marine Consultants, etc.).

As a result, SAFE's specific requirements should utilize all presently available sources and systems of information and management internal and external to Transport Canada. More sophisticated uses of GIS, such as data collection and digitizing facilities, and advanced spatial analysis capabilities are not required for SAFE at this time. This observation is important because it assists in identifying and excluding those GIS systems which are too costly and support functionality well beyond the current or anticipated needs of SAFE, Marine Occurrences, and Transport Canada.

Skills Required

SAFE will have a low technical and research skill requirement corresponding to Type (A) users. For example, Marine Occurrence Programs and Transport Canada personnel have a fairly even blend of administrative, operational, managerial, and analytical personnel.

Although a familiarity with risk management, marine safety, and database use is required, only an understanding of a graphic interface is necessary to learn a Type A application. While various levels of technical and research expertise are available in certain operations of Transport Canada, it can be expected that as demands for SAFE increase and the sophistication of applications advances, more technical and research skills would likely be needed.

Based on interviews with CCG and Transport Canada offices and observations from the Milestone 1 report, it was evident that a broad range of personnel are involved in the overall marine analysis and decision-making process. This includes operational and policy managers for policy development and evaluation, operations and policy analysts for risk and safety analysis, and managers to evaluate and recommend actions based on the results of risk analysis. SAFE must be able to accommodate this range of potential users.

Sophistication of GIS

Implementing a GIS for Marine Occurrences Programs and Transport Canada, will require that the GIS be user-friendly and customized to their needs, so that a broader range of staff will be encouraged to use it. It should be simple to use and satisfy both beginning and advanced GIS users. As well, it should be compatible with software and systems presently being used and proposed in the CCG Long-term Information Management Plan (e.g., Windows environment and menu structure). SAFE will be very intuitive so that training and assistance would be minimal.

The sophistication of GIS analysis and capabilities for SAFE as determined from the user and system requirements of the Milestone 1 Report would include standard GIS functionality for the short-term. For example, SAFE would provide the minimum functionality, such as a customized interface, development of safety indicators, trends analysis, thematic mapping of point and polygon data, raster images, spatial querying methods, and calculation of various marine indicators.

Options for Implementing a GIS

Implementation Options

A major consideration in evaluating GIS systems once the user has been defined is to determine how to acquire and implement GIS capabilities and evaluate whether it is suitable for their purposes.

This can be done in several ways. As shown in Figure 6, these range from developing a complete set of GIS software and hardware components in-house, to purchasing GIS software, to contracting for all GIS services and purchasing no GIS software or hardware. Each implementation option has its advantages and disadvantages depending on the organization's uses, scope of application, costs, and restrictions.

	Implementation Alternatives				
Considerations	***(I)*** **User Creates Own System**	***(II)*** **Buy Partial or "No-name" Software**	***(III)*** **Buy Popular GIS Software**	***(IV)*** **Buy Popular GIS Software and Hardware Equipment**	***(V)*** **Purchase GIS Services**
Costs					
Costs for System Implementation	Very High	Low	Low - Medium	Low	n.a.
Cost of GIS Components and Staffing	Very High	Low	Low - Medium	High	Moderate
Labour Costs Paid by User Over Time	Very High	Low	Low - Medium	Medium	Moderate
Support					
Technical and Software Support	Moderate	Very Poor	Very Good	Very Good	Varies
Technical Skill Required by User	Very High	Very Low	Very Low	High	Low
Resources Required	Very High	Very Low	Very Low	High	Moderate
Vendor					
Dependence on Supplier	High	High	Moderate	Moderate	Nearly Complete
Risk and Uncertainty	Very High	Very High	Very Low	Moderate	Very High
System					
Time Period until system is Fully Functional	Long	Short	Short	Moderate	n.a.
Customization	Complete	Very Poor	Very Good	Very Good	n.a.

Figure 6. GIS Implementation Options for SAFE

Adapting Dangermond and Smith's (1980) framework on alternative options for GIS implementation, it is possible to include several important evaluation factors for considering and recommending which option for SAFE would be most cost-effective, reliable, compatible, and practical for present use by Marine Occurrences and Transport Canada. Evaluation factors considered are listed below and Figure 7:

Costs

- *Costs for System Implementation*
- *Cost of GIS Components and Staffing*
- *Labour Costs Paid by User Over Time*

Support

- *Technical and Software Support*
- *Technical Skill Required by User*
- *Use of Existing Resources*

Vendor

- *Dependence on Supplier*
- *Risk and Uncertainty*

System

- *Time Period until system is fully functional*
- *Customization*

Recommendation for SAFE

Comparative Costs

Among the implementation options for GIS, we recommend buying one of the many available popular or leading GIS software packages available in the marketplace (Option III). The relative costs of system implementation, costs of components and staff, and labour costs over time for this option are relatively low (even with special "add-ons" and features), compared to other options.

Buying additional hardware along with a complete GIS system (Option (IV) would significantly add to system implementation and labour costs because of high cost of hardware and need to hire technical personnel or retrain present staff.

Buying "no-name" GIS software (Option II) with limited functionality to cut costs would provide an incomplete system, with no capability for applications development, and restrict future development needs and quality of GIS functionality.

Building a GIS system in-house (Option I) is definitely the most expensive option and not recommended. It requires a very large and long-term investment in GIS specialists, programmers, technicians, and all sorts of software and hardware. As one can expect, the costs of system implementation, costs of components and staffing, and labour costs over time would be extremely high, surpassing any one of the other implementation options.

Purchasing of GIS services from GIS consultants (Option V) would also prove to be a very costly investment. Consulting fees are usually high and deliverables may not always be completed on time. Also, there would probably have to be at least one person on staff to liaise on behalf of an organization, on matters of project management and technical aspects of GIS. Someone with GIS experience would be required or some staff would have to be trained (see Figure 7).

Overall Support

Ideal overall support comes with purchasing a popular GIS software package (Option III). With the purchase of reputable software, vendors usually provide one to several years of on-going user and technical support, with additional support based on annual charges. Most GIS software on the market has been developed with the same simplicity and user friendliness, as most other wording processing, spreadsheet, and graphics packages (e.g., Windows products). As a result, the level of technical skills previously required by GIS systems has declined so that beginners and advanced users can benefit from using GIS software. As well, very detailed on-line tutorial and documentation is provided by most popular GIS software. With option III, very few changes are required in an organization's staff or cost budgets.

Buying additional hardware in addition to popular GIS software (Option IV) would certainly enhance an organization's overall GIS. As well, it is expected that the technical and software support of vendors and manufacturers would be just as good. However, an organization should be certain of their need for additional hardware components, such as digitizers, scanners, advanced plotters and printers, file storage devices, etc. because they would create a need for more technical staff or knowledge, and demand more resources in terms of time, investment and personnel to maintain and troubleshoot hardware.

Buying "no-name" GIS software (Option II) would provide an organization with a severely limited GIS capability. Typically, vendors of low-cost GIS software or modules are so small that they are unable to offer any services or support to users. Also, there is little investment of time by the vendor to make the software user friendly or totally error-free. This puts much more pressure on the organization to have technical personnel on staff and more resources to learn, operate, and troubleshoot the software.   There is also the danger that vendors may suddenly disappear from the market, so that the organization is left with an outdated GIS software and forced to rethink its GIS plan and strategy.

Building your GIS system in-house (Option I) would probably require the most technical skill and resources. A moderate level of technical and software could be expected from GIS software vendors and hardware manufactures. However, because building a GIS system in-house requires the collective assembly of different programming languages, software, database management, various hardware, and so on, it is likely that support would likely be fragmented and vary depending on licensing agreements with the various companies and warranties. There would be a tremendous pressure on the organization to staff or contract technical support for system operation, troubleshooting, programming; and of course, GIS analysts and project managers.

Support with purchasing GIS services from consultants (Option V) would vary depending on contractual arrangements and the quality of work being done by the consultant. Typically, an organization will only receive data and analysis deliverables, and occasionally limited software modules distributed to them by the consultant. The consultant would provide support as contracted. This places pressure on the organization to ensure proper GIS resources to be able to manipulate and analyze data, operate the software, and envision changes to GIS needs.

Vendor

The relationship between user and vendor is probably best for buying leading or popular GIS software (Option III). As with any option, there is a moderate level of dependence on the supplier in terms of updated versions of the software, purchase of upgrades, add-ons, user groups, licenses and so on. The most distinguishing factor for this option is the low level of risk associated with this option. Leading or popular GIS vendors are all well established GIS software developers with at least 10 years in operation, and have (for the majority of them) grown and will likely to continue to grow as a result of the growing demand for GIS. They are the ones leading GIS and software technology into the future. In addition, the major and popular vendors are tied into partnerships with major data suppliers, software developers, and other database and operating systems corporations. There is a general consensus among GIS users that desktop GIS software is here to stay, because of its extensive GIS capabilities and relative low cost.

Buying additional hardware in addition to popular GIS software (Option IV) as one alternative means that the hardware must be compatible with software being used. This option is slightly more risky because of the uncertainty of how well hardware such as coloured printers, plotters, database management systems, local area networks, etc. will work with the GIS software being used. It may be better to consider and purchase GIS software which is compatible with existing hardware, recognizing the software's capabilities and limitations for future planned hardware items.

Option II to buy selected GIS modules or "no-name" GIS software is associated with higher levels of risk and uncertainty. As with other options, there is a dependence on the vendor for updates and licenses, etc. However, there is a definite risk that these types of vendors may be eventually forced out of the market by larger vendors, or they may have limited resources and investment to technologically maintain or advance their product to GIS industry standards.

Building your GIS system in-house (Option I) is a very risky and costly alternative. This option requires large amounts of investment in time, money and labour to fully implement the system. This option requires a long-term commitment and coordination among all management levels from initiation to completion. There is a real danger that if funding runs out or support declines a GIS project could be set back significantly, in terms of extended completion times and higher costs, and even possible termination with all of the incurred to-date costs.

Purchasing GIS consultant services involves the highest level of dependence on a supplier (Option V). The quality of GIS analysis, output, products and distributed software is in the hands of the consultant. With this option, an organization's GIS capability is restricted to the knowledge, technical expertise and GIS facilities maintained by the consultant. In addition, there is no guarantee that a consultant must provide additional services beyond contract requirements or end its working relationship if other more rewarding contracts emerge.

System

Buying a popular or leading GIS software package (Option III) has a clear advantage over other options in terms of system implementation and customization. GIS software packages require only installation and some learning to be fully functional. This should not take any longer than a week for experienced GIS users, or several weeks for GIS beginners. In addition, the majority of GIS software have been designed for open architecture and customized development, through either their own script programming language or utilities allowing GIS software to communicate and exchange data with third-party software (e.g., Windows Dynamic Data Exchange (DDE)).

Buying additional hardware in addition to popular GIS software (Option IV) has a similar advantage as Option III. However, the time and resources required to install, learn and trouble-shoot hardware, so that it is working properly with GIS software takes a longer period of time.

Buying selected GIS modules or "no-name" GIS software (Option II) is a poor alternative because the user is restricted to often very limited functionality of the software. The design of the software does not facilitate any open architecture or customized development, and the software is rarely compatible with the abundance of software on the market.

Option I building your GIS system in-house requires a long period for system implementation. The process of building a GIS from scratch requires so much planning such as conceptual design, user requirements, user surveys, network design, programming, benchmarking, testing, and so on. Because of this involvement, the user in theory should end up with a completely customized GIS. However, this may not always be the final result because of the relative importance placed on diverse interests and requirements by different departments and stakeholders which go into the design of the GIS.

System implementation and customization does not really apply (n.a.) in Option V purchasing GIS consultant services. There GIS deliverables or output to the client are usually in the form of databases, maps, or reports. Occasionally, consultants do provide distributed diskettes containing software or modules to view maps or extract relevant data. These products contain no GIS capabilities.

Summary

Among the implementation options for GIS, we recommend buying one of the many available popular or leading GIS software packages available in the marketplace (Option III).

As discussed in greater detail above, we support our recommendation with the following comparative advantages of Option III.

- Relatively Low Costs of System Implementation
- Relatively Low Costs of Components and Staff
- Relatively Low Labour Costs Over Time
- Comparatively Better Technical and Software Support
- Relatively Low Resource Requirements (e.g., labour, staffing)
- Comparatively Lower Level of Dependence and Uncertainty
- Comparatively Better System Functionality and Customization

Selecting a GIS / Desktop Mapping System

GIS Systems in the Marketplace

All of the GIS systems listed share common features but in many ways also show significant differences. It was therefore needed to exclude those systems which were not likely to be practical or cost-effective for SAFE.

A short-list of GIS systems was developed, based on specific considerations obtained from the user and system requirements of SAFE (as identified in Task 2 of the Milestone 1 Report). These considerations can be summarized into the following criteria categories.

1. PC-based GIS for Windows

- GIS software have same intuitive functionality and user friendliness as standard Windows software and can be integrated with other Windows software (e.g., Word, Excel, Access, etc.)

2. Reputable Vendor (Based on Years of GIS Experience, Guaranteed Customer Service and Support, Licensing, GIS & Software Partnerships)

- Vendor has long tradition in GIS and software development. The vendor provides exceptional customer, technical, software, and user support services. As well, the vendor is well integrated with enterprise-wide databases, software developers, and other leading data sources. The benefit is better overall GIS capabilities and relations.

3. Demonstrated Capability to Handle Marine/Risk Applications (Location Analysis, Regionalization, Routes, Raster Images, Network Planning)

- There is demonstrated capability from literature, demos, and experience for the GIS software to handle marine and risk applications, as required in SAFE.

4. Supports Open and Customized Development for SAFE

- The GIS software is designed for customized development to SAFE's requirements, using own or third-party programming languages and other Windows utilities.

Table 2. highlights those GIS systems to be evaluated for consideration as GIS software to be used for SAFE's development.

Table 2. Preliminary List of GIS Vendors

NAME OF GIS	NAME OF VENDOR
Arc/Info 7.0	Environmental Systems Research Institute Inc.
ArcView 2.0	Environmental Systems Research Institute Inc.
Argus Professional 3.0	Munro Garret International
Atlas GIS for Windows	Strategic Mapping Inc.
AutoCad	
Bently Microstation	Bently Microstation
Caris for Windows	Universal Systems
Caris Unix	Universal Systems
EPPL7	
ERDAS Imagine	Erdas Incorporated
GisPlus	Caliper Corporation
Idrisi	Clark Labs, Clark University
InfoCad	Digital Matrix Services
Infomark-GIS	Equifax National Decision Systems
MapGrafix 3.0	ComGrafix, Inc.
MapInfo 3.0	MapInfo Corporation
Mapping Office	Intergraph Software Solutions
Mapping Office	Intergraph Software Solutions
Pamap GIS	Essential Planning Systems Ltd.
PC Arc/Info	Environmental Systems Research Institute Inc.
ProGis	ProGis Corporation
Quickmap 2.51	Earth & Oceans Research Ltd.
Spans Explorer	Tydac
Spans Map	Tydac
Sparta-Site	Equifax National Decision Systems
Tactician 3.1	Tactician Corporation
TransCad	Caliper Corporation
Vision	SHL Systemhouse
VistaMap	Intergraph Software Solutions
WinGis	ProGis Corporation
WinMap	ProGis Corporation
	Denotes GIS Selected For Evaluation

Recommended GIS System for SAFE

Six GIS and mapping systems were selected for further evaluation. As shown in Table 2, all six of the GIS and mapping systems selected for evaluation have overlapping GIS capabilities as well as unique features to facilitate various spatial analysis and mapping functionality. Each of the systems have some strong advantages and disadvantages.

For this evaluation, the most important considerations are the main GIS capabilities and mapping functionality required by SAFE, in order for it to be an effective and fully functional analysis tool. The package recommended will therefore be able to perform all of the necessary spatial analysis and mapping tasks required by SAFE, and provide the best combination of user interface, geographic analysis capabilities, map analysis tools, reports, data management, vendor support, customization, and overall practicality.

A recommended option would be to use MapInfo 3.0. Of the systems evaluated, MapInfo 3.0 appeared to be the most practical option given the present requirements for SAFE and type of users.

MapInfo's greatest strengths are its flexibility, user friendliness, and open applications development environment. It ranked very well amongst its competitors and full-blown GIS systems with good and excellent ratings on many of the important criteria, such as user interface, input/output, analytical functionality, and mapping (see Figure 7 and Glossary of Evaluation Criteria).

As well, MapInfo provides comparable GIS capabilities needed by SAFE, without added technical sophistication of operation typical of the other GIS software and systems. Overall, MapInfo's functionality is compatible to the scope of SAFE, the low level of technical knowledge required to use it, and relatively low cost and short period of time of fully implementing MapInfo.

The higher-end GIS systems evaluated such as PC Arc/Info, Caris, and Spans are not recommended for SAFE. All three of these systems have very strong and advanced GIS capabilities and functionality. However, these systems are targeted for highly technical and research-intensive organizations. Since their market niche is highly technical, these products do not provide the same level of sophistication in the development of their user interface or even simple analytical functions. The Caris tool kit is in beta and there are no plans to develop for Windows 95, just NT. The level of functionality associated with these systems is beyond the present scope of SAFE and requires a higher level of technical and research support. As well, additional hardware is required for these systems to be fully operational. This translates into higher costs and a longer time period for implementing these systems.

Also, the remaining two GIS software evaluated which include ArcView and GisPlus are not recommended for SAFE. Although both provide good GIS capabilities, they are not as flexible or open as MapInfo for customized development and incorporating data from different sources. Part of the reason for this is that both systems have been designed to operate and integrate with their higher-end root GIS systems (e.g., ArcView from ArcInfo and GisPlus from TransCad). For example, ArcView does not allow a user to update the GIS database, just query and read from it. This would create significant problems with data transferability and manipulation which would have to be done in the higher-end GIS systems in order to be used by either ArcView or GisPlus. In contrast, MapInfo is flexible in this way because it can read and output a wider range of data, and translate data from a variety of sources.

It is important to highlight that as the longer-term demands for SAFE and complexity of SAFE change, it may be necessary to modify the overall software implementation strategy. If SAFE becomes a corporate-wide system used throughout the Transport Canada for larger-scale data manipulation, management and risk analysis, then alternative GIS options closer to technical and research users would have to be considered. A number of options could be feasible. For example, MapInfo's functionality could be easily migrated to a higher-end GIS system for geographical analysis or MapInfo could be set-up as the front-end GIS software and integrated with additional hardware and a leading database management systems such as Oracle.

Figure 7. Evaluation of Selected GIS Software and Systems

Glossary of Key Attributes

User Interface

The systems's front-end link between the user and the systems's functionality and operations.   It is an essential part of an analysis system allowing user's to efficiently access, manage, and analyze data through a series of menu selections and commands.

1. Intuitive
The layout and design of menu systems is straightforward allowing users to easily access any of the system's functionality

2. Default Settings
Common user needs have default settings such as fonts, workspaces, file formats, and working directories

3. Dialog Boxes
These are message or user input boxes which allow users to instruct the computer to perform certain operations with minimal effort

4. Help & Trouble Shooting Utilities
On-line help is provided and activated either through a help menu and/or help hot-keys

5. Ease of Resuming Work Sessions
Users can save and retrieve any version of their work for future use along with work details, tables, and main parameters

6. Ease of Use
The overall software adequate for beginners with little knowledge of computers and GIS, while also providing enough functionality for advanced technical and GIS users

Inputs and Outputs

System inputs and outputs include a systems's capability to transfer and present data in a variety of ways including spreadsheets, charts, tables, files, summaries, and maps.

1. Spreadsheets/Databases/Tables
A systems capability to output to one or more file and software formats (e.g., ascii, .dbf, .tab, .xls, .wk1, etc.)

2. Standard Summary Reports

The system provides default or customized summaries of data

3. Summary Statistics

The system can provide quick aggregations of any level of data

4. Thematic Mapping

Mapping functionality allows selected kinds of information relating to themes to be presented on maps such as the vessel accident densities, VTS coverage areas

5. Graphical Charts

Data is or is required to be presented as trend-lines, histograms, or pie charts

6. Spatial/Tabular Data Display

Data is presented or is required to be presented on maps or browser tables

7. Data Accuracy and Scale

A high level of data accuracy is required with respect to exact space, time, and relative distance relations (e.g., the relation between an accident location, time of accident and distance from emergency response)

Analytical Functions

Analytical functions are built-in or customized operations which allow the user to relate, calculate and manipulate a variety of data for more sophisticated analyses, such as cause/effect, optimal location, routes analysis, and so on.

1. Area or Zone Analysis

Small or large area comparative analyses such as the frequency of accidents in Canadian Coast Regions

2. Point-Point Distance

Calculation of space/time/distance relations in real time between points such as the time of emergency response to reach a vessel N.UC. before grounding

3. Linear/Traffic/Network Analysis

Analysis of vessel or traffic movements between ports or delineated regions (e.g., VTS)

4. Perimeter Distance

Calculation of real time distances for polygon or polyline objects such as the total distance of environmentally sensitive shoreline or VTS coverage zones

5. Centroids/Mean Centre

Calculation of a locational mean or average for selected geographical phenomena such as the relative centre of high risk vessel accident areas

6. Map Overlays

The process of stacking digital representations of various spatial data on top of each other and allowing analysis of all data elements based on the locations of the spatial data (e.g., layer of accident locations on top of a vessel movements map layer, on top of an oceans map layer)

7. New Attributes Calculation

Mathematical operators or functions are provided to calculate ratios, percentages, averages, variations, etc. from existing data

8. Database Querying

User defined criteria or ranges based on tabular or geographical information used to select and display a subset of records of a database (e.g., display all accident locations occurring between 1988 and 1991 in the St. Lawrence Region)

9. Region Creation/Adaptation

Delineating and modifying regions based on selected geographical and non-geographical information

10. Point Data Manipulation

Creating, verifying, and editing point data through geocoding, digitizing and visual inspection

11. Modeling/Simulation

Techniques provided to allow users to define a range of scenarios and estimate the effects, costs and benefits of such scenarios (e.g., the costs and benefits of tug escorts or environmental costs of oil spills)

12. Optimization/Minimizations

Methods of determining the optimal distribution of resources or minimum time/distance needed, such as in the case of allocating emergency response resources or location of emergency response vessels

Data Management

Data management includes system capabilities to facilitate efficient records management and storage, and compatibility with different file formats, systems and software.

1. Records Management
Add, delete and create tabular and geographical records or objects

2. Data Entry and Updating
User data screen for entering and editing all data elements

3. Relational Data Manipulation
Performs either tabular or spatial data relational operations, or both

4. Handling Different File Formats
Accepts and works with most standard files such as .dbf, .xls, .wk1, .bmp, etc.

5. Client-server Considerations
Facilities client-server technology or could be run on a network

6. Data Access
Capability to access a variety of data sources including information from Database management systems and other GIS formats

Mapping

1. Selecting Geographical Objects
GIS has various methods of selecting geographical objects from map, such as radius tool, polygon tool, select tool, and SQL

2. Power / Ease of Data Aggregation
Fast and efficient methods of aggregating data from a map and tables

3. Thematic Classification Methods
Various tools are available to create elaborate thematic maps, including imbedded shading, and options to imbed histograms and pie-charts with map objects

4. Display Quality
Professional and high quality of maps, graphics and resolution

5. *Presentation and Map Labeling Tools*
   Annotation tools are available to fully label and document maps and reports, including legends, symbols, colours, and design tool

6. *Projection Transformations*
   Maps can be transformed to any of the standard map projections

7. *Digitizing Support*
   GIS software supports direct digitizing software and/or add-on digitizing hardware

Vender Support

Quality and access to a variety of sources of technical and customer support and user assistance provided by GIS software vendor

Application Development

1. *Ease of Automating Menus Items*
   Software facilitates easy automation of certain menu item functionality

2. *Ease of Adding Functionality/Menu Items*
   Software provides tools such as programming languages or design kits to develop customized functionality

3. *Ease of Customized Programming*
   Software provides own programming language or utilities to integrate third-party programs

4. *Supported Hardware Components*
   Facilities for various hardware such as digitizers, coloured printers, scanners, and special tape drives are available for installation

5. *Functional Capability of Software*
   Software runs seamlessly with other leading software and Windows

Reports and Statistics

GIS software provides various functions to allow users to make quick summary calculations based on new variables and geographical regions

Modules and Application

1. *Integration with Microsoft Products*
   GIS software should run seamlessly with other Microsoft software through Dynamic Data Exchange (DDE)

2. *Strength of Third-party Applications / Partnerships*
   GIS software vendors have contractual and licensing agreements, as well as development initiatives, with major third-party software vendors, application developers, and industries

3. *In-house Modules*
   GIS software modules are developed and sold by vendors as add-ons to GIS software

Practicality

1. *Functionality Beyond SAFE's Needs*
   GIS software provides geographical capabilities beyond what is needed for SAFE and this is reflected in higher costs for the software

2. *Requires Added Modules / System Support for Full Benefits*
   The full benefits of the GIS are realized through integration with their root GIS systems or through purchase of add-on modules

3. *Quality of Marine / Environmental / Risk Applications*
   The quality level of SAFE-like applications demonstrated with the use of each GIS software

4. *GIS Sophistication Beyond Average SAFE User*
   GIS capabilities and orientation of GIS functionality makes use very difficult for average non-technical users

5. *Level of GIS User Experience Required*
   The level of experience required by users in geographical analysis and database processing in order to use the GIS software

6. *Costs of Implementation*
   The overall costs of purchasing software, installation, hardware and personnel

V. DEVELOP A DEMONSTRATION ANALYSIS TOOL

Introduction to SAFE/RAM Prototype

A prototype SAFE / Risk Analysis System was developed utilizing the Windows MapInfo development environment (Figure 8). Based on the design criteria developed from the user and system requirements in Task 2, the prototype was successfully developed with a customized interface, mapping and analysis tools, and capability to quantify marine risk and associated costs.

A step-by-step Risk Analysis Module (RAM) was also developed to guide users of SAFE through a risk methodology process; beginning with defining a problem and project, specifying a query to retrieve data, analyzing risk-related information, calculating risks and costs, and reporting the costs and benefits of control options designed to reduce marine risk (See Figure 9. Risk Analysis Step Manager).

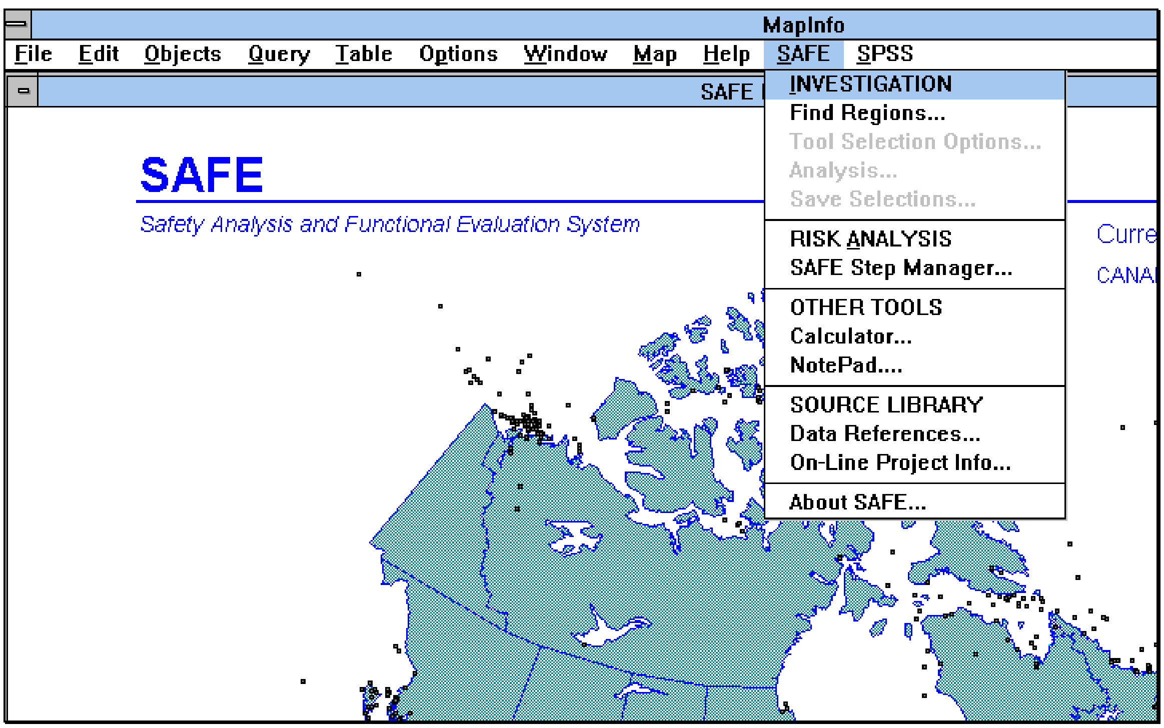

Figure 8. SAFE's Interface

Step Manager

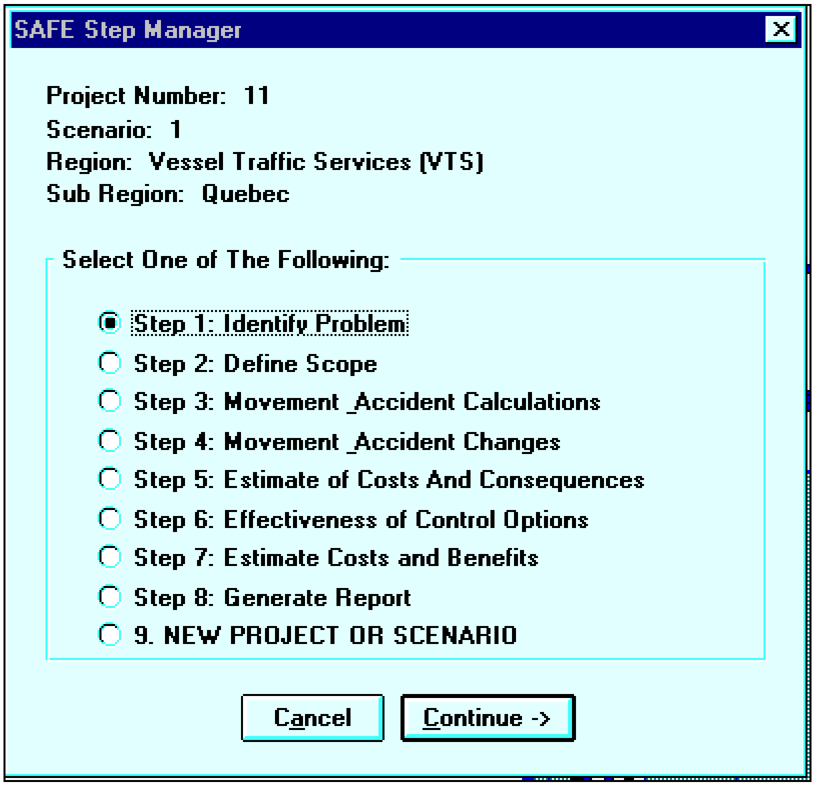

Figure 9. Risk Analysis Step Manager

Figure 9. Risk Analysis Step Manager dialog is the SAFE Step Manager. It basically acts as a tool that helps the user navigate through the SAFE risk analysis process. At the top, the usual information of Project Number, Scenario, Macro Region and Sub Region are present.

The unique feature in the Step Manager is that it insures that the user follows the sequence of steps in proper order. It does this by not allowing to user to go to a step unless they have completed the necessary information in the previous step. For instance, if the user has completed Step 2, they cannot jump into Step 7.

Dialog Controls

"Steps"

These radio buttons allow the user to select where in the risk management process they wish to go, provided that they have completed the necessary information leading up to those steps.

__Step 1. Framing the Question__

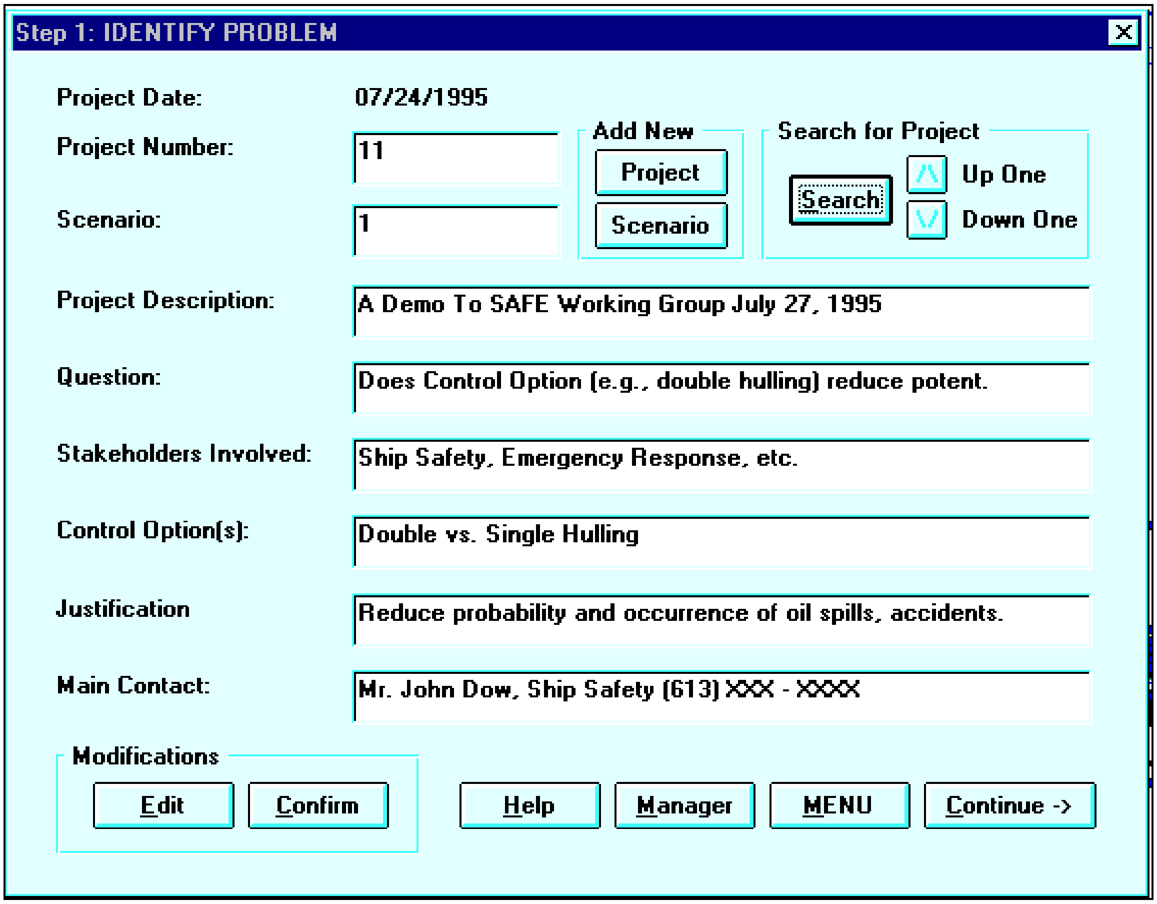

Figure 10. Step 1 Dialog Box

Figure 10 is an illustration of the SAFE Step 1 Dialog box. It allows users to enter information about a current project, create new projects and scenarios, scroll through some existing projects, and make revisions to them.

The dialog is made up of several text boxes that can be edited by the user. The contents of these boxes are saved to a file which makes them available for future use.

Dialog Controls

"New" Group

- PROJECT: This button defines a new project that essentially allows the user to start an analysis from scratch.

- SCENARIO: This button allows the user to define a scenario of the same project. This feature is useful because it allows the analyst to test the results of a project when few parameters are adjusted.

Text Boxes

- PROJECT DESCRIPTION: This text box allows the user to enter a brief description of the current project that they are working on. This description is then saved to a table that allows the user to return at a later date and recall what the project involved.

- QUESTION: The question text box essentially frames the problem that the analyst is trying to solve. It is, as the title suggests, the “question” that SAFE is to answer.
- STAKEHOLDERS INVOLVED: This box allows the analyst to enter the names of people and or organizations that have a vested interest in the outcome of the current project (i.e.: government, shipowners, etc.).

- CONTROL OPTIONS: Here the analyst enters which actual options will be tested in this project to determine their effect on risks and costs.

- JUSTIFICATION: This box gives the analyst the opportunity to justify the control options above and why they are being tested.

- MAIN CONTACT: Here the analyst can enter the names of any people or organizations that may have participated in the project in some way.

Buttons

- SEARCH: Enables the up and down areas to browse all available projects and scenarios.

- EDIT: Enables the text boxes so that the user can make additions and/or modifications.

- MANAGER: Returns the user to the SAFE Step Manager.

- MENU: Returns the user to the MapInfo menu.

- CONTINUE: Sends the user into the next step.

Step 2. Defining the Scope

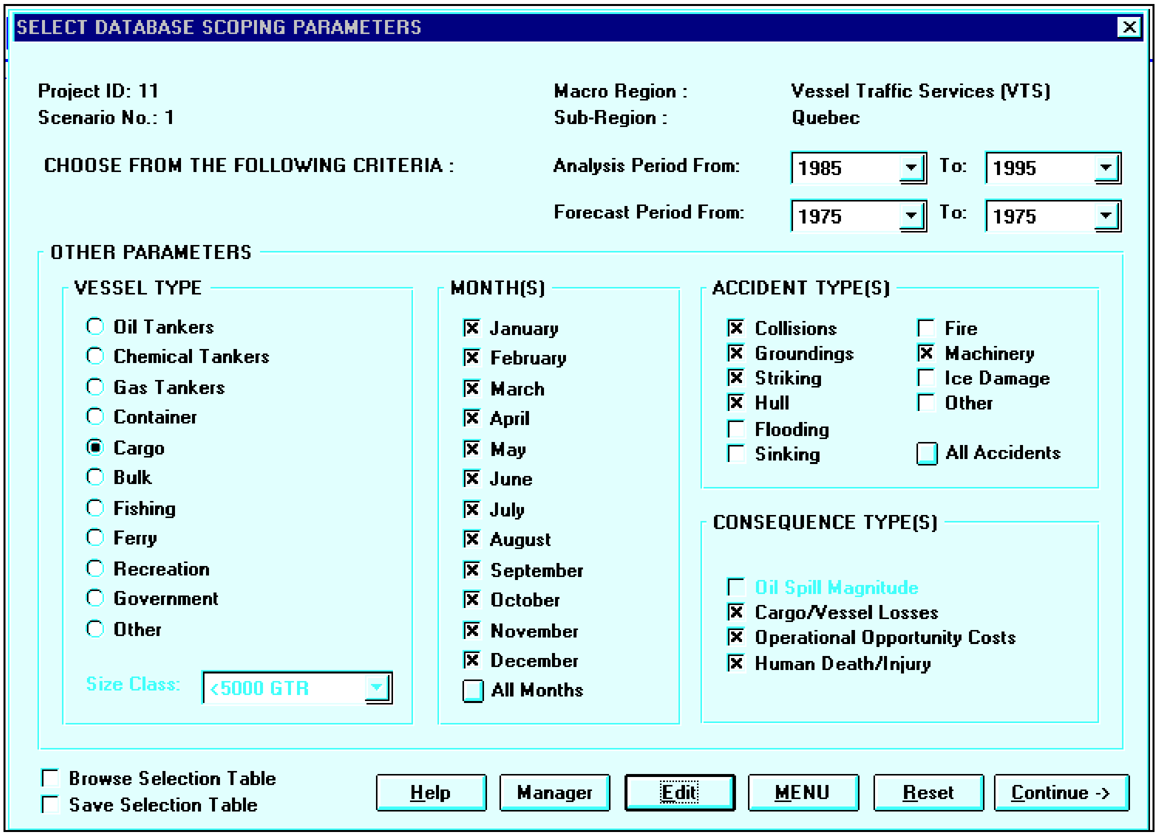

Figure 11. Select Database Scoping Parameters

The Figure 11 dialog allows the user to set the parameters of their database search. The information entered into this dialog is then retrieved form the appropriate databases using SQL commands. At the top of this dialog box appear Project ID, Scenario, Macro Region and Sub Region information. This information is carried over from Step 1, where the analysis began.

Dialog Controls

Analysis Group

- ANALYSIS PERIOD FROM (TO): This portion of the dialog allows the user to select which time range that they wish to extract from the historical casualty database. It retrieves all available actual data that falls within the range that the user specifies.

- FORECAST PERIOD FROM (TO): This portion of the dialog allows the user to select which range of years they wish to forecast into the future. Currently, users can select a forecast period up to 2005.

"Vessel Type" Group

This section in the dialog allows the user to select which vessel type they want to incorporate into the analysis. The available vessel types have been determined by what is available in the historical casualty database.

Currently, users are only able to select one vessel type per project or scenario by clicking on one of the radio control buttons.

"Month(s)" Group

This section allows the user to pick which time(s) of the year that they wish to examine. Users can pick as many months as they want, but they must pick at least one.

There is an "All Months" option button at the bottom of the months list.

"Accident Types" Group

Here the user can select which casualty types that they wish to examine. Like the months section, the user has the option to select "All Accidents," but they must select at least one.

"Consequence Types" Group

This section defines which consequences, or results of a casualty that SAFE will use for the estimation of costs. The availability of consequence types depends on the vessel type that they user has chosen (i.e.: Oil Spill Magnitude is only available if the user selected Oil Tankers as a vessel type"

Buttons

- EDIT: Allows the user to make additions/changes to the scoping parameters.
- RESET: Clears the dialog so that the user can start fresh.
- MANAGER: Returns the user to the SAFE Step Manager.
- MENU: Returns the user to the MapInfo menu.
- CONTINUE: Sends the user into the next step.

Step 3. Vessel Activity

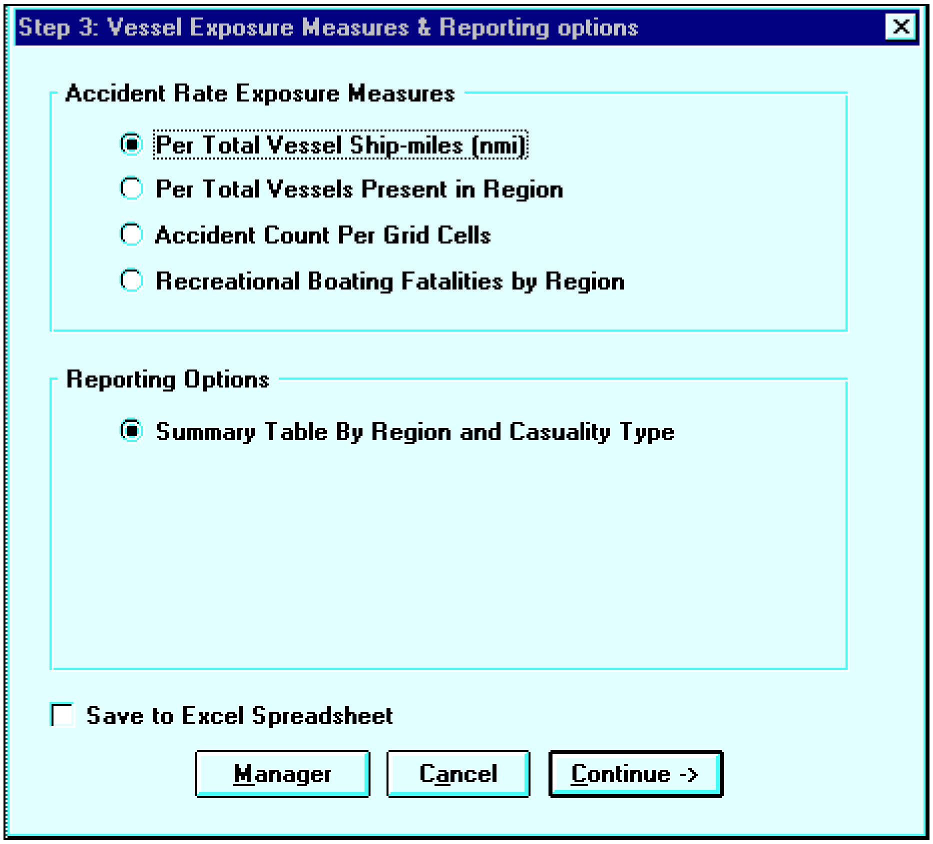

Figure 12. Vessel Exposure Measures & Reporting Options Dialog

Figure 12. Vessel Exposure Measures & Reporting Options Dialog allows the user to select how they wish to conduct their analysis. The Step 3 dialog box also gives the user the option to select different reporting (or output) options and to save output to an Excel spreadsheet.

Dialog Controls

"Accident Rate Exposure Measures" Group

In this control group, the user has 4 options to choose from that will determine how SAFE will analyze the Step 2 query results. Currently, the only available option is "Per Total Vessel Ship Miles (NM)."

“Reporting Options” Group

This control group allows the user to determine which type of reporting (or output) format that that they would like to use for the final output. Currently, there is only one reporting option: Summary Table by Region and Casualty Type.

Check boxes

SAVE TO EXCEL SPREADSHEET: This checkbox allows the user to save their final output to a Microsoft Excel spreadsheet, where they can then perform any further analysis that they wish.

Buttons

- MANAGER: Returns the user to the SAFE Step Manager.
- CONTINUE: Sends the user into the next step.
- CANCEL: Cancels the Step 3 dialog.

Step 4. Calculate and Modify Accident Rates

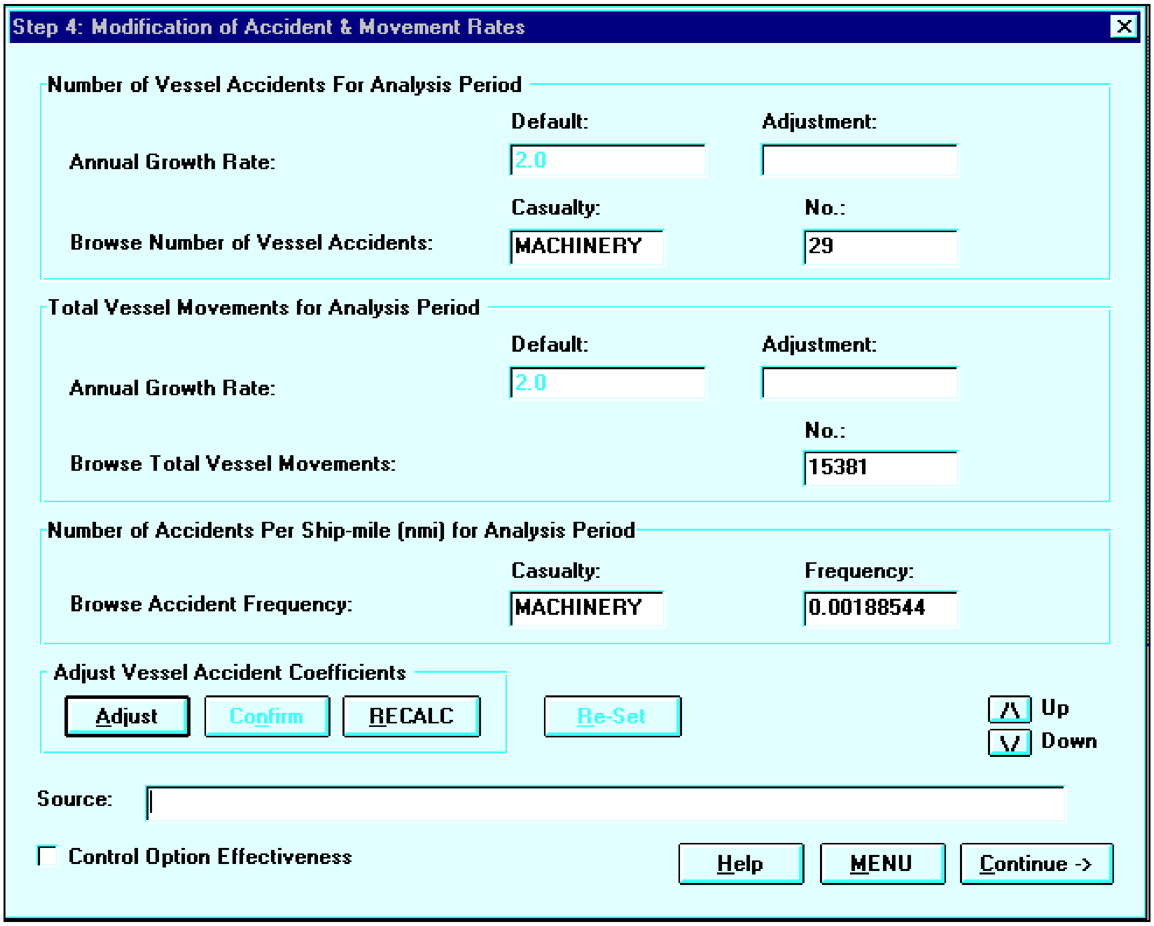

Figure 13. Modification of Accident & Movement Rates

Figure 13. Modification of Accident & Movement Rates dialog allows the user to interact and modify the data for the first time in the risk analysis process. At this point, the user can look at the results of the query and determine if they are consistent with their expectations. If not, they may do some adjustments here to bring the query results more in line with the situation at hand.

Dialog Controls

"Number of Vessel Accidents for Analysis Period" Group

In this control group, the user can browse through the query results and see the number of accidents through the length of their analysis period. Here, the users can the adjust the annual accident growth rate by factoring the default rate either up or down. This is done by simply adding a new growth rate to the "Adjustment" text box.

"Total Vessel Movements for Analysis Period" Group

Like the first control group, this group allows the user to browse through the query results and make any adjustments to the annual growth rate of vessel movements. This is done by adding a new growth rate to the "Adjustment" box.

Text Boxes

SOURCE: This text box allows the user to enter any documentation that supports the changes that they may have made in the growth rates for accident counts or ship miles. This ensures that the user will have an on-line record of the changes that were made to any of the growth rates and why.

The results of the SOURCE input will be recorded in a database for future reference.

Buttons

- ADJUST: This button enables the "Adjustment" text boxes so that the user can enter new growth rate values.
- CONFIRM: This button confirms the changes that the user has made so that the vessel movements and accident counts can be recalculated.
- RECALC: Performs the calculation of new accident and growth rate values.
- RESET: Undoes the calculations and resets the default values.
- MENU: Allows the user to use the standard MapInfo menu and functions.
- CONTINUE: Sends the user into the next step.

Step 5. Consequence Costs Estimations

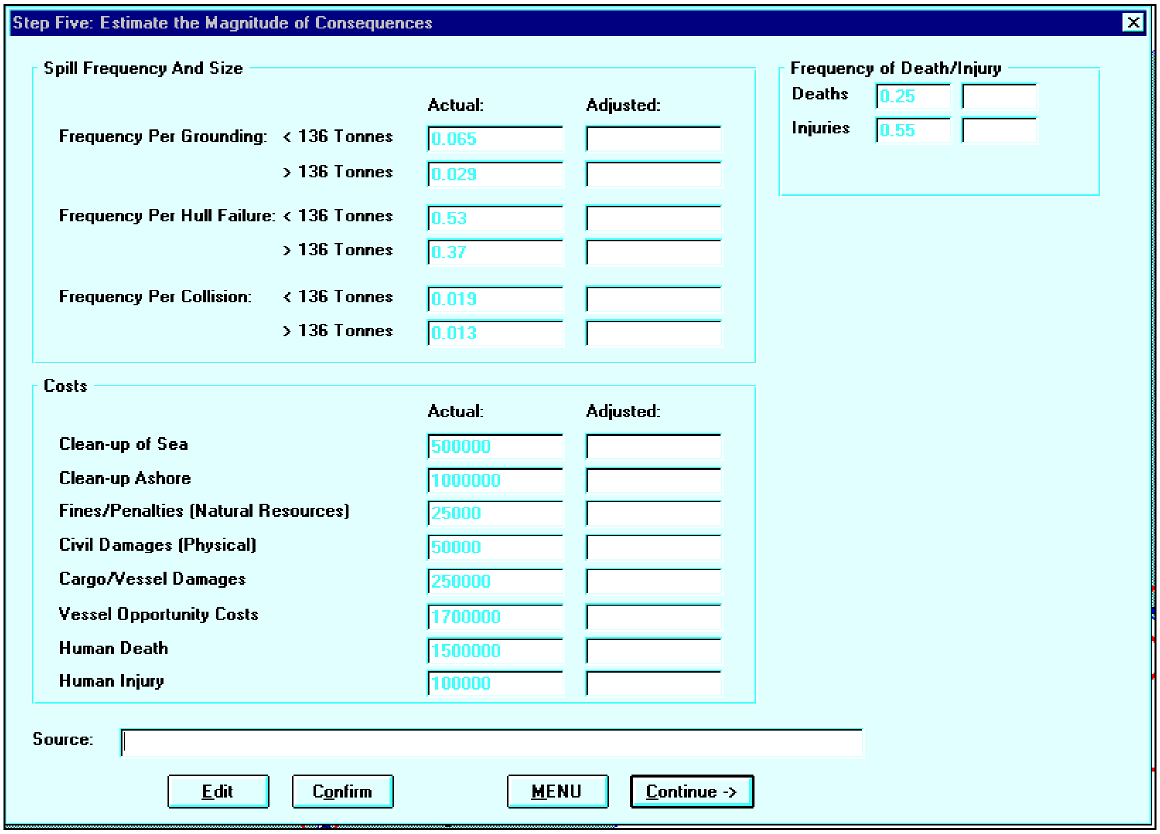

Figure 14. Consequence Magnitude Estimate Dialog

As in Step 4, the Figure 14 dialog allows the user to enter new information into the SAFE system to further modify the Step 2 query results. There are 2 major control groups in this dialog. The first group, relates only to oil spill casualties. Therefore, this portion of the dialog cannot be used unless the user selected Oil Tankers in the Step 2 query.

The second portion of the dialog pertains to all vessel types, although the default values are averaged and may need to be adjusted depending on the circumstances.

Dialog Controls

"Spill Frequency and Size" Group

As mentioned above, this portion of the dialog is only functional if Oil Tankers were selected as a vessel type in Step 2. Otherwise, this section remains "grayed out" and non-editable by the user.

As with the last step, the user can modify spill frequencies depending on the situation, by simply adding the new frequency to the "Adjustment" text boxes. If the user does not enter an adjustment value for a frequency, then the default value is used.

"Costs" Group

Unlike the Spill Frequency and Size Group, this control group remains active irrespective of the chosen vessel type. This is because this section deals with the costs of a casualty, which is applicable to all ship types. There are of course costs that will not apply to a certain ship type, but the user simply has to reduce
the cost of that consequence and rate the applicable ones higher.

As in the top control group, the adjustment of average costs is simply a matter of entering the new value in the "Adjustment" text boxes.

"Frequency of Death and Injuries" Group

This control group is set apart from the others because it deals with the nature of human death and injury. Like the other boxes, the user can alter the frequencies depending on the situation, and enter the source accordingly. This group remains active irrespective of vessel type.

Text Boxes

SOURCE: Like Step 4, this source box allows the user to enter documentation that can support the changes that they may have made to the default frequencies or consequence costs.

Buttons

- EDIT: Makes all the "Adjustment" text boxes editable so that the user can enter new frequency or cost values.

- CONFIRM: Confirms any changes that they user may have made.

- CONTINUE: Moves the user on to the next step.

- MENU: Allows the user to use the standard MapInfo menu and functions.

Steps 6/7. Cost And Benefit Estimation (Effects of Control Option)

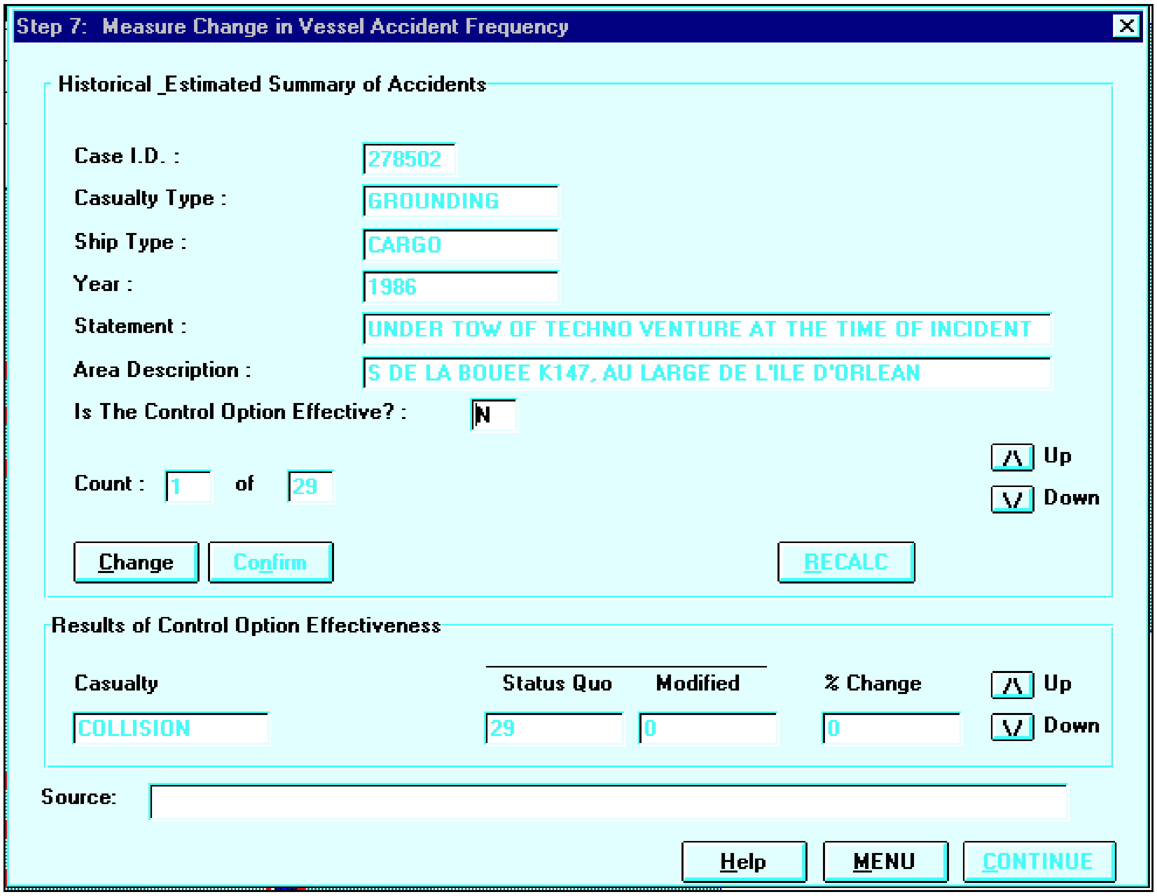

Figure 15. Expert Input of Effect of Control Option

Figure 15 is the Step 7 dialog, that allows the user to perform a case by case review of the query results and assess the effectiveness of a control option in preventing that accident. In effect, this dialog is a key component to the SAFE risk analysis system, as it allows for the input of "expert judgment" and estimation of costs and benefits based on the effectiveness of a control option(s) in reducing vessel accidents.

Dialog Controls

"Case by Case Summary of Accidents" Group

This group allows for a case by case review of the Step 2 query results in order to test the effect of a control option on each one. In effect, the user can use expert judgment on a case by case basis which will, in later steps, provide an output of the cost savings as a result of effective control options.

“Results of Control Option Effectiveness”

In this control group, the user can browse the results of the effective control options on accident counts. This will allow them to preview their assessments before moving on to the next stage.

Text Boxes

As in the last 2 steps, there is a Source text box where the user can enter support for any of the control options that they deem effective.

Buttons

- CHANGE: Makes the “Control Option Effective?” text box editable where the user can enter Yes (Y) if the control option would have been effective in preventing an accident. The default value is No (N).

- CONFIRM: Confirms any changes that they user may have made.

- RECALC: Recalculates accident counts given effective control options.

- CONTINUE: Moves the user on to the next step.

- MENU: Allows the user to use the standard MapInfo menu and functions.

Step 8. Stakeholders’ Concern

The needs, issues and concerns of all stakeholders must be measured directly by survey or estimation, relating to the first 7 steps of the risk assessment process. It should be noted that some control options may be removed and/or various critical risk parameters modified, if upon review by stakeholders find results of the unrealistic from a risk, cost or benefit, or parameter point of view (i.e., too high costs, minimal risk reduction, etc.).

Although there is no specific dialog box for stakeholder’s concerns, there feedback and concerns are recorded and documented on a on-going basis through “Source” user entry boxes in the various steps, and saved to an accessible on-line documentation file for reference.

Step 9. Answer(s) and Report

The following is a sample report of SAFE's Risk Assessment Process (Figure 16). The report shows the resulting reduction in average annual vessel accidents by types of accidents and associated costs of the accidents for a certain type of vessel, based on the effectiveness of a control option(s).

SAFE REPORT	**WORKSHEET A - Details of Project**		
Project :	***11***		
Scenario :	***1***		
Region :	***Vessel Traffic Services (VTS)***		
Sub-Region :	***Quebec***		
ACCIDENTS :	*STATUS QUO*	*NET CHANGE*	*FINAL RESULTS*
COLLISION	3	1	2
GROUNDING	5	4	1
STRIKING	10	0	10
HULL	1	0	1
MACHINERY	2	1	1
TOTAL	21	6	15
COSTS ($):			
CLEAN-UP AT SEA			
CLEAN-UP AT SHORE			
FINES/PENALITIES			
CIVIL DAMAGES			
CARGO/VESSEL DAMAGES	$3,495	$1,073	$2,422
VESSEL OPPORTUNITY COSTS	$23,763	$7,295	$16,468
HUMAN DEATH	$20,967	$6,437	$14,530
HUMAN INJURY	$1,398	$429	$969
TOTAL	$49,623	$15,234	$34,389

Figure 16. Report Output

REFERENCES

Arnoff, Stan, (1989), Geographic Information Systems: A Management Perspective, WDL Publications, Ottawa, Canada

Burrough, P.A., (1986), Principles of Geographical Information Systems for Land Resources Assessment, Monographs on Soil and Resources Survey No. 12, Oxford Science Publications, Oxford.

Dangermond, J. and Smith, L., (1980), Alternative Approaches for Applying GIS Technology, In Proceedings of the ASCE Specialty Conference on the Planning and Engineering Interface with a Modernized Land Data System, Denver, Colorado.

PART TWO