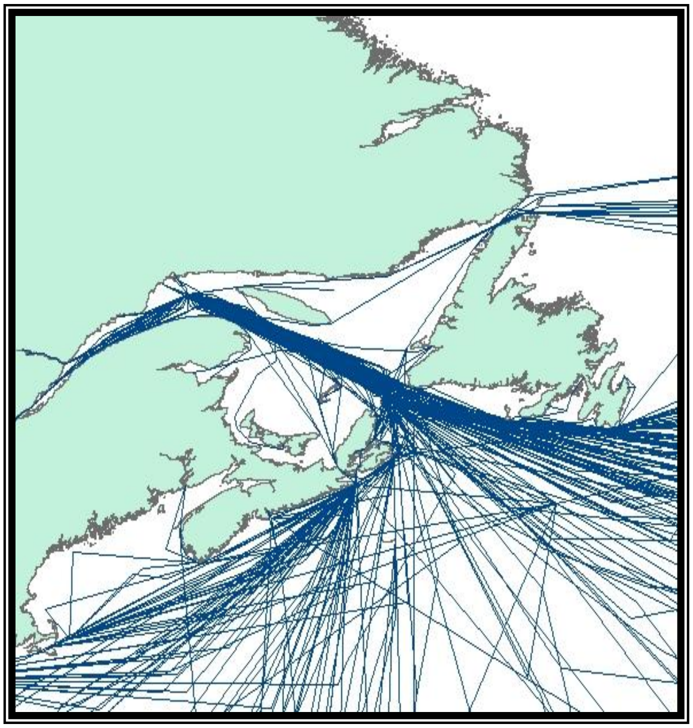

Maritime Activity & Risk Investigation Network

MARIN Report: #2006-03

Cruise Ship Activity and Risk Analysis for Improved SAR Response Planning

Prepared By:

Pelot, R.; Hilliard, C.;
Mukesh, M. D.; Deacoff, C.;
Wootton, D.; Moyst, H.

March, 2006

Sponsors

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1 Executive Summary

This report summarizes the work completed by the Maritime Activity and Risk Investigation Network (MARIN) in respect of the NIF project entitled “Cruise Ship Activity and Risk Analysis for Improved SAR Response Planning”. A review is presented of the literature reviewed for the project, organized by the topic groups established in the proposal.

An account of the modelling of cruise ship traffic information is given, and notable trends in cruise activity are outlined. Various sources of information were tapped to provide a reliable picture of the traffic along both the East and West coast.

An expert workshop was conducted to assess the risks associated with large passenger vessels (LPV). Dozens of questions were asked to solicit estimations of the relative frequency of occurrence of various risk factors, their potential contribution to overall risks, as well as an assessment of the relative magnitude of consequences of various types of incidents. This pilot study not only provides insight into the state of the industry from a safety point of view, but yields useful quantitative estimates for incident risk assessment that can be merged with those from other traffic types for improved SAR resource planning.

To facilitate the impact of SAR resource allocation, new tools were added to the MARIS (Maritime Activity and Risk Investigation System) GIS-based software developed by MARIN. The new Operational Capability Tool (OCT) can calculate coverage and response times in various ways to evaluate the deployment of SAR vessels, and the impacts of cruise vessels traveling into areas remote from SAR facilities. The updated version of MARIS with these new tools has been delivered to the Coast Guard managers.

Finally, the main conclusions drawn from the work are noted and suggestions are made of further opportunities for exploration. Throughout, references are made to the more detailed reports generated by MARIN as supplement to the project.

2 Acknowledgements

The authors would first and foremost like to thank the National Search and Rescue Secretariat for providing financial support for this project though their New Search and Rescue (SAR) Initiatives Fund (NIF) Program. Many thanks are also due to all participants of the Large Passenger Vessel Expert Workshop. We would also like to thank the Coast Guard representatives that were able to consult with us on an ongoing basis, and provided partner funding for this work. In particular, the assistance of Paul Kendrick, Brian LeBlanc, Brian Stone and Mike Voigt, and Ian Gillis has been invaluable. Special thanks are due to the research assistants in the Maritime Activity and Risk Investigation Network (MARIN) for their respective contributions. We would like to also thank Dalhousie University for housing the MARIN group and providing administrative support.

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5 Introduction

This report summarizes and presents the work accomplished by the Maritime Activity and Risk Investigation Network (MARIN) under the New Search and Rescue Initiatives Fund (NIF) project entitled "Cruise Ship Activity and Risk Analysis for Improved SAR Response Planning". This project was undertaken "*To quantify and analyse historic and projected risks and traffic patterns associated with cruise ship operations in Canadian waters, to assist with SAR response planning and other risk mitigation measures.*" The need for this project was established on the basis of increasing cruise ship traffic [4], particularly on the East Coast of Canada [2, 5, 6, 7, 8] and in increasingly more remote areas as “adventure” or "niche" cruises [3]. In addition to this, the potential severity of cruise ship incidents [9, 10], given the numbers of people on board [7, 11, 12], limitations of SAR resources and lack of significant amount of historical precedent to draw from all make this a very important topic for study.

The report is laid out according to the objectives set forth in the original NIF proposal. Firstly, the cruise ship regime is established, taking a view of both Canadian and International considerations. Safety, regulation and management regimes are all reviewed to establish a solid base of information about the industry. In the second section, the process of developing patterns of activity for cruise vessels across Canada is outlined. The data from which these patterns are drawn are discussed. The third section of the report covers the development of a risk model for the determination of areas of concern. The records of cruise ship incidents available are compared and contrasted. Within this section, the difficulties encountered in modelling risk for rare events, such as large passenger vessel incidents, are detailed. Trends within the cruise industry are reviewed and the, sometimes conflicting, projections are considered with respect to the situation in Canada. Finally, the development of measures and software tools for evaluating SAR resource allocation is described, along with the application of these methods to the current as well as projected cruise vessel activity in Canada.

In conclusion, suggestions are made regarding further research, and uses of the software[1] for evaluating response, considering the trend scenarios presented.

[1] MARIS - Maritime Activity and Risk Investigation Software © 2006 Ronald Pelot

6 Identification of Risk Factors, Data and Information Sources

In order to properly develop a model of the risks associated with the cruise industry in Canada, it was necessary to first summarize the state of the operating environment in a holistic manner. This was accomplished by conducting a literature review encompassing the different aspects of cruise ship operation. The review was divided into four main categories:

1. cruise ship safety
2. general large vessel safety
3. worldwide traffic and safety schemes (with a particular focus on those schemes that directly affect cruise vessels)
4. management regimes relevant to the cruise industry

Through this review, a picture was established of the risk factors that may be associated with the cruise industry, and what potential effect they could have on SAR resources.

6.1 Cruise Ship Safety

The collection of information regarding cruise ship safety is of primary importance in developing a base of knowledge upon which to build a risk model. Safety standards and regulations and, more importantly, practice and compliance define the characteristics of a “typical” cruise ship.

This literature review was focused specifically on cruise ships, but in many instances research and regulation do not distinguish between cruise ships and other large passenger carrying vessels, including the various classes of ferries. Efforts were made to note where regulations are made specific to cruise vessels.

Cruise vessel safety may be broken down into topics according to how the issue of safety is related to the vessels. Safety regulations, defining obligations of cruise vessels with respect to the passengers', vessels', and crew's safety is one such topic. Operational safety is another topic, encompassing the operating locations and weather conditions, as well as the general practices on board the vessel while underway, including rescue planning. Safety as relates to vessel construction, though less directly related to accident response planning, can also factor into SAR considerations. Organizational safety, including the maintenance and training policies of the cruise lines is another area worthy of discussion. These different aspects of safety are discussed in detail as noted in literature.

6.1.1 Safety Regulations

The primary set of regulations affecting the safe operation of cruise vessels is the International Convention for the Safety of Life at Sea (SOLAS), originally drafted in 1974 [13, 14, 15]. This convention covers many aspects of maritime safety and, as such, has provisions for cruise vessels among other types of vessels. In addition to SOLAS, the International Convention on Standards of Training Certification and Watchkeeping for Seafarers (STCW), 1978 [16] is an important set of regulations, which specify standards of training for all seafarers, including those operating cruise vessels. The third major source of regulation which must be noted with regard to cruise vessels is the Convention on the International Regulations for Preventing Collisions at sea (COLREG), 1972. These regulatory devices are international in nature. Canada has a history of adopting international standards for safety regulation, through participation in these conventions and other participation at the IMO. Because of this approach, Canada has incorporated these conventions into its Canada Shipping Act, 2001 (CSA2001) [17] and has made little other safety regulation regarding cruise vessels, aside from these conventions. A full list of international conventions adopted by the Canada Shipping Act, 2001 is included in Appendix A.

Currently, there are several prominent issues with regard to safety regulations affecting the cruise vessel industry. The ability of cruise and other large passenger vessels to evacuate in accordance with the established regulations is a concern [18, 19, 20, 21, 22, 23, 24]. Consequently, initiatives to regulate towards the avoidance of evacuation necessity have been put forth, through increasing survivability requirements [3, 21, 22]. The suitability of standard life saving appliances (LSA) in varying weather conditions is under review [25, 26, 27, 28, 29], as well as the required amount and standards of medical and sanitation facilities on board vessels [30]. A key issue raised in several arenas is the facility for recovery of persons from water, and the time required to do so (regarding vessels of opportunity providing assistance), relating to existing regulation [31, 32, 33, 34, 35, 36]. The major source of these drives is the IMO, but individual governments contribute to these initiatives through their own regulatory processes.

6.1.2 Construction Safety

It has been established that regulating particular aspects of ship design has had the deleterious effect of causing shipbuilders to build vessels that exploit the extremes of design allowed. This has been referred to in the literature as "compliance culture" [37, 38], in which the regulations are taken to be guidelines, rather than the minimum standards, as they are intended. This is of some concern with regard to cruise vessels as the trend has been for new cruise vessels to increase in size [7, 12, 39], with the potential to completely outstrip the safety benefit of established regulations. Vessel size is not strictly constrained by regulation for passenger vessels, and, based on some projections [39], will continue to grow. This could be problematic from the SAR perspective for several reasons. In order to make more efficient use of vessel space for revenue purposes, hull design, a fundamental factor in vessel handling has changed drastically [40, 41], and along with the use of stabilizers and azimuthal propulsion units, has altered the basic architectural properties of cruise vessels. Possibly one of the most important changes in safety regarding cruise vessel construction may be with respect to means of rescue. Recent review of Lifesaving Appliances (LSA) has revealed undesirable properties, such as high failure rate [25, 27, 28, 33, 34] and unsuitability in more extreme conditions [25, 27, 28, 33, 34]. Though not yet widespread, fundamental changes to the design of lifeboats, liferafts and marine evacuation systems (MES) have recently been subject to major initiatives for improvement as these problems are addressed.

As cruise lines focus more and more on maximizing the profit per vessel [41], cruise vessels increase in size to achieve better economy of scale [3]. When the size of these vessels increase, they deviate more from the vessels that existing safety regimes were developed to handle. Concerns have been raised with the ability of less-able persons to navigate about large vessels in emergencies [25, 29, 42], particularly where stairs are involved. The increasing size of open areas both in proportion with, and independent of, vessel size has caused concern about the stability of these vessels, and the safety of these areas in emergency situations [40]. Increased capacity alone demands that careful attention be given to evacuation scenarios, possibly reevaluating time estimates for evacuation [19, 21, 22, 43].

Hull design has changed dramatically from the early transoceanic passenger vessels to the cruise vessels in use today [41]. The more stable, slim hulls with deep draft, built for speed have been replaced with wider, shallow draft hulls built to increase vessel capacity. Stabilizers have been developed to address passenger discomfort, and azimuthal propulsion systems have been developed to increase maneuverability, but cases have already been cited where these systems fail [44], with undesirable results, negatively affecting safety. This does not mean to suggest that the vessels are implicitly unsafe, but that understanding of these new properties must be considered throughout their operating envelope.

Recent meetings of IMO working groups [20, 27, 28, 33, 34] have addressed several issues regarding the evacuation systems of large passenger vessels including, but not limited to, cruise vessels. It was established that existing lifeboat and liferaft systems were not ideal evacuation solutions for several reasons. Maintenance of lifeboat systems was noted as being onerous, possibly leading to deployment failure [20, 27, 28, 33, 34]. Deployment of the systems was decidedly non-trivial, approaching impossible in unfavourable conditions, such as in the Estonia disaster [20, 27, 28, 33, 34]. Some groups have suggested that higher quality lifeboats with accompanying deployment equipment could address some of these problems [45]. Chute and slide based systems and accompanying liferafts or lifeboats were noted to have shortcomings as well. Similarly to the lifeboat systems, deployment in less than ideal conditions is difficult at best. These systems involve significant exposure to weather, which has the potential to be extremely hazardous in consideration of colder waters [25]. Of note is that some dissatisfaction has been expressed with regard to cost, in response to suggestions that MES and LSA should be developed for use in all weather and climate conditions to be encountered by a given vessel [46, 47, 48]. Overall, a strong indication that there is room for improvement in these systems is the almost universal reluctance to conduct sea trials due to the risk of injury or death [36, 45]. This, of course, must be tempered with the reality that these systems are rarely put into use [36, 45].

6.1.3 Organizational Safety

Because the cruise industry exists to generate revenue and because safety measures have an implied cost, it is to be expected that cruise lines balance safety measures with expense [49]. Due to the commercial nature of the business, negative events (i.e. incidents and accidents) that reflect poorly on the lines affect profits, giving additional impetus to conduct operations safely. Worldwide, the cruise industry enjoys a relatively low incident rate, suggesting that this balance between cost and benefit is carefully managed by the industry.

Some issues addressed in this tradeoff may be considered to be organizational safety issues, and some research discusses the whole concept as "corporate risk taking" [45, 50, 51]. Organizational safety may be broadly evaluated as adherence to regulations and the balance between proactive and reactive solutions to potential problems. Policies on maintenance cycles and crew training are two examples of organizational safety issues. A few articles of note were recognized throughout the literature survey. The quality and amount of medical and sanitation service available on cruise vessels had several citations, particularly in light of the number of "Norwalk-type" viral outbreaks over the previous years. The organizational decision to operate in newer, more exotic locations was also mentioned, and was recognized in the proposal of this project with respect to the colder waters of Canada. A perennial issue regarding the cruise organizations, and shipping in general, is the practice of using "flags of convenience" or registration in "open register" countries. The implications of these three organizational considerations are discussed briefly as they comprise the majority of the organizational safety issues relating to cruise vessels.

In North America, cruise vessels are limited in their obligations for carrying medical personnel and facilities on board [30]. The major international cruise ship association, the International Council of Cruise Lines (ICCL), "representing 90% of the North American cruise capacity" [42], in conjunction with the American College of Emergency Physicians have developed voluntary guidelines "Medical Facilities Guidelines" [52] for medical facilities, staffing, equipment and procedures. While not mandatory, these guidelines outline the requirements for reasonable care as appropriate to cruise vessels. Some articles have concerns with the demographics (e.g. age distribution or theme cruises with focus on children or less-able persons) on board cruise vessels giving rise to particular problems that general guidelines would not address [27, 28, 53, 54]. These guidelines are also established with respect to everyday operations, and do not directly cover medical assistance in the event of a major disaster. Reports analyzing the outcome of the ferry disasters in Europe have suggested several approaches to this for a "lessons learned" point of view [35, 55].

For reasons later developed in discussion about current trends in the cruise industry, there has been a rise in the number of non-traditional cruises [3, 56]. These cruises can vary from themes on board to the destinations attended. As mentioned earlier, theme cruises may be organized for a particular demographic or function, for example, "age minimum" cruises [3] or cruises as a business conference [3]. Of potentially greater concern, with respect to safety and response, is the operation of cruises to non-traditional locations. These locations are generally chosen for their remoteness, which is a disadvantage with respect to fast response in the event of an incident [47, 48]. Furthermore, due to the infrequency of travel to such locations, charting and navigational information may not be maintained as diligently as in better-travelled areas [57]. Specifically to Canada, the increase in operation of cruise vessels along the coast of Labrador has raised concerns these types of concerns, compounded by the prevalence of cold and inclement weather.

Registration of a vessel under a "flag of convenience" or "open register" is generally done to avoid expense. Generally, this exempts the vessel from as much regulation as possible, except those required by port states in order to permit landing [8, 42, 58]. Canada and the US both require vessels registered under their flags to be built within the country and crewed by citizens of the country [8, 56, 58]. Wage laws and workers' rights laws of the countries apply to their registered vessels [44]. Taxes must be paid on income generated by the vessels only in their country of registry [42]. To avoid these expenses and restrictions, cruise lines often register their vessels under "flags of convenience". While not all "flag of convenience" states have high accident rates within their registered fleets, some do, and studies have been conducted suggesting that this is an indicator of potential risk [44, 50, 51, 59].

6.1.4 Summary Comments

In conclusion, many of the contemporary issues of cruise vessel safety have been mentioned in this section, but for the sake of brevity, not all relevant issues could be presented. As a deliverable to the project, a full categorized listing of appropriate references is presented separately for further exploration.

6.2 General Large Vessel Safety

Excepting large passenger vessels, little documentation was gleaned from general large vessel safety literature. While the literature exists, differences in safety information are primarily due to the specifics of the large vessels (e.g. bulk tanker) and were not relevant. Where safety was concerned, and the literature was relevant, the topics were covered within the cruise vessel literature. One exception to this is the issue of large passenger vessels, primarily ferries. With respect to evacuation and life saving appliances, some valuable information was also gleaned from offshore oil industry literature.

6.2.1 Large Passenger Vessels

In conducting this literature review for cruise vessel safety, most information was not limited to cruise vessels alone, but rather large passenger vessels. As noted in the various sections of this report, this information was considered in spite of its wider application because it was inclusive of cruise vessels. Some articles were specifically written with other large passenger vessels in mind (namely, ferries). While much of this information is specific to components of ferries alone, such as the visors of roll-on-roll-off (ro-ro) vessels, the methods by which the problems were approached may be applicable to cruise research.

One piece of insight gained from this work relates to vessel development. In an article presented to the Royal Institute of Naval Architects (RINA), the difficulty of designing "inherently unsound" vessels, (Ro-Ro cargo vessels) was expressed [60]. Because the vessels had prior history of use, it was perceived as difficult to suggest that other designs would have marked safety improvements. This was expressed in concert with the idea that “safety cases” (presenting arguments for vessel safety on a vessel-by-vessel basis) would provide a better environment to address these concerns as well as giving designers more freedom than under prescriptive regulation. This may have implications as cruise vessels grow larger. Designers may be solicited for designs that can be constructed to meet prescriptive regulation, but that still fail to maintain safety.

Because of the similarities in ferry and cruise vessel construction, a few ferry safety studies have been performed with direct application to cruise vessels. The sensitivity of ferry superstructure to wind conditions was discussed in the literature. Both cruise and ferries are vessels with shallow draft and large superstructure (as compared with other varieties of merchant ship)[41, 61]. In the article mentioned [61], heeling of vessels in wind was noted, and discussed as a contributing factor in capsize. While cruise vessels have provisions for stability while under way, in accident scenarios, where stability equipment may lose function, heeling due to windage could contribute to significant evacuation difficulties. A second issue addressed was the difficulty in dispersing water when suppressing fire in large open areas aboard ferries [60]. The atria of cruise vessels also share this property, and any further research into this topic for ferries would apply to cruise vessels as well.

6.2.2 Other Large Vessels

Large vessels operating in service roles are more likely to encounter cold water and ice conditions due to the nature of their tasks. This is an area of literature with potential value when considering route changes to the north of passenger vessels. While not the focus of this report, articles on cold water survival [62], and the behaviour of ships in cold and icy water [63] would prove valuable tools for rescue planning in the North. Consideration of Personal Flotation Devices (PFD) or other thermal protection suitable for cold water, as are employed on offshore oil platforms may be of use [64]. This type of protection has have been also discussed in relation to small passenger tour accidents [65]. In general, the experiences of the offshore oil industry with regard to evacuation and cold water merit additional research by those developing cold water cruise vessel safety procedures.

6.2.3 Summary Comments

In summary, there are a number of aspects of large passenger vessel literature that make it useful in consideration of cruise vessel risk exploration. In fact, many studies and regulations avoid separating the cruise ships and ferries into two groups. In terms of similarities, the number of passengers aboard and the response of the vessels' construction to inclement weather are areas where research may be shared where not already done so explicitly. Information regarding cold water as may pertain to "adventure" cruising by cruise vessels may be sourced from research undertaken by the offshore oil industry for North Atlantic operations. In addition to this, the Transportation Safety Board of Canada has made note of the dangers to persons immersed in cold water.

6.3 Worldwide Traffic and Safety Schemes

The key traffic and safety schemes observed worldwide are developed by the IMO Maritime Safety Committee through conventions. The IMO member states (166 currently) gather regularly to amend existing conventions as new developments arise, and to introduce new conventions as appropriate. Traffic schemes are primarily addressed through the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs). COLREG handles procedural considerations of traffic conduct. Safety of life is addressed by the MSC via the International Convention for the Safety of Life at Sea

(SOLAS). This convention comprises safety topics, ranging from carriage requirements for lifesaving appliances to construction specifications for safety, as well as some safety requirements for navigation. Requirements for the training of seafarers including masters, watchkeepers, engineers and radio operators is outlined by the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). Search and Rescue operations and procedures are outlined in the International Convention on Maritime Search and Rescue [66]. In terms of applicability, all of these conventions and regulations apply only insofar as countries are signatories to them. In general, however, the IMO member states comprise the large majority of vessels in service. With respect to this project, cruise vessels in particular are subjected to these regulations primarily because port states will not allow their citizens on board vessels not meeting the obligations of these international conventions [56]. As noted earlier, Canada generally develops its maritime policy based on international agreements, and incorporates them into binding acts such as the Canada Shipping Act by reference. Supplementary to these, Canada is a participator in both the Paris MOU and the Tokyo MOU, Port State Control (PSC) regimes for mutual enforcement of international regulation. These topics are discussed further to outline the effective arena of each one.

6.3.1 COLREG

The COLREG(s) or Collision Regulations are an international regulatory device designed to reduce the frequency of collisions [67]. COLREG has application to 96% of the world's merchant tonnage [14]. These regulations provide guidelines for many aspects of navigation as a formalized set of standards. Included in these standards are specifications for signalling, routeing and actions to be taken when approaching other vessels. The COLREGs specify the signalling equipment and language(s) to be used by ocean-going vessels. These regulations also indicate the areas in which traffic routeing schemes must be observed. These schemes are also listed in the IMO "Ships' Routeing" [68] publication. Most critically, the COLREGs define standard procedures to be undertaken when vessels are in sight of one another. Specific instructions are made for right-of-way in situations where arbitration is required, including passing, head-on encounters and crossing traffic lanes. These regulations do not give specific rules for cruise vessels, but cruise vessels all meet the conditions requiring the observation of the COLREGs, being chiefly that they travel on the high seas.

6.3.2 SOLAS

The International Convention for Safety of Life at Sea is generally considered the document of primary international importance regarding maritime safety [15]. SOLAS covers roughly 98% of the world's merchant tonnage [14], which includes cruise vessels. This convention is far reaching in its scope, and has provisions for a large variety of different vessel classes. Many of the SOLAS requirements have specific stipulations for passenger vessels. Chapter 2 of SOLAS stipulates the degree of watertight subdivision in passenger vessels to maintain stability and floatation for as long as possible. Requirements for the survivability of essential systems in emergency situations are defined. Construction of fire protection, detection and extinguishing facilities are also covered in Chapter 2, including boundaries to prevent fire spread and the maintenance of escape routes during fires. Chapter 3 specifies the lifesaving appliance requirements in terms of function and availability. The radio facilities required by passenger and other vessels are listed in Chapter 4. Emergency beacons (i.e. Emergency Position Indicating Radiobeacon (EPIRB) and Search and Rescue Transponder (SART)) are specified, as well as the requirement of signatory countries to facilitate response to radio contacts. Obligations of signatory countries to provide charting and SAR response are covered in Chapter 5. This includes routeing services, weather and ice patrol. Also listed are the obligations for masters and governments to ensure that vessels are "sufficiently and efficiently" manned with respect to safety. Carriage of Automatic

Identification Systems (AIS) and Voyage Data Recorders (VDR) are also required for specified vessels under Chapter 5 (including all passenger vessels). Chapter 9 requires observation of the International Safety Management (ISM) Code [69] by vessel owners or responsible representatives, including the establishment of a Safety Management System (SMS). This is considered to be the beginning of risk-based regulation for vessels, requiring planning for safety as a goal, rather than using specific metrics. This trend is discussed further in subsequent sections. Finally, Chapter 11, in two parts, provides for special measures enhancing maritime safety and security by authorizing ports to conduct inspections, and requiring the International Ship and Port Facilities Code (ISPS Code) be observed regarding security levels.

6.3.3 STCW

As its name implies, the Standards of Training and Certification for Watchkeepers defines the required courses and training that watchkeepers must complete in order to legally work onboard vessels in that capacity [16]. This set of standards finds its application on 97.55% of the world's merchant tonnage [14]. Over time, amendments have expanded the document to include other crew, over and above those who may have watchkeeping obligations. Originally, masters, mates, engineers, and radio officers were all included in the convention, as applied to watchkeeping training. Amendments have since been made [70] requiring training for emergency, occupational safety and medical aid for all seafarers. Additional amendments in 1997 [71, 72] established training requirements for crew on passenger vessels regarding crowd management, familiarization and provision of services to passengers in the interest of their safety.

6.3.4 International Convention on Maritime Search and Rescue

The International Convention on Maritime Search and Rescue has some direct application to cruise vessels beyond the definition of resources that they would expect to call upon in the event of an emergency. Chapter 5 of the convention does allow specification of ship reporting systems, to which cruise vessels may be required to report. The conditions under which vessels are expected to assist persons in distress are covered. Also, more recently, the definition of "places of safety" and process for identifying such places for persons in distress has been defined with consideration for the large numbers of passengers onboard large passenger vessels, as well as the locations in which they operate [47, 48, 57]. Other portions of this convention define the communication facilities, including the radio frequencies, codes and language that are to be employed in emergency situations. In addition to this, the convention defines the areas of responsibility on the oceans, and the countries that are responsible for them.

6.3.5 Canadian Maritime Policy

The primary regulatory instruments that are employed in Canada related to shipping are the Canada Shipping Act (CSA) [73] and the Canada Shipping Act 2001 (CSA2001)[17]. As was noted above, Canada primarily draws its maritime regulation as a party to internationally developed conventions and regulations. These conventions and regulations are put into force in Canada by the CSA documents - Clause 29 of the CSA2001 incorporates the "conventions, protocols and resolutions that Canada has signed that relate to matters that are within the scope of this Act" to be brought into force either by the authority of the Minister of Transport or by the Minister of Fisheries [17] (See Appendix A for a listing of these protocols).

6.3.6 Port State Control

Canada is signatory to both the Paris MOU [74] and the Tokyo MOU [75], and conducts inspections of vessels landing as per the provisions of both of these regimes. The Memoranda of Understanding (MOU) permit detention of vessels that fail to meet international standards as set out in the IMO conventions SOLAS, STCW and COLREG as well as the pollution convention MARPOL, International Labour Organization workplace standards and Load Line Conventions. The purpose of these detentions is generally to prevent the sailing of vessels that pose a danger to themselves, other vessels, their occupants or the environment. Vessels are detained until suitable measures have been undertaken to allow them to safely sail. Failure to observe any subsequent instruction (e.g. further refit for compliance) results in banning from the MOU signatory states.

6.3.7 Summary Comments

As noted in the discussion, Canada primarily opts into selected international regulations, rather than developing them independently. These international regulatory devices are put into action through the Canada Shipping Act (2001). Of those to which Canada is a party, the foremost with respect to safety is SOLAS, covering a broad range of topics. The STCW, which defines training standards, has been recently amended to include requirements for training crew for handling passengers in emergency situations. COLREG defines standard protocol for traffic, and references the traffic separation schemes which must be observed. The International convention on Maritime SAR defines the responsibilities of individual countries with respect to SAR. This convention primarily defines the standards of response required, which may need to be carefully examined in the context of cruising to remote areas. Finally, port state control through the Tokyo MOU and Paris MOU provides an avenue for enforcing compliance of vessels to the safety regulations in place.

6.4 Cruise Industry Management Regimes

In addition to safety regulations already outlined, many additional factors figure into the operation of the cruise industry. Generally these additional factors may be classified as either non-safety regulations or as other drivers within the industry. Among the non-safety regulations are the international conventions defined by IMO, MARPOL, the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 and the pollution provisions of the International Safety Management (ISM) Code. Within Canada, the Canada Shipping Act, 2001 [17] specifies the degree to which Canada adopts international agreements on pollution, and incorporates pollution related clauses. Other regulations affecting the operation of cruise vessels in Canadian waters include "Cabotage" laws, specifically the Passenger Vessel Services Act of the US, the working condition and salary provisions of the International Labour Organization (ILO), and the voluntary inspection of cruise vessels conducted by Occupational Health and Safety (OHSA) within Canada. In addition to these regulations, several other drivers affect the conduct and practices of the cruise industry. The world market for cruises, and influences upon it must be considered. In addition, organizational changes, including mergers and bankruptcies can effect changes among the different operators. All of these requirements affect the overall operating regime of the cruise industry.

6.4.1 International Pollution Regulations

MARPOL is the primary international regulatory device regarding pollution. Fuel carriage, oily bilge and air pollution, all of which relate to cruise vessels, are addressed within MARPOL. The volume of passengers on board cruise vessels makes provisions for black water, grey water, sewage and garbage relevant, but these sections are not universally adopted by signatories due to requirements to provide shoreside reception facilities [76]. In general, MARPOL sets out limitations on the discharge of liquid contaminants, both processed and unprocessed, often with respect to the distance from shore and travelling speed. Some "special areas" are also set out, in which no discharge of any kind is permitted. The International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004, defines the qualities required of discharged ballast water and requirements upon discharge and intake of ballast water. This was developed out of concern about the transfer of invasive species between regions of the world, but has yet to be ratified by a sufficient proportion of the concerned parties to set an “entering into force” date [77]. Lastly, the ISM Code [69], which is an overarching set of guidelines for ensuring safety of vessels and the maritime environment, also imposes pollution prevention requirements. The code requires the establishment of a Safety Management System (SMS) that undertakes a risk-based approach to prevent damage to the environment among other safety concerns. This code is required as a provision of SOLAS, and is designed to foster a proactive, owner oriented approach to effectively managing the risk of pollution.

6.4.2 Canadian Pollution Regulations

Regulation of maritime pollution in Canada as relates to cruise vessels is accomplished through the provisions of the Canada Shipping Act, 2001 [17]. The CSA2001 prohibits discharge, citing the Canadian Environmental Protection Act (CEPA)[78], and requires oil emergency plans be present on vessels, and reasonably followed. Specific to MARPOL, Canada has implemented only three annexes so far, through the CSA, [79], those relating to oil pollution, noxious liquid substances in bulk and packaged goods in bulk. Provisions are made in the CSA2001, however, that prohibit the dumping of sewage [80] and of garbage [81] in some defined areas of Canadian waters. In addition to the CSA2001, the Fisheries Act [82] and the Oceans Act [83] provide supplementary regulation regarding pollution. The Fisheries Act prohibits pollution of any kind within Canadian Waters to the extent that it is "deleterious" to fish, while the Oceans

Act assigns a pollution enforcement mandate for the Canadian Coast Guard. Unfortunately, Canadian regulations regarding pollution are not perceived as appreciably enforced outside of those regarding oil pollution [84].

6.4.3 Other Relevant Non-Safety Related Regulations

As is done in many other commercial shipping endeavours, the cruise shipping industry makes use of "flag of convenience" or "open register" vessel registration to avoid the onerous regulation and expensive crewing standards present in their areas of operation [51]. Specifically, in North America, cruise vessels are often registered outside of the US and Canada [3, 44, 56] to avoid having to crew the vessels with US or Canadian citizens respectively, and to avoid local minimum wage and workplace standards laws [42]. This places these vessels under obligation to observe "Cabotage" laws in place in Canada and in the US, which require foreign owned or registered vessels’ itineraries to have at least one international port of call. This is cited [7] as one of the main reasons for the calls on Canadian ports. Efforts to repeal these requirements have met with opposition [58]. It has been noted that proposed changes to the US PVSA [58, 85] would not likely have the intended effect on US cruising, as the providers have had a long period of acclimatization with the act, and no particular opposition to it [58]. It could be expected, however, that an impact would be noted in the West Coast of Canada, where vessels would no longer be required to land at a Canadian port during inside passage cruises. In spite of the desire to avoid the more stringent employee laws of Canada and the US, the provisions of the International Labour Organization (ILO)[56] still require the lines to submit to standards of reasonable pay and working conditions as established on a worldwide basis. Cruise vessels operating in Canada are also subject to voluntary unannounced testing of the cleanliness of their vessels by Occupational Health and Safety inspectors [56]. This program serves both the vessels' reputations, and the interests of Canadian and other passengers' health.

6.4.4 Other Cruise Management Concerns

Due to the consumer oriented nature of the industry, cruise lines must take into consideration current events when conducting operations. In the recent past, widespread illness aboard cruise vessels required action by the cruise vessels to allay fears of the passengers [86], potentially the above mentioned OHSA inspections. War and terrorism affect the mindset of potential passengers, and may restrict the portions of the world in which cruising is feasible, or affect the means of travel. Reluctance to fly following the events of September 11, 2001 has been noted [7, 8, 87], affecting fly-to-cruise plans, and the potential effect on the industry of an attack on a cruise vessel has been also been contemplated [8].

Because liability of cruise lines to passengers is not universally established in law [88], and because the vessels themselves are significant investments, cruise operators register their vessels within classification societies [89] (e.g. Lloyd's of London) for insurance purposes. Since these societies' requirements for entry are not equally stringent, this may suggest concerns with regard to the management of the cruise vessels. Choice of registers with lax requirements may indicate a reluctance to take extra safety precautions.

Over time, the tendency for cruise lines has been to consolidate into aggregates formed through buyouts. This trend is discussed later, but the implications for the market are important as well. The purpose of this is to achieve better economy of scale to increase profits. Larger market share implies more power to control the market. The side effect has been to drive smaller operators into smaller markets where competition from larger lines is limited [3]. Also, as lines approach bankruptcy, larger lines swallow up the remaining businesses.

6.4.5 Summary Comments

Many non-safety factors are worthy of consideration with respect to the management directions of the cruise industry. Regulation by the Canada Shipping Act (2001) and MARPOL set out the guidelines for pollution prevention that are to be heeded by cruise vessels. The cabotage laws of the United States helped to define the operating routes of cruise vessels by instituting port landing requirements. There is continued debate as to the effects that relaxing these laws would have in the United States. The potential exists for significant changes to port calls if the laws are changed, but it is unknown if they would be realized. Viral outbreaks affect public perception and can cause fluctuations in the number of passengers. Lastly, the continued consolidation of the cruise market has complex effects, which are better explored as a trend that has been ongoing.

7 Data Acquisition and Traffic Pattern Generation

The modelling of traffic patterns for cruise vessels in Canada was a stepwise process. First, several datasets had to be considered for the development of the modelled traffic patterns as input. Information about cruise vessel travel is held by several different organizations, at varying levels of detail both about the cruise vessels themselves, and the locations to which they travel. It is non-trivial selecting the input data for the traffic model, as the output is derivative of the quality of this input. The selected data was subjected to a preparation process to achieve the format necessary for its use in a GIS[2]. A previously developed process of "track generation", described below, was used to transform the sparse input data into spatial representations of the movement of the cruise vessels. Following the pattern generation, the data was added to other traffic data already available for analysis via MARIS.

While many studies rely exclusively on port calls to define marine traffic, this approach misses several key features of the traffic. Most importantly, when traffic is aggregated by port of call, the extent of the vessels' movements themselves are ignored. It is fairly safe to say that the risk to passengers, considering response, is more prominent when the vessels are not docked in port. The extent to which SAR resources can address the traffic can only be effectively be evaluated if the trafficked regions are known. More specifically to this project, possessing the spatial extent of the cruise traffic allows comparative evaluation with the other marine traffic data modelled by MARIN [90, 91, 92] and included as part of the MARIS [93] software package.

[2] Geographical Information System (GIS) – A computerized system for the analysis of spatially referenced information

7.1 Cruise Traffic Data Sources

Four primary datasets were established at the outset of the project as potential sources of cruise vessel traffic information. The first data source polled was the collective of reporting authorities across Canada. Because of previous work with the data from the ECAREG reporting authority in Atlantic Canada [94, 95, 96, 97], it was suggested that an overall picture of cruise vessel traffic could be assembled by aggregating the reporting authority data from the comparable sources in the other regions of Canada. Inconsistencies in the previous data received suggested that a degree of data cleaning would be required, but the reports themselves were considered worthwhile, as they are the results of legally binding reporting requirements. This was interpreted to imply a high degree of reliability. Unfortunately, there was a delay in obtaining data from the other regions of Canada, leading to the pursuit of supplementary data. Another dataset that had been used for previous analyses is that recorded by maritime insurers (i.e. Lloyd's of London) [96, 97]. This data has excellent information on the properties of vessels worldwide. Three features of this data, however, make it unfavourable as a sole source of traffic information. The first issue with the data from the insurers is the coarse spatial referencing and temporal resolution. Because insurers have limited use for any more than port of sailing and port of landing, spatial information is not present or not available from their records. Insurer data is also only guaranteed to be collected on insured vessels. This would imply either acquisition from all registries, or at least a time consuming vetting of the vessels present in the data. Finally, the cost and delivery schedule of the data is a concern, as previous requests were at a significant expense and did involve some delay. Cruise providers themselves were also considered as a source for positional data. Because of the number of different providers, however, this was considered infeasible. Without an explicit mandate to collect the route data, it was believed that some providers would be reluctant to provide detailed information about vessels. The time scale of collection may also make concurrency difficult, as the vessels' schedules are not always static. Aggregation of the data was judged to be a potentially time consuming task, with suspected inconsistencies in the formatting of the data obtained. The data source employed as a basis for the model was from travel planning publications [98, 99]. These documents, utilized by travel agents, were believed to give a reasonable upper bound to the amount of traffic expected in a given region. While planned sailings may deviate within a season (usually due to cancellations or unplanned maintenance [44]), the guides seek to present the total of all possible sailings for a given year in advance. Vessel details provided in the guides were quite extensive, particularly with the critical parameters for analysis of the vessels including capacity for both crew and passengers and overall tonnage. Positional information in the publications was not ideal, being limited to ports of call, but all available information was uniformly formatted.

7.2 Traffic Path Generation Process

In preparation for the generation of the GIS "layer" of the cruise traffic paths, the information from the travel publications was entered into a database, specifying the cruises as individual "trips", having a start port, a series of intermediate ports of call, and an end port, which may be the same as the start port (i.e. round trips). The locations of all ports were referenced in a worldwide gazetteer [100] and plotted on a world map [101] for verification purposes. The "track generation" algorithm, mentioned earlier, was developed to generate reasonable paths across water between series of points, as are present in the database created of the cruise trips. This process is discussed in greater detail in prior publications [91, 102], but in essence it consists of three steps. The first step is the selection of the data to be utilized as input. GIS layers representing the landmass and data points to be routed around the landmass are required. After these data are obtained, a "node network" must be created, consisting of a series of waypoints to be used as intermediate points between each of the data points for routing around the landmass. This "node network" must undergo some formatting to test that it is valid (i.e. it is a closed network without any "stranded" waypoints that are not connected to any others) and to pre-calculate the distance information for the network. The last step is performed by the "track generation" module of the MARIS software, developed by the MARIN Lab. In a simplified sense, this step involves inserting segments of the network in between the data points to form complete track lines that do not intersect land. The resultant data were added to MARIS for evaluation and visualization by the CCG.

7.3 Summary Comments

The traffic data available through the ECAREG and Lloyd's datasets, though suitable for some statistical analyses, was not of sufficient extent for use as a representation of cruise vessel traffic in Canadian waters. The Cruise Guide information, though suitable only as a model, was determined to be a reasonable representation of the traffic.

8 Risk Model Development

Statistical data on cruise vessel incidents and accidents is limited. This occurs for a number of reasons. Some agencies that collect this information do so for liability purposes, so there is reluctance on the part of the operators to report near-miss, incident, non-accident data [49]. Also, many organizations that collect such data do so with goals other than risk modelling or analysis, ranging from Search and Rescue reporting and self-evaluation [103] to insurance loss records [104]. In the interest of developing a risk model relevant to cruise vessels, the available data were analysed to establish risk factors. Due to the infrequency of incidents, it was determined to be inappropriate to employ standard statistical model-building techniques to characterize potential cruise risks. Expert opinion was solicited via a risk assessment workshop for use in place of statistical incident data to form a basis upon which a model was built. The model itself was formed as a holistic, hierarchical model, encompassing risk factors at varying levels of aggregation. This approach has been recently employed by Det Norske Veritas (DNV) in a model for grounding risk [10] and is also utilized by many industries where risk is the result of many complex factors [105]. Supplementary to this basic model, a number of matrices were developed to characterize cruise vessel risk in a more readily accessible manner.

8.1 Incident Data Analysis

This study collated and statistically characterized available passenger vessel risk factor data (by estimate of mean and variance). The purpose of this work was to develop the basis for a risk model for the prediction of probability of occurrence and consequence of passenger vessel marine accidents. The three major marine incident-related databases procured for this purpose were the Marine Casualty Information System (MARSIS) from the Transportation Safety

Board of Canada, Statistical Information for Search and Rescue (SISAR) from the CCG, and the Lloyd's casualty database.

8.1.1 Comparison of Marine Incident Databases

Only passenger vessel incidents are selected from these databases for comparison. Table 1 compares the number of incidents, type of incidents and passenger vessel types as reported in each of these databases. The number of incidents reported in SISAR database falls far short of those recorded in the MARSIS database and Lloyd's database has even fewer reported incidents. When the reported numbers of incidents for the period 1988 to 2001 from MARSIS and SISAR databases are compared, MARSIS has higher counts for all years.

Databases	SISAR	Lloyds	MARSIS
Period of data entries	1988 - 2001	1995 – 2003	1973 – 2003
Number of incidents	129	43	1366
Type of incidents reported	Capsized, Disabled, False alarm, Grounded, Man overboard, Medical, On fire, Other, Suicide attempt, Taking on water	Collision, Contact, Fire/Explosion, Hull/Machinery damage, Wrecked/Stranded	Accident aboard ship, Anchor lost, Capsize, Collision, Contact, Fire & Explosion, Foundering & Grounding, Grounding, Machinery Damage, Striking
Passenger Vessel Types	Cruise ship, Ferry boat	Passenger, Passenger Ship, Passenger Ro-Ro/Cargo Ship, Passenger General Cargo Ship	Barge - Passenger/Vehicle, Crew boat, Ferry - Passenger, Ferry - Passenger/Train, Ferry - Passenger/Vehicle, Ferry - Passenger/Vehicle/Train, Ferry - Other, Passenger, Passenger - Cargo, Passenger - Container, Ro-Ro Passenger Cargo Ships - Other, Tender - Personnel/Passengers

Table 1 - Comparison of Canadian passenger vessel incidents data

The differences in the incident records arise because of the objectives of maintaining these databases vary with those agencies. MARSIS is maintained by the Transportation Safety Board, which collates incident reports through an overarching monitoring of almost all transportation accidents and incidents across Canada. As a result, this database has consolidated data over 30 years from 1973 to 2003, relying on 56 independent sources for reporting marine incidents, and thus accounting for the relatively large quantity of incident data in its database compared to that of SISAR and Lloyd’s. Since TSB is the official regulating body of all modes of transportation in Canada, it could safely be assumed that their figures are fairly representative and all inclusive. SISAR is a database maintained by Canadian Coast Guard's Search and Rescue team, which reports only incidents that it has directly or indirectly assisted as part of its SAR response. It seems most likely that the CCG does not record most incidents not requiring SAR response. This might explain why SISAR database has fewer incidents when compared to MARSIS. The Lloyd's database obtained has worldwide extent, but focuses on collating merchant fleet incidents on a liability basis, and hence Lloyd’s would not have all Canadian passenger vessel incidents recorded in its database.

8.1.2 Risk Factors

The voyage of vessels through open seas is influenced by the atmospheric and sea conditions; abnormal wave heights, very cold temperatures and high wind velocity can affect the stability of ships while navigating [106] and during evacuation procedures [25] in the aftermath of accidents, thereby increasing the severity of the accidents. Visibility is also influenced by marine weather conditions. Many incidents are reported relating weather as an associating factor to the incidents. The IMO Secretary General has pointed out that over a five-year period about 30% of ship losses have occurred in bad weather [107]. As an example, weather related risk factors include, (i) Daytime, (ii) Visibility, (iii) Sea-states, (iv) Wind speed, and (v) Wave height. The estimated probabilities for the likely states of risk factors are presented in Table 2. For detailed presentation of results and analysis, see the full report “Risk Factor Characterization For Large Passenger Vessels” [108].

8.1.2.1 Daytime

The MARSIS database provides the "timestamp" of passenger vessel accidents, which may be used for frequency counts of accidents occurring in daytime and nighttime. While the location, time, and time zone of accidents vary widely, local time is taken into account within the data when determining whether an accident is associated with day or night. An algorithm developed by NOAA[3] was employed to obtain the local sunrise and sunset timings on the days of accidents. Results indicate that 80% of the time, accidents happened during the night.

8.1.2.2 Visibility

Marine weather can affect visibility, signal transmission, and other external conditions. The MARSIS database provides numerical visibility distances for all the incidents. It shows for 75% of the time, the visibility is 10 nm, and for most of the remaining time, visibility is 20 nm. Entries drawn from the historic records of the COMAR[4] weather database, however, are qualitative descriptors, hence categorized, as "Fair", "Fair-Poor", "Poor". While roughly 50% of the time visibility was "Fair", one-third of time visibility was "Poor".

8.1.2.3 Sea state

Sea state can affect the stability of the ships - damaging the hull of the ships, decreasing the time-to-sink, cause capsizing and sinking of vessels when combined with abnormal weather conditions, etc. MARSIS has 17 different types of entries to describe the sea state observed in the Atlantic Ocean, classified into three major states categories - light, moderate, and heavy. Almost 80% of the time, sea state appears to be "Low", and for 10% of the time, it is "Heavy".

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[3] National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce - http://www.srrb.noaa.gov/highlights/sunrise/calcdetails.html

[4] COded MARine weather forecasts, maintained by Environment Canada

8.1.2.4 Wind Speed

The COMAR database has wind speed (Knots, 1 nautical mile/hour) for the years 1996 to 2003. About 50% of the time, the wind speed is 30-45 nm/hr with considerable degree of variability. MARSIS was also noted to maintain records on Wind Speed, with a fill rate of 70.66% for that database field. Results are shown in Table 2.

8.1.2.5 Wave height

Another weather component that is perceived to be affecting the safety of ships is the wave characteristics (wave height, period and length, and swell height, period and length). The Environment Canada COMAR database was also used to characterize the wave heights.

No.	Risk factors	States	Mean Proportion	States	Mean Proportion
	Databases	COMAR		MARSIS	
1	Daytime	Day Night	0.5 0.5	Day Night	0.20 0.80
2	Visibility	F FP P	0.47 0.21 0.33	10 20 30	0.75 0.23 0.03
3	Sea state	Low Moderate Heavy			0.79 0.11 0.10
4	Wind speed	0-15 15-30 30-45 45-60	0.19 0.19 0.48 0.27	0-15 15-30 30-45 45-60	0.69 0.22 0.05 0.04
5	Wave height	1 2 3 >4	0.23 0.34 0.22 0.21		

Table 2 - Summary of estimated probabilities

It should be noted that COMAR had daily weather data, which was then averaged over the years - these estimates are likely to be of overall average representation of Atlantic weather states. MARSIS entries for weather are incident-and-location specific, in the sense that those factors were observed where and when the incidents occurred. Because of these differences, a direct cross-comparison of these weather estimates cannot be made.

8.2 Risk Assessment Workshop

Due to the limited number of historical cruise incidents, particularly in Canadian waters, it was deemed unreasonable to draw conclusions based on the numbers available. Of the remaining options available for obtaining information about cruise risks, expert opinion was decided upon as the most accessible route. Physical modelling was avoided as being too small-scale for the scope of the project. An Expert Opinion Elicitation workshop was conducted by MARIN, June 14-15, 2005, which called for the participation of marine engineering professionals, marine policy and decision makers, Coast Guard personnel, and administrators, researchers, and consultants of Canadian shipping industry. The objective of this workshop was to collate risk information of events and factors leading to marine accidents, and based on the workshop inputs to establish the following:

- Estimates of the probabilities of occurrence of specific risk factors with respect to Large Passenger Vessels (LPV)
- The influence of these risk factors on the occurrence of different incident types
- Relative consequence severities of different incident types, considering LPV

In the previous section, statistical analyses were completed only for the very few weather risk factors for which data were available. In order to characterize other risk factors, expert opinions were elicited through this workshop. The following section summarizes the main findings of workshop proceedings - the full workshop report covers methodology, results and discussion [109].

8.3 Expert Opinion Elicitation

The inherent risks of marine accidents primarily arise from the uncertainty and variability of the contributing causal factors. The usual methods, such as multivariate statistics fall short of efficiently handling such large numbers of risk factors with complex inter-relations between them. Three approaches exist to characterize these risk factors: (i) for factors with sufficiently large and reliable historical data, standard statistical principles can help estimate the frequency of each possible state of occurrence with descriptive statistics; (ii) physical or mathematical models can be developed for risk factors to estimate likelihood of incident occurrences; (iii) for factors for which it is improbable or impossible to collect a sufficient amount of data for characterization, an alternate heuristic approach such as Expert Opinion Elicitation may be appropriate.

When it is improbable to measure and quantify risk factors, the opinions and judgments of experts are valuable for estimating the relevant parameters. Though this method does not rigorously apply any mathematical principles in eliciting the opinion and judgment of experts, it is the most pragmatic approach to consolidate the firsthand information on the salient risk factors.

8.3.1 Risk factors

Experts were provided with questions and probability choices in a questionnaire format, and were asked for their responses through a combination of electronic and paper submission. The questionnaire focused on three main areas: risk factors which may contribute to cruise ship incidents, quantitative assessment of incidents, and evacuation scenarios. The questions posed required the experts to judge the probabilities of various pre-defined states occurring for each of the risk factors or situations.

Analysis of the workshop proceedings yielded four separate types of results: (i) probability estimates for individual risk factors, (ii) probability estimates for incident occurrences, (iii) estimates of the influence ratings of risk factors on various accident types, and (iv) estimates of accident consequence severity. All of the results were analysed by our panel of experts. The observations presented in this section are intended to reflect the general assessment elicited from the experts at the workshop. Although the discussion often mentions probabilities, it is **important to recall that these are the mean estimates of the experts' responses, and not measured values**.

The following discussion is grouped by the risk factor categories. Summary statistics documenting estimated probabilities and their standard deviations, and overall statistics for individual, issue-based, and multiple-part questions are available in the main report [109].

8.3.1.1 <u>Danger detection</u>

In Atlantic Canada, LPV encounter varied weather. Experts' judgments on Atlantic Canada's marine weather conditions indicate that only 33% of the time is the weather 'fine and clear'. As much as 65% of the time, vessels are subject to a small craft warning or greater. Nearly 10% of the time, these vessels are subject to a storm or hurricane warning. Vessels travelling through Atlantic Canada often experience limited visibility. Nearly 25% of the time, the visibility is less than one nautical mile. More than one third of the time, vessels encounter fog. Furthermore, it was noted that LPV transit predominately at night.

Experts suggest that the bridge view of LPV is considered to be “standard or better” on 90% of the vessels, indicating that typically LPV are very well-designed. Aids to navigation are generally good within the operating environment for LPV. However, 15% of the time the aids to navigation are not perceived to be as good as they could be. There is some question as to whether this is a problem with the aids to navigation, or whether the vessels are traveling in lower trafficked areas and that aren’t marked to the same level as large ports.

Overall, the officers of the watch (OOW) onboard LPV are able to detect danger most of the time despite frequently travelling in unfamiliar waters, at night and in often-poor visibility conditions. In terms of navigational tools, most of the time LPV have appropriate charts (88%) and have functioning, properly tuned radars (85%). Signal quality of radar appears to be average and good for 90% of vessel transits. ECDIS is installed on all LPV and appears to have a very low failure rate (0.2%). With ECDIS, the OOW will detect navigational dangers almost all the time. Radar display greatly aids OOW in detecting dangers at all times. Taking advantage of the navigational aids on the bridge, the OOW would almost certainly be able to respond to navigational hazards encountered. Not surprisingly, the OOW would have a lower danger detection probability if forced to rely on conventional paper charts (73% as opposed to 99+%).

Automatic Identification Systems (AIS) usage was noted to be a contentious issue throughout the workshop. Concerns were raised that AIS was being used for purposes for which it was not initially designed. The estimated probability that AIS was being used for navigation and collision avoidance was 55% though, as designed, AIS was intended for identification alone. The information available through AIS was thought to be incorrect about 23% of the time, or at least not fully correct and complete. The concern was that the OOW might make a decision based on poor information that could lead to an accident scenario. The probability of detecting danger with AIS was significantly lower than other available navigation resources, only being able to detect danger 41% of the time.

Grounding and collision alarms do not seem to be very effective in assisting the OOW to detect danger. This is likely because the OOW would detect grounding or collision using other instruments first, and that the alarm would only give enough warning to allow the OOW to make an emergency change in course. Given the available bridge resources, the OOW will detect danger nearly 100% of the time. This likely plays a role in the low incident rate for LPV.

8.3.1.2 Management Factors

The safety culture of LPV is perceived to be above standard, with only 7% of vessels falling into the 'fair' safety culture group, and no vessels were thought to have a poor safety culture. Maintenance routines were followed 85% of the time. Paper charts onboard LPV are corrected well above standard (80% were above standard), slightly better than electronic chart corrections (73% were above standard). No explanations as to why paper charts were updated more quickly than electronic charts were given, but it was established in discussion that the processes are separate. Due to the nature of the LPV industry, passage planning was well above standard. In general the safety culture is exceptional.

8.3.1.3 Human Factors

Frequently (46% of the time) the OOW operates under a high workload. There is a very real possibility that the OOW could be fatigued. The OOW is also reported to be frequently experiencing moderate to many distractions (63% of the time). At times, the OOW is required to perform non-navigational tasks in addition to navigational duties. Roughly half the time, the OOW would be working in low distraction levels. For 17% of the time, they would be working in high distraction levels. Similarly, the OOW would be working in a high stress environment 17% of the time. However, less than 40% of the time OOW would be in a low stress environment.

Surprisingly, for one fourth of their transit time, OOW were assumed to be incapable or unfit to perform their duties (6% of the time they would be incapable and 21% of the time being less capable). The most likely causes for incapacitation are the result of sickness, seasickness or fatigue, rather than intoxication; nonetheless, these figures are somewhat alarming. The performance level of the OOW was typically average. Nearly 9% of OOWs were believed to perform poorly. OOW on LPV in general appear to be working under high stress, significant distraction levels, and pressures of non-navigational tasks, resulting in high fatigue levels, average performance ability, and occasionally be considered incapable or unfit to perform their duties. Despite these factors, it is believed that OOW detect danger and act appropriately 99% of the time.

8.3.1.4 Technical reliability

The steering and propulsion systems of LPV are very well designed, and don't tend to fail. The loss of vessel stability is a very rare event. In addition, LPV make use of autopilot 66% of the time.

8.3.1.5 Support

Other officers, Vessel Traffic Services (VTS) and pilots support the OOW. Communication between the OOW and support is generally good. Where pilotage is required, a pilot is almost always available. In the rare cases where a pilot is unable to board the vessel, they will be available via radio. A pilot would be able to identify relevant dangers almost all of the time. While underway, nearly 35% of the time cruise vessels operate without an auxiliary officer on the bridge with the OOW. Thirty percent of the time, the OOW would be the only person on the bridge that could serve navigational vigilance. Over 30% of the time the vessel would be monitored by VTS, which would be able to warn the OOW of dangers more than 60% of the time. Navigational vigilance helps to warn the OOW of danger 77% of the time.

The following incident types are in order from most likely to least likely according to the experts: Accident Aboard Ship, Fire/Explosion, Allision, Fall Overboard, Bottom Contact, Grounding, Accidental Taking on Water, Collision, Premature / Accidental Departure, Sinking, Capsize. The overall likelihood of having an incident was assessed to be rare, or very unlikely. Interestingly, rudder/propeller damage was assessed at similar occurrence rates as fire/explosion.

Thirty percent of grounding incidents would result in minor or no damage, however, most (61%) groundings resulted in major vessel damage. Fewer than 10% of grounding incidents would result in catastrophic vessel damage. In incidents where a vessel takes on water, most of the time (82%) it would stay afloat. For the remaining 18% of the time a vessel would be 3 times as likely to stay afloat longer than 30 minutes. As noted earlier, SOLAS requires a vessel to be ready to evacuate in 30 minutes (not to have evacuated the vessel in 30 minutes). In instances where a vessel sinks in less than 30 minutes a great number of passengers would not be able to evacuate in an orderly fashion.

Mandatory evacuation drill performance was assessed at standard level. Both substandard and above standard drills were estimated as occurring less than 15% of the time. Most of the time (84%) the means of evacuation exceeded applicable standards. This is a good sign, however, it is concerning to note that evacuation times were expected to take longer than the standards allow 71% of the time with only 29% meeting or exceeding the evacuation time standards.

With respect to the ability or inability to leave ship during an evacuation, several important factors were discovered. If people are called to muster stations, 18% of the time they do not abandon ship. Nearly 25% of the time they cannot evacuate due to the precarious conditions. Thirty percent of the time the evacuation proceeds successfully. Nearly 25% of time, evacuations fail or run out of time to evacuate. Given the weather conditions experienced and the state of the vessel, about 50% of the time that people muster in an orderly manner the evacuation fails to proceed properly and 50% of the time the evacuation proceeds.

Evacuation from a vessel implies a destination out of harm’s way. Most evacuations are to a lifeboat (35%) or a life raft (30%). A further 23% of people will 'evacuate' to a safe place on the vessel. Nearly 13% of the time people are required to evacuate into the water. This is of concern, as in Atlantic Canada the water temperature is frequently below 15C. In a LPV incident, a fatality is expected to occur 30% of the time.

Due to the nature of LPV transits, their routes are frequently far away from response units. The experts indicated that a response vessel would rarely be able to get to the vessel in less than 1 hour. About half of the time a responding vessel could arrive in 1 to 5 hours, and the remaining 40% of the time assistance would arrive on scene after 5 hours. In the event of a LPV evacuation, persons may be in life rafts, lifeboats, or the water for a significant period of time. Unfortunately, the geography of the East Coast shoreline makes it infeasible to get a shore-based resource on scene in less than an hour, particularly in some of the remote places LPV transit. It is alarming to note that northern waters tend to be much colder and much more remote from possible responders, yet it is increasingly while also attracting cruise vessel transits with due to its striking scenery.

8.3.2 Accident Probability Estimates

The participants' estimates of accident probabilities are given in Table 3. These were obtained by computing the average[5] of the subjective estimates provided by the pool of experts. The resulting order of most frequently occurring accidents is: *accident aboard ship*, *fire / explosion*, *allision*, *fall overboard*, *bottom contact*, *grounding*, *foundering*, *collision*, *accidental departure*, *sinking*, and *capsizing*.

Accident Types	Estimated of Probability of Accident
Accident aboard ship	5.59E-03
Fire / Explosion	1.43E-04
Allision	6.49E-05
Fall overboard	4.22E-05
Bottom Contact	3.16E-05
Grounding	1.78E-05
Foundering	1.78E-05
Collision	1.33E-05
Accidental departure	4.22E-06
Sink	3.16E-06
Capsize	1.54E-06

Table 3 - Accident probability estimates

8.3.3 Risk Factor Influence

A matrix was prepared for the expert participants' input of quantitative estimates on the ‘Influence of Risk Factors on Accident Types.’ Experts rated the influence of risk factors on the severity of accident consequence using a provided form. The resulting ratings were averaged over 15 participants to yield results that indicate the relative influence of risk factors classes on accident types (See Appendix C for table). In general, risk factors such as *human factors*, *management factors* and *weather*, were rated to be influential in that specific order, across all of the accident types. In all types of accidents, *human factors* were considered to be the primary and secondary influence factors. *Management*

[5] Specifically, the geometric average: the sum of all values divided by the number of values

factors seem to affect most of the accidents at the secondary and tertiary levels. *Weather* seems to particularly affect accidents such as *foundering*, *capsizing*, and *sinking* as a primary risk factor.

8.3.4 Consequence Severity

Another matrix, 'Consequence Severity', was compiled to explore the relative severity of specified accident types on a range of consequences. The consequences of accidents are damages incurred to resources. The primary resource categories addressed in this exercise were *people*, *property*, *environment*, and *financial*. While this categorical list is not comprehensive, items within the list were considered broadly representative of the resources most subject to damage following an accident involving a cruise ship (See Appendix D for table).

In estimating consequence severity, experts were asked to assume that consequences include all costs, from the moment of incident occurrence until incident resolution (e.g. vessel repair, legal fees determined and paid, environmental effects tallied).

Based on the methodology employed, the most severe accidents as rated by pool of experts are *capsizing and sinking*. Following this are: *collision*, *fire / explosion*, *grounding*, *foundering*, *allision*, *bottom contact*, *accident aboard vessel*, *fall onboard*, *accidental / premature departure*, and as the least severe accident, *near-collision*, in that order (See Table 4 below).

Accident	**Severity Ranking**
Capsizing	81.54
Sinking	78.83
Collision	73.44
Fire/Explosion	68.63
Grounding	56.65
Foundering	55.26
Allision	53.78
Bottom Contact	38.922
Accident aboard vessel	28.00
Fall onboard	27.55
Accident/Premature Departure	23.57
Near-Collision	11.33

Table 4 - Severity ranking of consequences for marine accidents

8.3.5 Consequence-Probability Analysis

The overall objective of this risk assessment is ultimately to estimate the risk of events. These estimates may be compared with socially acceptable levels, in order to alert the industry to improve the infrastructure and safety procedures so that higher levels of risk can be reduced. Risk profiles are developed here to show the frequency of incidents in combination with their severity of consequence. Both the probabilities and consequence severity were calculated using the experts' judgment. Appendix E is a figure included to present the risk profile of the major cruise vessel accidents (note that the vertical axis is logarithmic). As determined using the experts' opinions, these risk profiles can be viewed as a square with four quadrants, low probability-low consequence, low probability-high consequence, high probability-low consequence, and high probability-high consequence. *Accident aboard ship* incidents have relatively high probability and consequence among all accidents, while accidents such as, *bottom contact*, *capsize*, *fall overboard*, and *accidental departure* fall in the low probability-low consequence segment. *Collision*, *fire* / *explosion*, *allision* and *sinking* have high consequence ratings despite relatively low probability occurrences.

8.4 Summary Comments

The likelihood of an LPV incident occurring is extremely small. This is in large part due to the good design of LPVs, quality crew, and the installation of quality navigational aids. However, the probability of an incident occurring is not zero and as the number of vessel-movements increase, so do the chances of an incident occurring. Several factors arose as possible contributing factors to an incident, such as crew fatigue and over-extending the role of AIS in collision detection. Some incidents, such as fires, are difficult to prepare for as they don’t exhibit a single root cause. While the number of incidents occurring is reassuringly low, the outcomes of an incident could be catastrophic. The sheer numbers of passengers aboard make evacuations difficult. Evacuations are not only difficult, but can also result in additional casualties following the initial incident. Furthermore it is not always possible to evacuate successfully into appropriate lifeboats or life rafts meaning that some survivors might be forced to evacuate into the water.

It is difficult to get response units on scene quickly, particularly in remote areas. This complicates the task of rescuing the survivors as they disperse, and additionally reduces the likelihood of rescuing persons in the water. Given the low incident rates observed, and the outcomes of the incidents if they were to occur, the focus of LPV safety should be on ensuring the vessel stays afloat as long as possible, and that an incident is contained to as small an area as possible. It is in the passengers’ best interests to remain aboard the vessel as long as it is safe. The evacuation and retrieval phase is particularly dangerous and should be avoided when possible.

8.4.1 Limitations

Due to unavoidable constraints in organizing this risk workshop, the shortcomings of the small size of expert group and limited time availability narrowed the scope of workshop to focus only on specific risk factors and accident types. Also, with the subjective assessment of probabilistic estimates of factors, events and accidents, these results should be interpreted within the preliminary nature and scope of this pilot study.

9 Cruise Trends

Trends can be established for many different aspects of the cruise industry. Some characteristics have been constant since the cruise industry began, while others are more recent. The most relevant trends to this project are in the arenas of cruise vessel incidents and cruise vessel traffic. Cruise vessel traffic, in particular, has been historically subject to notable trends. The characteristics of the cruise vessels themselves, when viewed in terms of construction exhibit trends. Many of these are relevant to search and rescue, either directly, as they impact rescue efforts or indirectly, as they may influence incident occurrence. Policies of the cruise industry are subject to trends, which may range from standard operating procedures on vessels to the reactions to market changes. Finally, regulation of cruise vessels exhibits some trend characteristics, as the approaches that governing bodies take to legislation change over time. Within these trends, some are numeric in nature, such as the number of passengers or tonnage of vessels, while others are more subjective, and cannot be expressed with numbers alone, such as the tendencies of safety regulation. Whether it is due to vested interest or different projections for the industry, different organizations have different views on the future of the cruise industry. In cases where expectations are different, each is noted. Where appropriate, notes are made about how theses different in projections may affect SAR planning. Each of the main trend topic areas are summarized, as depicted in the literature and data obtained over the course of this project.

9.1 Cruise Ship Incidents

Worldwide, the cruise industry is subjected to few incidents [1]. In addition, it is suggested that the overall number of merchant vessel incidents (including cruise) may be decreasing [106, 110]. This is particularly fortunate, because some past cruise and large passenger vessel incidents have involved significant loss of life [41, 111]. The more serious incidents, when they do occur, tend to be in regions of the world where monetary constraints may hamper safety efforts [51, 59]. Incidents, such as hijackings are generally experienced in areas where piracy is known to exist, and some vessels in those areas take specific measures to mitigate this risk.

Year		**Passenger (Cruise)**	**Passenger**
1994	Number	2	2
	Avg. GT	43334	26486
	Avg. Age	45	42
	Lives Lost	4	0
1995	Number	0	10
	Avg. GT	0	18980
	Avg. Age	0	30
	Lives Lost	0	3
1996	Number	1	3
	Avg. GT	2204	14716
	Avg. Age	34	20
	Lives Lost	0	4
1997	Number	2	1
	Avg. GT	39149	491
	Avg. Age	52	44
	Lives Lost	0	0
1998	Number	1	2
	Avg. GT	676	549
	Avg. Age	71	26
	Lives Lost	31	40
1999	Number	0	2
	Avg. GT	0	3019
	Avg. Age	0	14
	Lives Lost	0	74

Table 5 - Total Losses by Type (1994-1999) [1]

Within Canada, SAR incidents involving cruise vessels are often medical evacuations, involving individuals with pre-existing conditions. These incidents are generally handled by airlift or by transfer to a nearby vessel. Incidents have been experienced in Canadian waters with potential to become serious accidents, but favorable conditions have generally prevailed, and significant human casualties have been avoided [112]. It has been proposed that this trend has been an artifact of the relatively low cruise traffic counts in Canada, and that the potential for more serious accidents is real. As a baseline, overall maritime accidents are few in number (approximately 500 in 2004 [113]), and relatively constant in Canada over the past few years. Corresponding traffic, however, has increased over this period, effectively reducing the rate of incidents. Marine fatalities are also low, between 10 and 30 per year, and constant over the previous years, as well [113].

9.2 Cruise Ship Traffic

Worldwide, there has been an ongoing trend of increasing cruise volume for a number of years, which is projected to continue [3]. Because the U.S. dominates the cruise market [56], the chilling effect of the events of September 11, 2001 on recreational air travel [3] has increased the number of vacationers opting for cruise vacations [3]. In addition to this, the European cruise industry has been growing, and is estimated to possess the potential to support further growth in the future [3].

	2000	**2001**	**2002**
Number of Ships	163	167	176
Lower Berths	165381	173846	196694
Global Passengers	8000000	8400000	9220000
Passengers Residing in U.S.	6570000	6800000	7510000
U.S. Embarkations	5310000	5900000	6500000

Table 6 - Operating Statistics [114]

In concert with worldwide trends, there has been a perceived rise in cruise ship traffic in Canada in recent years, as cited by the Chairperson of the TSB in the Annual Report to Parliament for 1999-2000. In reality, increases in cruise traffic have not been as large as anticipated. Some regions have certainly seen increases. Atlantic Canada has been experiencing growth for several years, with Halifax being the primary East Coast port [2, 5](see Table 7). Projections suggest that Halifax will continue to grow in number of landed passengers, even in the absence of further port development [5]. Cruising in the Atlantic region has even been extended into the "fall colour season", where cruises seek to capture the colour of the leaves in September and October [56]. In addition to the primary port landings in Atlantic Canada, there has been some increased traffic to the more northerly outports along the Labrador coast, and extending into the Arctic [56]. This activity is exemplary of the growing trend toward “adventure” and "niche" cruises. These are growing subset of the cruise market catering to specific groups of passengers that are not interested in the standard cruise itineraries. Included in these more specialized cruises are the Great Lakes "pocket cruises" (e.g. between Quebec and Montreal or Kingston and Rochester). The number of these cruises is also projected to rise [56]. On the West Coast, some ports in British Columbia have been posting gains. This increase has been offset somewhat by the reduced number of calls to Vancouver, Canada's primary cruise port of call. Since reaching a peak in 2002, cruise calls to the port of Vancouver have decreased somewhat (see Table 7).

Year	Vancouver	Montreal	Quebec City	Halifax	Saint John
1992	449,239	34,872	41,141	30,112	5,500
1993	519,942	30,626	38,642	30,917	12,379
1994	591,409	33,920	36,401	37,717	23,629
1995	596,724	27,384	38,981	30,257	12,226
1996	701,547	19,078	21,464	36,584	8,543
1997	816,537	29,324	36,569	44,328	19,813
1998	873,102	32,583	43,838	47,987	28,418
1999	947,659	18,306	34,628	107,837	40,000
2000	1,053,989	25,200	35,855	138,313	101,410
2001	1,060,383	23,900	48,776	160,241	88,190
2002	1,125,252	38,000	66,365	157,036	71,168
2003	953,376	33,600	59,000	170,425	83,946
2004 (prelim.)	929,976	40,000	62,000	212,000	138,622

Table 7 - Transportation in Canada 2004 Annual Report [2]

This trend has been linked to the increased homeporting of vessels in Seattle [113], which are making their international landings as per the U.S. cabotage laws in other British Columbia coastal ports.

9.3 Cruise Vessel Construction

Oft quoted in literature is the tendency towards larger, higher capacity new cruise vessels [8]. More thorough examination indicates that increasing size is not the only changing characteristic in new cruise vessels, nor is size increasing for all new vessels. Faster vessels are being built to travel to distant locations without the use of airlines [3, 8]. This is in response to continuing reluctance of large numbers of U.S. passengers to fly-to-cruise, as was more common in the mid and early '90s [115]. The increased speed primarily allows for greater range of destinations within the Caribbean for cruises of established length. The increased speeds allow for more flexibility in the potential relocation of cruise vessels in off-seasons. The cabins on vessels are being built larger and a greater proportion with balconies in response to passenger demand [3, 41]. In addition to the cabins, common areas are also being designed in larger sizes with more open space [12]. New vessels are also quickly adopting new technologies, including azimuthal propulsion units for better control in congested or confined areas and enhanced pollution management systems to meet pollution regulations in light of the increased number of passengers on board [56, 116]. The common practice of retrofitting older vessels is being phased out for two main reasons. The coming into effect of increasingly more stringent fire regulations is making refits cost-prohibitive [117], while the revenue generated in the cruise industry is generally held by the consolidated cruise lines, which are primarily concentrating on new vessels. It has been noted though, that this trend may reverse if a larger number of small cruise operators believe it is in their financial interests to take on the operation of some of these vessels in "niche" markets where the larger lines are not competitive [117]. Between 2000 and 2005, cruise vessel capacity has increased 50%, to approximately 100000 beds [8]. Within these vessels, the tendency has been toward vessels with large numbers of berths and large tonnages [115, 118], as noted in the table of vessels on order as of January, 2002, below.

	Total Fleet					
Group / Cruise Line	**Ships**	**GT**	**GT/Berth**	**Berths**	**Avg. GT**	**Avg. Berths**
4 Main Groups	31	3006656	41.7	72046	96989	2324
Smaller North American	3	203000	66.7	3044	67667	1015
Smaller European	3	178600	37.6	4746	59333	1582
Smaller Asian	0	0	0	0	0	0
Total	37	3388256	42.4	79836	91574	2158

Table 8 - State of Order Book (January 2002) [3]

These increases in tonnage and number of berths are usually executed at the expense of hull form which, in turn, is compensated for by stabilizers. Economy of scale and footprint (floor space required) of services in demand (by passengers) are the major driving factors behind the size increases [3]. Limitations on size are at this point due to financial constraints of the lines, rather than architectural impossibility [3, 41]. Following the recent burst of construction, however, the number of vessels on order is relatively few. This may be due to capital constraints [41], or, as others have suggested, the difficulty in making use of available capacity without resorting to fare cutting [8].

9.4 Cruise Industry

Trends concerning the cruise industry tend to be influenced by revenue. A quote from Carnival Corporation’s VP of External Relations, Tim Gallagher, “The reason why Carnival Corporation makes the kind of money we do is because we pay great, great attention to controlling our costs"[6], suggests that this is not a casual relationship. Recent trends in industry are toward consolidation. In general, three major companies dominate (North America particularly): Carnival Cruise Lines, Royal Caribbean Cruise Lines and Star Cruises (See Appendix B for a breakdown of their component companies). The drive toward consolidation is in the interest of economy of scale [3]. Increased buying power and limited competition lead to increased profit.

Aside from consolidation, the other focus changing the cruise industry is the search for new markets of cruise customers. There are two trends in this area, a focus on new cruise types and locations, and attempts to change the demographic of cruise passengers. New cruise locations, such as the East Coast of Canada and Greenland are of interest to the cruise industry to attract different strata of the population as customers. "Adventure" cruises, with themes of expedition and exploration, and travel to remote areas, are pursued by smaller cruise providers who seek to obtain a share of the cruise market without directly competing with the large aggregate cruise lines [3, 119]. Because the nature of these cruises is to reach areas not covered by traditional cruise lines [119], this may lead them into increasingly remote areas. Attempts by the cruise industry to change the basic demographic of cruise passengers have taken several forms. Shorter duration, less expensive cruise itineraries have been developed to cater to the limited free time and expendable income of younger generations. Family oriented cruises have also been created both to increase the potential market immediately, and to influence future vacation habits among younger passengers [3]. This process has been ongoing for a number of years, and the effects are beginning to become apparent (see Table 9).

[6] [8] Tim Gallagher, Carnival Corporation's VP of Ext. Relations)

Demographic		1992	2000
Sex (%)	Men	45	51
	Women	55	49
Age (%)	25-39 years	44	43
	40-59 years	35	44
	60 years or over	21	13
	Average age (years)	44.3	43.0
Children in the Family Unit (%)	Yes	43	51
	Holiday with children	65	52
Number of Family Members	1-2	47	48
	3-4	41	38
	5 or more	12	13
	Average	2.9	2.9
Annual Income (thousands of US$)	20-39	45	30
	40-59	34	31
	Over 60	21	39
	Average	47.7	60.4
Education (%)	GCSEs	25	24
	A-Levels	75	76
Marital Status (%)	Single	30	31
	Married	70	69
Employment Status (%)	Employed	74	76
	Unemployed / Retired	26	24

Table 9 - Demographic Profile of Cruise Passengers in the U.S. and Canada [3]

Inexpensive cruises are also associated with the disinclination of cruise operators to operate vessels at less than capacity. It has become customary to discount cruise fares as the date of sailing approaches. This prevents the undesirable perception of a less popular ship, but can be a source of ire for passengers that pay premium price [3]. At the same time that these younger markets are pursued, older demographics are sought for their greater free time and expendable income resources. Some lines even go so far as to place minimum age restrictions on their cruises (e.g. Swan Hellenic, Saga).

9.5 Cruise Vessel Regulations

Holistically, the major trend in regulation for all vessels is the change of focus from reactive regulation to preventative regulation. New regulations are more often geared to require planning for safety (e.g. International Safety Management (ISM) Code [38, 56, 120]), rather than compliance to specific standards. Safety management practices are not intended to entirely replace existing standards, but to discourage the "compliance culture" that ensues when organizations or industry focus heavily on meeting regulatory criteria. This type of approach is also designed to mitigate the restrictive effects of prescriptive regulation on new, alternative design as well [38]. Development of regulation has also begun to make use of risk management techniques. Unfortunately, due to the subjective nature of this type of regulation, the issue of enforcement across international jurisdictions with different views could become complicated [60]. The Formal Safety Assessment (FSA) approach coming into use through the IMO is the primary example. This process involves risk analyses conducted on environments with a perceived need for regulation to establish what portions of the environment would be best addressed by regulation, and the type of regulation required [49]. With regard to specific regulation, the Large Passenger Vessel Workgroup at IMO has been actively reviewing maritime policy involving large passenger vessels, including cruise vessels (see project reference list for complete index).

The issue of "Cabotage" laws, though not a trend in itself has the potential to affect the development of Canadian cruise vessel traffic. The port landing requirements of the US "Passenger Vessel Services Act of 1886" (PVSA) for cruise vessels not registered in the US have provided Canada with a number of cruise vessel landings seeking to meet these requirements [8, 56]. On several occasions, attempts have been made to repeal this piece of legislation, though usually with the intention of drawing the cruise vessel industry into US jurisdiction

[58]. Due to the expense in this operation for the cruise industry, it is unlikely that this situation would occur without drastic alterations to the North American cruise business model. If the foreign port requirement of the cabotage laws was somehow obviated without the dissolution of the cruise industry, it could have dire consequences for cruising in Canada.

9.6 Summary Comments

The trend of increasing numbers of cruise passengers that was established at the outset of the project has persisted over the course of this work. The industry has been actively encouraging such growth, and incentives such as themed and shorter duration cruises have attracted a greater number of younger passengers. In terms of passenger distribution, Canada's East Coast has had continued growth, while on the West Coast, some shuffling between ports has been noted as more cruise vessels are opting to meet their cabotage requirements by stopping at ports other than Vancouver. Also, on the East Coast, the drive for more exotic and themed cruises has developed a market for "adventure" cruises that explore areas farther north as has been popular on the West Coast for some time. The trend of larger vessels seems to have reached a temporary plateau for the moment, as the number of vessels on order has decreased, but it has been established that the constraints are more monetary than architectural. In regulations, the idea of risk based assessments is taking hold as it becomes clear that prescriptive regulations developed by regulatory bodies cannot keep pace with design.

10 Development of Evaluation Measures and Techniques

The mandate of this project with regard to evaluation of SAR response has been to develop "measures" to evaluate the efficiency of current or proposed SAR resource allocations or contingency plans with respect to the risk profiles developed. To this end, the MARIN group have conducted a preliminary SAR Vessel Capability study and have developed a tool, the "Operational Capability Tool" (OCT) within the MARIS application for use by the Canadian Coast Guard.

10.1 Vessel Capability Study

The vessel capability study was undertaken to classify response resources according to their capabilities. Thus, the potential SAR coverage for a passenger vessel in case of an incident can reflect the response resources available. The first task in the study was the collection of the vessel specifications from the appropriate authorities within the CCG. After the vessel information was assembled, meetings with CCG representatives were conducted to establish metrics upon which resources may be evaluated, with respect to differing incidents. After the key characteristics of the vessels were established, rankings of the vessels were obtained from representatives for the vessels on each of the metrics.

Prior studies on the stationing of SAR vessels chiefly examined the characteristics of the station site, rather than the vessel characteristics [121]. This was chiefly born of the necessity to place a vessel of an established type at a given location. Vessel characteristics were considered only as required to evaluate the sites under consideration. It was suggested within MARIN that comparative evaluation of vessels with respect to response might require the consideration of a suite of characteristics for each potential responding vessel.

As an example involving vessels of opportunity responding to an incident, it may be preferable to task a fishing vessel to assist another in the event of an incident, in favour of tasking a tanker where the large freeboard presents a serious impediment. This study, however, was mostly concerned with primary SAR resources, as a starting point. In research by MARIN team members, three meetings were conducted, and CCG representatives were solicited for their information regarding the capabilities of SAR vessels. The result of these meetings was the establishment of classes of SAR vessels, and the differences between the classes. Because of time constraints, it was not feasible to evaluate each CCG vessel individually. As a result of the discussions with the CCG representatives, ten aspects of the vessels were noted as significant enough to merit differentiation, six of which were suitable for preliminary analysis [122].

Analysed:

- Speed
- Survivor Recovery Ability
- Ice Classification
- Maximum Sea State
- Communication and Navigation Equipment
- Towing Capability

Not Analysed:

- Fire Fighting Ability
- Range
- Survivor Capacity
- Standby Response Time

Ratings for each of the criteria were obtained from the Coast Guard representatives for each of the vessel class derived. These values were utilized to rank the vessels for differing situations using the preference function modelling software, TETRA [123]. TETRA is a multi-criteria decision making tool that takes into account the criteria specified as well as a set of weightings according to a given situation, and calculates the optimal selection from among a number of options using the given information. This tool was used to consider vessels from the various classes, according to their capabilities for response to hypothetical incident scenarios [122].

This model is reusable, and can be adapted to a number of different scenarios. The model provides reliable output for determining the most suitable vessel from among the different classes of SAR vessels in differing incident types. The model is also open-ended, so if additional work were undertaken to make information regarding the remaining criteria suitable for analysis it could be incorporated, making the model more suitable for practical application.

10.2 Operational Capability Tool

The Operational Capability Tool (OCT) allows evaluation of the capability of SAR resources in space, under a variety of different conditions, as relevant to any response requirements, including response to hypothetical cruise vessel incidents or accidents. This tool was developed in response to discussion following a presentation of the MARIS application to CCG in early 2004. Previous work conducted in the MARIN lab was tapped to develop the required underlying model. Throughout the vessel capability study, information obtained regarding vessels and the capabilities of the differing classes was input into the tool. Potential uses for the tool in the future include response scenario evaluation, and station placement and vessel relocation analyses.

Following discussion with CCG representatives regarding contemporary IMO work in the Large Passenger Vessel Safety working group, the concept of the OCT was developed. The issue of "remoteness from SAR resources" was under discussion [21, 47], and concern was raised about the "adventure” cruises frequenting the coast of Labrador. In order to explore the potential difficulties arising from this trend, it was suggested that the distance to the operating area from stationed SAR vessels be analysed. The potential to develop this type of what-if scenario into a dynamic tool was realized, and work prototyping the OCT was begun.

Because only local SAR resource information was available prior to the vessel capabilities study, the tool was initially limited to the East Coast of Canada. Within this region, gridded areas were established, and distances between them were calculated, taking into consideration navigation around the landmasses by using the techniques developed for the Traffic Generation process in MARIS [102]. The initial version of the tool included only the ability to select individual vessels for consideration. The result provided a gridded GIS layer with values attached to each grid indicating whether or not the vessel could reach the grid, based on the vessel's associated range. This grid was made available for display in combination with any of the other data available (e.g. historical incidents, modelled traffic) via MARIS for visual comparison.

Revisions to the OCT have progressed since its inception. The Canada-wide SAR vessel information was a great boost to the tool, providing a stable baseline of established vessels for consideration. The coverage of the tool was expended to three regions, SRR Halifax, SRR Trenton and SRR Victoria, each with their appropriate vessels. Facilities were added for the creation of hypothetical vessels for what-if scenarios involving vessels of opportunity and for inclusion of new or relocated SAR vessels. Though data is not yet available, provisions were made to accommodate airborne SAR in response consideration. Selection of responding vessels was modified to allow specification of vessels by characteristic. It is anticipated that this will be updated to include the categorizations present in the vessel capability study. Output from the tool was expanded to include the first vessel on scene, the total number of vessels on scene and weightings by historical traffic or incidents [124].

With the SAR vessel data fully specified, the software was built to express their characteristics for comparative evaluation (i.e. station placement), and conjunctive evaluation (i.e. response ability). Given the parameters for the hypothetical situations, the OCT is capable of providing analysis of SAR coverage or capabilities for many different scenarios, including those involving cruise vessels or other large passenger vessels.

10.3 Summary Comments

There is great potential in the response capability tools developed as a part of this project. By using these tools and the modelled cruise traffic data, it is possible to make assessments of the system of resources with respect to these vessels. By using historical data available in MARIS, areas of high and low response coverage can be compared to incident and traffic densities. The tools' facilities can be used to evaluate response vessel re-stationing or placement of new vessels. A number of Coast Guard representatives have already received training with the MARIS program and are exploring its functionality. One avenue that should be followed up to enhance the utility of the tool is the inclusion of the air resources that are available for response.

11 Conclusions

The cruise project has collated a large amount of valuable reference material for ready use by Coast Guard decision markers. The cruise traffic data developed will be of use in MARIS for comparative evaluation with other traffic. The traffic data also provide a clearer illustration of the spatial extent of cruise vessels' operation in Canadian waters. Though limited by data, the risk assessment exercise gathered valuable expert insight into varied aspects of passenger vessel accidents. This information is useful in highlighting areas for more detailed research. The cruise trends outlined in the report may assist in creating scenarios for analysing SAR capability. The Operational Capability Tool (OCT) will prove a useful means for examining the resources available to SAR.

Because of the complex nature of the issues explored in the cruise literature, detail was avoided in the topics presented. The references cited can provide details on specific issues, and can be noted at the end of this document and in greater detail in the supplemental spreadsheets.

Over the course of the project, some tasks or sub-projects were established that may be informative for SAR, but that fell outside the scope or time constraints:

- A detailed comparison of ferries and cruise vessels drawing specific contrasts and comparisons
- Additional meetings with CCG SAR representatives to further refine differences in vessels for capability analysis, and to improve the OCT
- Further exploration of trends through discussions with operators and stakeholders

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13 Appendices

Appendix A - List of International Conventions Included in CSA

- Minimum Age (Sea) Convention, 1920
- Unemployment Indemnity (Shipwreck) Convention, 1920
- Medical Examination of Young Persons (Sea) Convention, 1921
- Minimum Age (Trimmers and Stokers), 1921
- Marking of Weight (Packages Transported By Vessels) Convention, 1926
- Seaman's Articles of Agreement Convention, 1926
- Protection of Accidents (Dockers) Convention (revised), 1932
- Minimum Age (Sea) Convention (revised), 1936
- Certification of Able Seamen Convention, 1946
- Certification of Ships' Cooks Convention, 1946
- Food and Catering (Ship's Crews) Convention, 1946
- Medical Examination (Seafarers') Convention, 1946
- Seafarers' Identity Documents Convention, 1958
- Convention of Facilitation of International Maritime Traffic, 1965
- International Convention on Load Lines, 1966
- International Convention on Tonnage Measurement of Ships, 1969
- Convention on the International Regulations for Preventing Collisions at Sea, 1972
- International Convention for the Prevention of Pollution From Ships, 1973
- International Convention for the Safety of Life at Sea of 1974
- Convention on the International Maritime Satellite Organization (INMARSAT), 1976
- Merchant Shipping (Minimum Standards) Convention, 1976
- International Convention on Standards of Training Certification and Watchkeeping for Seafarers, 1978
- Protocol of 1978, relating to the International Convention for the Prevention of Pollution From Ships
- Protocol of 1978, relating to the International Convention for the Safety of Life at Sea
- Convention for the Suppression of Unlawful Acts Against the Safety of Maritime Navigation, 1978
- Protocol of 1988, relating to the International Convention for the Safety of Life at Sea
- Protocol for the Suppression of Unlawful Acts Against the Safety of Fixed Platforms on the Continental Shelf
- Protocol of 1988 relating to the International Convention on Load Lines
- International Convention on Oil Pollution Preparedness Response and Cooperation, 1990

- Protocol of 1997 relating to the International Convention for the Prevention of Pollution From Ships
- International Convention on Maritime Search and Rescue, 1979
- International Convention on Oil Pollution Preparedness Response and Cooperation, 1990

Appendix B - Breakdown of Major Cruise Lines [7]

Carnival Cruise Lines

- Holland America Line
- Windstar Cruises
- Costa Cruises
- Cunard Line
- Seabourne Cruises
- Princess Cruises
- P&O Cruises
- Swan Hellenic Cruises
- Aida Cruises
- Seetours
- A'Rosa Cruises
- P&O Australia
- Ocean Village

Royal Caribbean Cruise Lines

- Royal Caribbean International
- Celebrity Cruises
- Island Cruises (joint with First Choice Holidays)

Star Cruises

- Star Cruises
- Norwegian Cruise Line
- Orient Line

Appendix C - Average ratings of risk factor influence on 12 marine accident types

Risk Factors	Grounding	Bottom contact	Collision	Near-collision	Allision	Fire/ Explosion	Foundering	Capsizing	Sinking	Accidental/ Premature departure	Accident aboard vessel	Fall overboard
Weather	6.20	5.67	5.67	5.6	5.93	1.87	8.40	8.27	7.53	4.30	6.47	6.47
Visual Detection	6.67	5.93	8.87	8.87	7.27	0.27	1.93	2.00	2.60	1.27	0.93	0.47
Navigational aid detection	9.13	9.00	6.33	6.20	5.87	0.40	0.87	0.80	0.80	0.47	0.20	0.00
Management factors	7.13	7.07	5.93	5.93	6.13	7.60	6.07	6.07	5.40	5.13	6.53	3.27
Human factors	8.67	8.60	8.80	8.87	8.93	6.93	7.33	7.20	6.93	6.80	7.73	7.60
Technical reliability	6.33	6.40	5.40	5.47	5.60	6.47	5.67	5.60	5.67	4.80	3.07	1.07
Support	7.13	7.07	7.87	7.93	7.53	2.07	2.20	2.53	2.53	3.13	1.00	0.30

Appendix D - Typical Consequence Severity Rating

Accident types	Consequences										
	People		Property				Environment		Financial		
	Death	Injury	Ship (structural)	Ship (Non-structural)	Ship (Private property onboard)	Non-Ship (other ship, wharf, etc.)	Fluid	Solid	Revenue loss	Legal cost	Repair costs
Accident aboard Vessel	3	8	2	7	2	0	0	0	3	4	6
Accidental/Premature Departure	4	5	3	2	1	4	1	1	1	1	1
Allision	2	5	8	7	3	8	5	6	7	5	7
Bottom contact	1	3	8	5	2	0	8	8	7	0	7
Capsizing	10	10	7	9	10	1	10	7	10	10	0
Collision	7	8	10	8	9	10	9	8	9	9	10
Fall overboard	8	8	0	0	0	0	1	0	0	1	0
Fire/Explosion	8	10	8	10	7	2	4	4	9	7	8
Foundering	9	9	4	9	9	0	9	7	10	9	0
Grounding	2	3	9	5	5	0	8	10	9	8	9
Near-Collision	0	0	0	5	4	1	0	0	3	3	4
Sinking	9	9	7	9	9	0	9	7	10	9	0

Appendix E - Risk Profile of Major Cruise Vessel Accidents