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Integrated Risk Management System for Ship Safety

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Abstract

According to the increase of the requirement for the safety and environmental protection at sea, safety is a core design factor of maritime systems. Safety is defined as a perceived quality that determines to what extent the management, engineering and operation of a system is free of danger to life, property and the environment. There are many possible approaches in dealing with the safety of ships. The risk-based approach is one of the most systematic and reasonable way currently in design, operation and regulatory works for ship safety.

This paper proposes a concept of total risk management for ship safety, and introduces a prototype system implemented based on this concept as a framework of design and operation of ships.

Keywords: risk management, ship safety

1 Introduction

Even with previous efforts to decrease major marine accidents, the number of marine accident has remained more or less the same. Consequently, many international organizations and governments recognized the importance of new risk-based approach to reduce marine accidents (IMO 2002, USCG 2000). Currently, risks are considered primarily during design phase in order to build safer ships. In some cases, safety is no longer a restriction or constraint applied to design but an explicit objective to be achieved. Residual risks which cannot be entirely removed during design stage of marine systems should be managed during the operational phase, as well as the unexpected risks that may arise due to extreme external conditions that are not considered during design phase. When an accident has already occurred, necessary measures should be taken to mitigate the accident where risk assessment and management can play a critical role.

Recently research has been undertaken in the area of risk assessment for ships and other marine systems (Brandsater 2002, DNV 2000; Safer Euroro 2003; The shipbuilding research association of Japan 1997) . However, since risk assessment can often be a very time consuming process, most of this research is limited to the design stage of marine systems. While, these efforts will enhance the safety of marine systems by building safer ships, not all risks can be removed during design stage. Therefore, risk management should be done during whole lifecycle of marine systems including the operational phase and accident mitigation activities as well. Furthermore, risk management efforts throughout the lifecycle should be integrated in order to provide a more systematic and efficient means to

ensure safety.

This paper proposes an integrated risk management system. An integrated risk management system is a risk-based, systematic and technical means to ensure the safety of marine systems during its whole life cycle. The proposed system integrates risk assessment and management activities performed during design and the operation phase. It also integrates prevention and mitigation activities for possible accidents. The system uses risk-based methodologies as well as conventional deterministic and performance-based methodologies and takes account of various accident causes such as engineering factors, human factors and environmental factors. To verify the effectiveness of the system, a prototype system has been built and is being tested for a passenger craft in its operational phase.

2 Integrated Risk Management System

Previous marine system safety assessments are based on the rules and regulations of international organizations such as the Class Societies and IMO. However, this rule-based approach has limitations since the rules and regulations are made in recognition of previous accidents, thus new type of accidents are not reflected and the rules and regulations are not as applicable to new types of ships. To overcome such limitations, a performance-based approach including performance calculation and experiments is used, but this also has limitations in cost and technological aspects as a means to assess and manage overall system safety. The Total Risk Management System (TRMS) is an integrated risk management system and is a systematic and technical tool to assess and manage the safety of marine systems including ships in an integrated manner.

As shown in Figure 1, TRMS is based on a probabilistic risk assessment approach. It integrates risk management activities required throughout the lifecycle of a marine system. TRMS considers various causes for marine accidents (technical, human and environmental elements). Therefore, TRMS is a system, which can be used at any time during lifecycle of marine systems, maintaining proper relationships among risk management activities

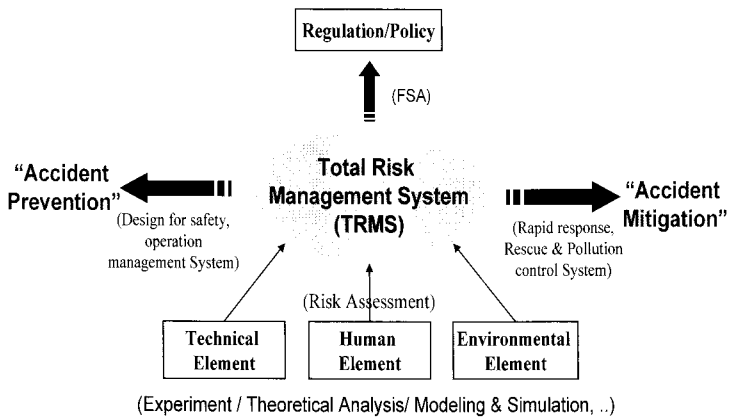

Figure 1: Basic concept of TRMS

TRMS is to be extensively used during the design phase of the life cycle. During ship design, using the TRMS framework will enable the design and construction of safer marine systems by identifying various hazards contained in design alternatives. Thus, the designer can select safer design alternatives. During the design stage, performance analysis

of marine systems will be done as well as risk assessment. Also, the risk model is built during the design stage from identified hazards, possible accidents scenarios and their expected consequences. The risk model is the main component, which is used throughout the lifecycle of a marine system in order to integrate risk management activities at the different stages. All risk assessment activities during the lifecycle of a marine system is based on the risk model. During the operation stage, the same framework is used but most of the time consuming analysis will not be performed. However, analysis results from the design stage will be stored in a database, and the database will be used for risk assessment during the operation stage. During the operation stage, real-time risk management will be necessary, therefore, risk assessment will be performed using the risk model, which has been built during the design stage, and other information gathered during operation. If an accident has occurred, all efforts must be given to mitigating the accident. The TRMS framework will also be used as a decision support system for mitigation activities as well as in emergency situations.

TRMS uses risk contribution trees (RCT) for building the risk model. Accidents are divided into eight categories: collision, grounding, fire, flooding, explosion, sinking, capsizing and structural damage. For each accident category, the accident cause is investigated using a fault tree and the expected outcomes of the accident are estimated using an event tree. Figure 2 shows the risk contribution tree method.

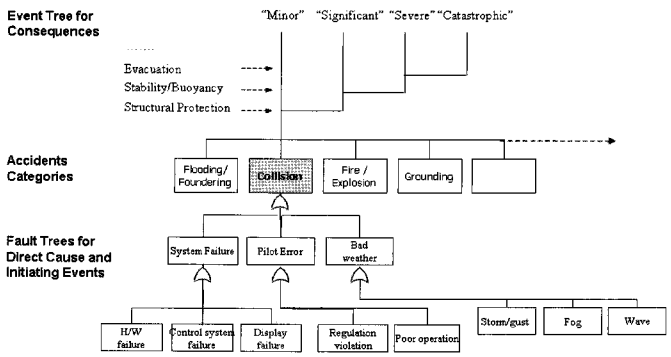

Figure 2: Risk Contribution Tree(RCT)

The risk model is built during the design stage. All relevant hazards are identified as a first step during risk assessment at the design stage. Then identified hazards are screened in order to select those significant hazards that can lead to frequent accidents or accidents that are critical to safety. Using these significant hazards, the risk model is built. Causes for the accidents are investigated using fault tree analysis (FTA) and probable outcomes of the accidents are estimated using event tree analysis (ETA). The risk model also takes account of dependencies between accidents, i.e an accident that can lead to another accident. Also it considers various causes such as technical, human and environmental elements, so that these elements are not regarded separately.

3 Development of Prototype System

In order to test the effectiveness of the TRMS system, a prototype system has been built. The prototype system is an implementation of the TRMS framework to be used during the operation stage of a passenger vessel. It is designed to be on-board real-time system, which continuously monitors risks that the passenger vessel faces during its operation.

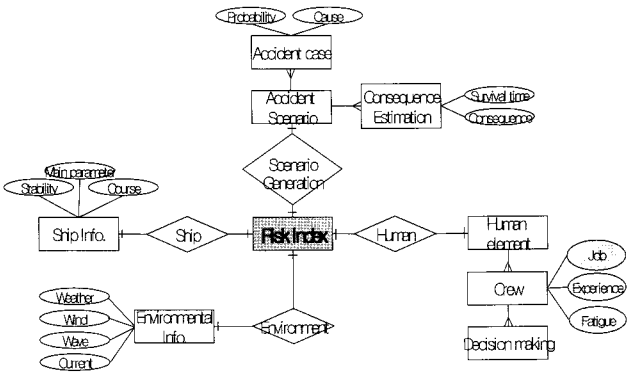

Figure 3: Data model for TRMS

The prototype system includes the risk model, a risk assessment processor, a risk monitor and a TRMS database (DB). The risk model provides the logical relationship between the causes of accidents and their consequences. The TRMS DB stores previous accident cases and other information that is necessary for calculating risk such as the basic event probabilities for the fault tree in the risk model and the branch probabilities for the event tree in the risk model. The risk assessment processor calculates risk using the risk model and the TRMS DB shows it to the user in an intuitive format through the risk monitor. Figure 3 shows the data model used in the prototype system.

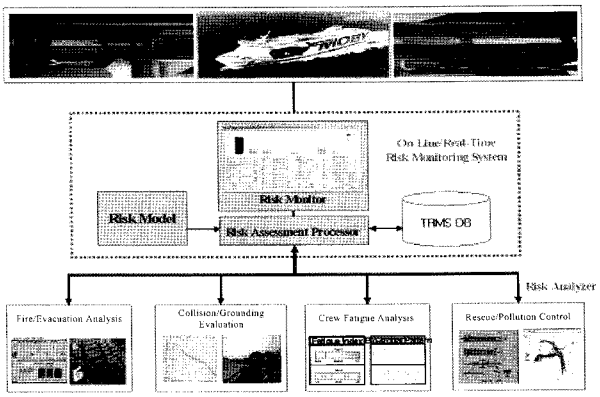

Figure 4: Structure of TRMS prototype

The prototype system also interfaces with other on-board systems that can give various data for risk assessment. In this particular case of a passenger vessel, four other on-board systems (sub modules) are interfaced with the prototype system. They are a fire/evacuation analysis system, a collision/grounding evaluation system, a crew fatigue analysis system and a rescue/pollution control system. The fire/evacuation analysis system performs fire and evacuation simulations and estimates how many people will be able to evacuate in case of certain fire accidents. The collision/grounding evaluation system detects nearby ships and other marine structures in order to aid the user in selecting routes with the least probability of collision or grounding. The crew fatigue analysis system estimates how tired crew members are from various interactions between the crew and the system. Crew fatigue accounts for a large part of the accident causes. The rescue/pollution control system estimate how much oil will be spilled to the sea in case of certain accidents, and aids

decision making during rescue and pollution control activities. The prototype system receives various pieces of information from these sub modules and uses them for calculating risk. Figure 4 shows structure of the prototype system.

The risk model is built at the design stage to become the basis for risk assessment. For the prototype system, a generic risk model has been built and used for risk assessment. Figure 5 shows the accident cause model (fault tree) for a collision accident. As shown in the figure, various accident causes including technical, human and environmental elements are included in the accident cause model, so each element is not separately analyzed.

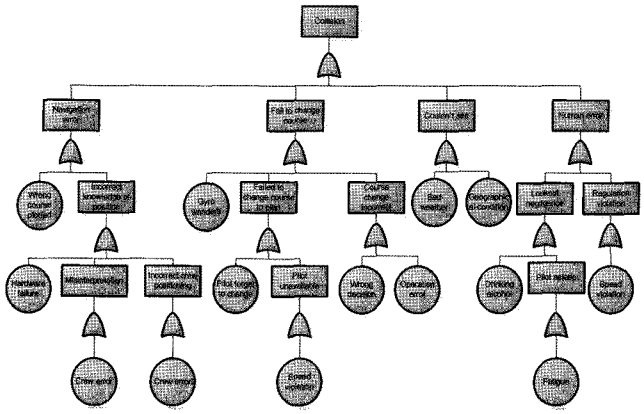

Figure 5: Accident cause model

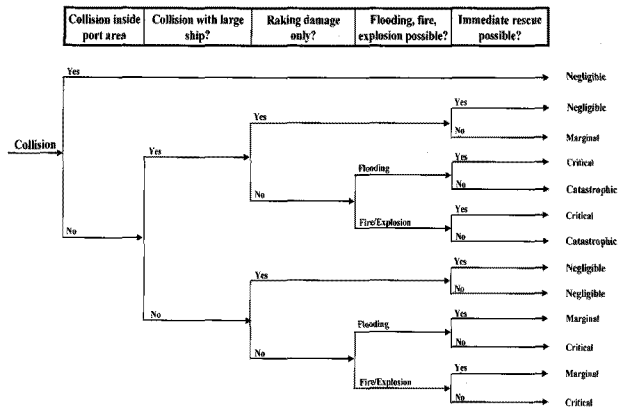

Figure 6: Accident consequence model

Figure 6 shows the accident consequence model (event tree) for a collision accident. As shown in the figure, each accident is not independent of others, but their relationship is also considered in the risk model. In case of a collision accident, the consequence depends upon whether any other accidents can occur or not.

Figure 7 shows the main window of the implemented system. In the main window, the risk index is displayed together with detailed risk information. To be more intuitive, the risk index has one of three colors. Red means appropriate action should be taken, yellow means caution should be taken and green means no action is necessary. Fatigue information and navigational information are also displayed. One of four sub modules is also displayed as well at the user's choice.

Figure 8 shows the FTA/ETA window. This is the current risk model used for the risk assessment, and the user can select any event of the fault tree and the event tree to get the frequency and consequence value of each event.

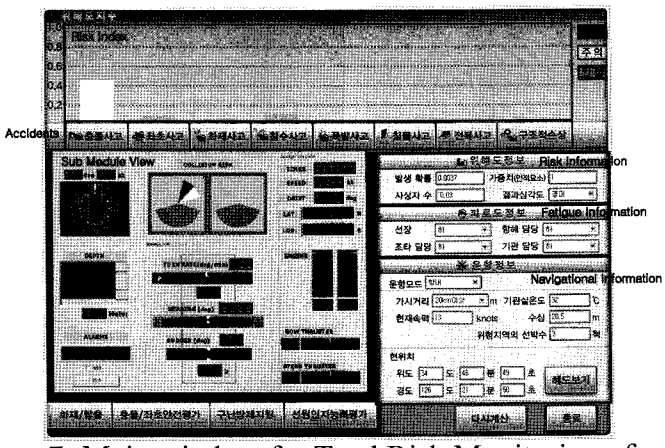

Figure 7: Main window for Total Risk Monitoring of a Ship

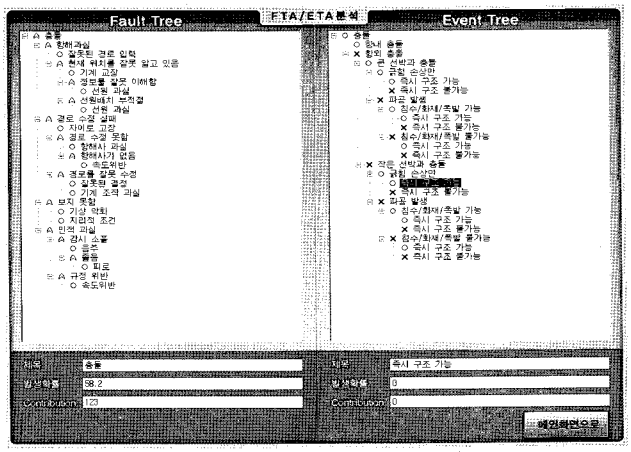

Figure 8: FTA/ETA window

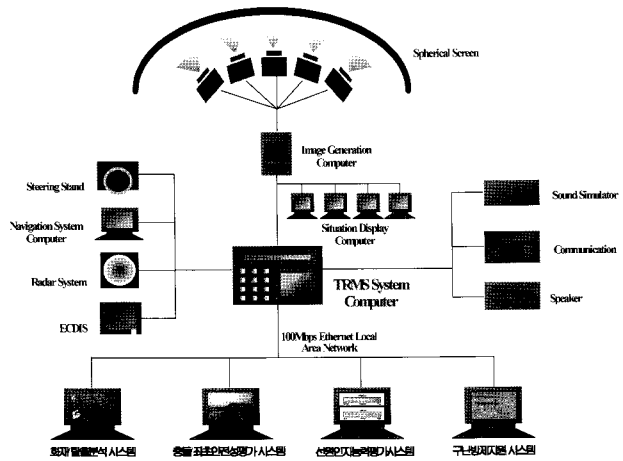

Figure 9: Configuration of TRMS in ship operation simulation

The prototype system has been tested on ship operation simulation environment. The prototype system are equipped as a component to the ship operation simulation system as shown in Figure 9.

Figure 10 shows a view of simulation for the ship entering a harbour while TRMS system is in use.

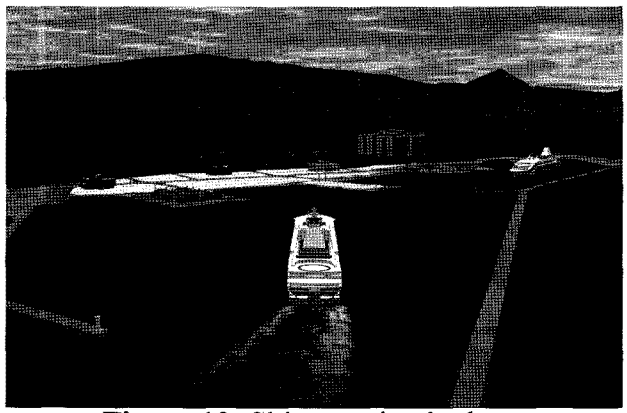

Figure 10: Ship entering harbour

5 Conclusions

The risk of marine accidents is steadily increasing due to the increase in international trade and overseas transport, and faster, larger transport. Therefore, the rules and regulations are becoming stricter to protect human, property and environment. However, rules and regulations are not enough to ensure safety of marine systems and risk-based methods must be used more and more in order to cover areas that cannot be protected by the conventional rule-based approach.

This paper proposes an integrated risk management system. An integrated risk management system is a risk-based, systematic and technical means to ensure the safety of marine systems during its whole lifecycle. It integrates risk assessment and management activities performed during design and the operation phase, as well as prevention and mitigation activities of possible accidents. To verify the effectiveness of the system, a prototype system has been built and is being tested for a passenger craft in its operation stage.

The prototype system is designed to address various accident causes and consequences effectively using a risk-based approach, and to be a means to ensure ship safety during ship operation by constantly assessing remaining risks that are either not considered at all during the design or, for those that were considered, by using higher levels than considered during the design phase. In addition, the system can also be used as an active means to correspond with international activities such as IMO as the organization has adopted a risk-based approach in its rule-making process.

The prototype system will be extended by adding a decision support system or expert system. Using the risk index and risk model, the decision support system can generate recommendations to reduce the current risk level. If such recommendations are accepted and implemented by the user, then the prototype system will recalculate current risk level reflecting the accepted recommendations.

Acknowledgements

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