# Management of Human Error in Shipping Operations

By J. WANG and S.M. ZHANG

*Investigations of marine disasters have often identified poor standards and training of seafarers as key contributing factors. The Standards of Training, Certification and Watchkeeping for Seafarers (STCW 95) introduced new requirements for maritime education and training, and imposed new responsibilities on flag states (countries that register fishing boats) and shipping companies. STCW also takes into account technical innovation in maritime training. This article examines the role of human factors in maritime safety and discusses ways to reduce human error in ship operations. Training and communication problems are analyzed, as are possible solutions. Discussion then turns to requirements for better training methods and the role of modern communication systems in onboard training. Some scientific approaches for dealing with human error are also discussed. Finally, conclusions and recommendations are offered.*

Shipping is a vital industry, carrying 97 percent of world trade (Wang and McOwan). Modern merchant shipping is a specialized, complex operation that is governed by comprehensive rules and regulations developed by national and international authorities. Vessels have increased in number and become faster, more sophisticated and expensive. Thanks to modern technology and modern navigation equipment, marine transportation is more efficient than ever before.

However, injury and fatality statistics indicate that shipping remains a high-risk industry. One of the key concerns in the effort to achieve higher safety standards aboard ships is the qualification of crew members. In many cases, ship safety is closely related to human error. Human error is defined as "an action [or omission] which can be identified as the immediate cause of the event [from which liability arises]" (UK P&I Clubs). It can also be defined as "a departure from acceptable or desirable practice on the part of an individual that can result in unacceptable or undesirable results" (ABS).

Reducing human error offers considerable economic incentives. It can be achieved in several ways.

- Installation of safety warning devices, such as sensors and alarms, to detect problems and signal that corrective action is needed.
- Improved training, supervision and communications.
- Increased level of automation.
- Better vessel design, and improved operation and maintenance.

Better operation may be the most effective way to reduce human error in the shipping industry (Anderson, et al 67+). Better equipment design may also significantly reduce human error—or at least control the magnitude of its possible consequences. Various formal safety assessment methods may be used individually or in combination to improve, via design, a ship's safety (Wang, et al; Wang and Ruxton; Wang). However, this article's focus is the role of better training and education.

### CURRENT STATE OF THE INDUSTRY

Today's advanced shipping technology—borne out of the increasing pressure to ensure quick, efficient, cost-effective service—has decreased the size of onboard crews. Consequently, responsibility for ship and human safety has been placed on individual crew members who may not have requisite training and certification.

In addition, many shipping companies are now organized on a global basis, which has changed the traditional interrelation between a national economy and a shipping company. In addition, this trend toward internationalization affects vessel registration and has led to widespread employment of international crews (those from maritime-labor supplying countries who work on board ships that fly foreign flags), cross trading and intercompany cooperation. Because of low labor costs, developing and third-world countries are now a major supplier of new crew members. However, the increased use of international crews has created further challenges, including training and communication aboard ships.

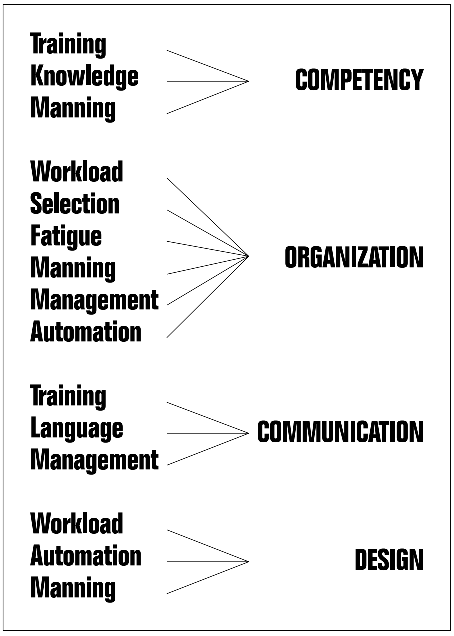
To address ship safety problems that involve the human element, the Standards of Training, Certification and Watchkeeping for Seafarers (STCW 95) were introduced; they took effect Feb. 1, 1997. These standards center on monitoring mechanisms, enforcement measures and procedures to ensure their uniform application. While the International Safety Management (ISM) code addresses the "technical aspects" of ship operations, STCW 95 attempts to improve the human element (Cowley 1+).

To minimize poor human decisions, shipping companies must ensure that both shore and sea staff are properly trained. The rapid technological developments in ship operations should prompt re-examination of the way seafarers are trained. STCW 95 takes into account the role of modern technology (e.g., simulators, the Internet) in maritime training; such technology may help shipping companies effectively meet the international regulations and higher training standards.

### HUMAN FACTORS & MARINE SAFETY

Although today's vessels feature modern navigational equipment, marine casualties (such as a collision of vessels or stranding) and accidents involving oil tankers, bulk carriers, general cargo vessels and passenger ships occur on occasion. Typically, the details of such disasters are scrutinized in order to improve international conventions and regulations. For example, following the tragic loss of the Ro-Ro ferry *Herald of Free Enterprise* in 1987, the International Maritime Organization (IMO) began to assess the role of the human element in maritime casualties and accidents. The results were incorporated into STCW 95.

**FIGURE 1**
**Human Element Framework**




A maritime casualty is an incident on board a vessel or external to it that produces material damage, or poses imminent threat of material damage, to a vessel or cargo. It usually involves loss of life, vessel, cargo or operation, as well as damage to the marine environment.

In 1982, 402 ships were lost; total tonnage lost peaked in 1986. Over the last several years, however, the world's ship casualties have gradually declined, a trend attributed to advancement of marine technology and establishment and implementation of international conventions and regulations.

Despite these improvements, concern remains, particularly when one remembers several recent catastrophies. For example, the *Scandinavian Star* disaster in 1990 resulted in 158 deaths (MJP). (See sidebar, page 26.) In the 1993 accident involving the crude oil tanker *Braer,* some 85,000 tons of crude oil were dumped into the sea. The *Estonia* capsized in the Baltic Sea in September 1994, killing more than 900 people.

According to some sources, 80 percent of maritime casualties are due to human error (Mitchell and Bright). This assertion can be traced to 1976, when a research board in the U.K. concluded that the human error percentage was equal to 80 percent (Goulielmos). At that time, no guidelines were in place to help shippers reduce human error involved in accidents at sea (Millar). In recent years, however, human error has become a focus, leading to more-advanced research.

What are considered the leading causes of human error?

- lack of knowledge and experience;
- overconfidence;
- recklessness in responding to commercial pressures;
- fatigue (related mainly to collisions);
- discomfort, boredom, anger, unhappiness, illness, confusion and lack of adequate communication (Goulielmos).

In many cases, serious casualties are preceded by less-noticeable incidents that involve human errors such as omission, misconduct and underestimation of hazardous situations. Therefore, employee competence, preparedness and communication are crucial factors in reducing maritime casualities.

What areas should the industry target in its efforts to reduce human error?

- development/training;
- commercial pressures/workload;
- hours of work and rest/fatigue;
- manning levels;
- selection procedures;
- communication/cultural matching;
- organizational management;
- competency and skills;
- automation.

Components of the human system on board a ship may be grouped into four categories that compose a human element framework (Figure 1). To reduce human error, these broad areas must be addressed.

1) **Competency.** This element can clearly be addressed by enhanced training and assessment, which in turn can be dependent on relevant, effective education. STCW 95 directs flag states on competency issues much like other conventions offer direction on ship structure and equipment (hardware).

2) **Organization and methods.** Several high-profile accidents (such as the capsize of the *Herald of Free Enterprise*) have pointed to ineffective management as evidenced by poor planning. Clearly, effective management is crucial to any shipping operation.

3) **Communication.** The growing number of multinational crews heightens the need for effective communication. This encompasses both language and cultural differences among shipmates.

4) **Design.** Automation should be increased to further reduce human involvement in the design process. In addition, the workload of each crew member should be limited to an acceptable level.

## TRAINING PROBLEMS

As noted, human error plays a role in most marine accidents, including those where structural or equipment failure may be identified as the primary cause. The knowledge, skill, experience, health and behavior of seafarers are directly related to safety at sea; therefore, inadequate training and poor communication due to language barriers need to be addressed.

Seafarers from traditional maritime countries—such as Norway, U.K. and Japan—are known for their strong vessel operation knowledge and practical skills. Since the shipping recession, however, the total number of experienced seafarers from these countries has declined sharply.

Today, the Asian region—in particular, India and the Philippines—is considered the "powerhouse" of global shipping, with nearly two-thirds of the world's seafaring population from this area. The Philippines alone has some 280,000 registered seafarers, and countries such as China and Vietnam have an enormous pool waiting to be tapped.

In many cases, financial constraints impact the quality and delivery of maritime training. Due to lack of funds, maritime training institutions often operate irregularly in the countries from which crew members are recruited, and many of the facilities are insufficient and out-of-date (Alam). Because of these problems, training institutions located in developing countries often cannot sufficiently train the large number of crew members needed in the international market.

To meet these challenges, these institutions must revise their programs and upgrade their facilities, which requires increased investment. In addition, ship owners must be prepared to invest in training and retraining. To best achieve these goals—and to ensure safety and protect lives and property—key stakeholders must form stronger alliances. This cooperation can take various forms:

1) Invest in training facilities to increase the practical skills of the seafarer.

2) Provide a certain number of qualified seafarers for a company according to its manpower planning strategy.

3) Establish a special fund for upgrading qualifications of maritime trainers as required in STCW 95.

4) Develop new training curricula to meet shipping company needs (Metevelis).

Many established owners and managers recognize the importance of seafarer training. In return for their investment, these owners/managers:

1) meet requirements of national regulations and international conventions;

2) ensure better performance from crew and ships;

3) reduce accidents and claims;

4) establish a better defense against claims and reduce damage to reputation should an accident occur.

5) improve the quality of operations;

6) improve crew morale by demonstrating that owners or managers are caring employers;

7) sustain a successful business.

Seafarers also benefit. They:

1) obtain higher qualifications;

2) improve promotional prospects;

3) expand employment opportunities;

4) increase personal knowledge/skills;

5) increase personal satisfaction by feeling "on top of the job";

6) gain enhanced self-confidence;

7) earn a better wage.

In addition, governments can benefit from providing appropriate training for seafarers. They:

1) help nationals—especially young people—get jobs, thereby reducing unemployment;

2) increase income tax revenue;

3) protect the marine environment by helping seafarers expand their knowledge;

4) provide an adequate maritime infrastructure of key parties, including pilots, harbor masters, surveyors, inspectors, marine officials, ship repairers, insurance assessors and arbitrators.

### *Training Models*

Maritime education and training systems can be divided into two models: 1) step-by-step maritime training and examination and 2) continuous study and examination. The former starts with pre-sea training, followed by post-sea training after a requisite amount of sea service prior to the examination for each grade of certificate. An advantage of this model is that theoretical studies, training and sea experience are well-arranged and combined even though they may not meet the requirements of an academic degree. However, this approach can be costly.

The latter strategy combines maritime training with an academic degree. Many developing countries—in particular China—are shifting from the step-by-step model to the continuous one. The primary reason for this change is that trainees need not only a professional certificate, but also an academic degree that encompasses other requirements of society (Sidin and Sarma).

However, a gap exists between training and job requirements in the continuous learning process. As a result, knowledge may not be properly absorbed and the emphasis on theoretical learning may diminish the value of practical training. In addition, many training institutions are short-staffed and have a large number of trainees; therefore, each individual's training and practice time is relatively limited.

This problem could be addressed by revising the curriculum to meet STCW 95 requirements, which allows for use of simulators and computers to conduct training (see page 27). However, while this may solve the problem of practical training at sea, it introduces new challenges: 1) attempting to install modern equipment in dated facilities; and 2) cost.

Since STCW 95 places high priority on seafarer competence, the following steps should be considered to improve their practical skills:

1) Develop new training facilities and obtain needed equipment through partnerships forged between maritime education and training institutions and ship owners, and/or through government investments, bilateral agreements, and international or regional agreements.

2) Enhance practical training activities.

3) Ensure that each trainee has enough training time and individual practice; in addition, this training must be assessed by an effective method.

4) Require shipping companies and manning agencies to ensure that seafarers receive onboard training according to STCW 95; these training programs should be approved by marine administrations. In addition, it must be made clear that shipping companies and senior officers or supervisors aboard ships are responsible for training junior officers and other crew members.

In accordance with STCW 95 requirements, all training programs must be evaluated, problems identified and solutions devised. Since training institutions in developing countries may face unique problems, both internal and external evaluations should be conducted. The internal evaluation should focus on quality-related aspects such as facilities, instructor qualification and quantity, materials (availability and content) and methodology. The external evaluation can focus on the qualification level of trainees in terms of knowledge, competence and suitability. This assessment may be performed by those who hire trainees. Any weaknesses identified must then be addressed.

In addition, IMO has initiated a technical cooperation program to help developing countries raise their training standards. The key objective is to identify weaknesses and determine which problems the institutions can solve on their own and which need cooperative solutions.

## COMMUNICATION PROBLEMS

As mentioned, mixed nationalities aboard the vessel mean a variety of languages—in some cases more than 10—may be spoken. This can cause communication difficulties; inadequate

## Training Problems

Investigation of the *Scandinavian Star* accident identified the following training problems.

•Management was not ready to begin the operation. It took little into account for the safety of passengers. Investigators concluded that management relied too heavily on the manning agent to recruit crew members from Portugal.

•Many crew members were not qualified to work on board passenger vessels. In addition, many deck officers had little or no safety training. Furthermore, most of the 48 Portuguese deck and engineering crew did not have certificates for handling lifesaving equipment.

•No fire and abandon ship drills were conducted, which investigators attributed to poor management. As a result, when the fire occurred, many crew members were unfamiliar with the emergency plan and did not know how to respond appropriately.

•Inadequate training was only compounded by the language barrier. The crew could not communicate effectively with each other in order to evacuate passengers expeditiously.

•No command system was in place, and the captain did not issue any general orders for mobilization of various groups according to the emergency plan.

As this list shows, education, certification and training are vital human aspects of the effort to prevent maritime casualties. Clearly, untrained or inadequately trained personnel pose a potential risk to lives and property.

communication between officers and crew can pose a hazard that directly affects vessel operation and safety. Under normal situations, a language barrier may not lead to problems since the seafarer has time to repeat the request or solve a problem in other ways. In an emergency situation, however, some seafarers may not be able to exchange crucial information, a problem well-demonstrated by the *Scandinavian Star* disaster.

Modern ship-to-ship and ship-to-shore communication technology enables direct voice communication. Through these devices, officers on duty can directly communicate with other vessels. Such communication is crucial when vessels are in visual contact (on radar) and heading toward each other. Collisions may arise because a ship misunderstands another ship's intention. Such situations are only compounded by communication problems—such as when those speaking do not share a common language.

In addition, crew members must be able to communicate effectively with vessel traffic service centers, especially in dense traffic areas. These centers collect key data from vessels and provide services in return. This exchange requires clear, effective communication as well.

As in many business situations, English is widely used as an external communication language. In many cases, English language studies are available for marine officers, but their availability varies for petty officers and ratings; in some cases, such training simply is not available.

To overcome this challenge, manning patterns should ensure that international crews on duty have sufficient knowledge of English; this will ensure that crew members can clearly communicate with each other in order to operate vessels safely and ensure personal safety in emergency situations. In the authors' opinion, the IMO should also strive to develop more maritime English training programs/materials through technical cooperation among key stakeholders, particularly in countries where English is not the native language.

### KEY ELEMENTS OF STCW 95

Before STCW 95 was introduced, STCW 78 was the only convention that addressed seafarer education and training. That convention was largely successful, as reflected by establishment of initial basic international standards; formulation of criteria for certification of marine administrations; and provision of a method to improve safety at sea and ensure cleaner oceans. It also provided guidelines for creation of maritime education and training in developing countries.

However, as noted, several maritime casualties in the late 1980s revealed problems related to company management and crew competence. The 1978 convention simply did not address human error or the increased use of international crews.

STCW 95 features two key parts. Part A is mandatory by means of references to the text of the convention while Part B contains recommended guidance. The mandatory section prescribes the required standards. According to IMO, Part B should be implemented to the greatest degree possible in order to achieve universal implementation of these standards.

Before STCW 95, maritime training institutions were faced with free interpretation of international standards—in other words, no precise standards or criteria were available. The new standards provide these institutions with identical criteria, which can only promote overall improvement of training in developing countries.

By redefining and clarifying the meaning of competence, STCW 1995 has shifted the emphasis from knowledge to skills, which creates more-evident and more-easily monitored standards of competence. In the authors' opinion, these specific standards will increase training levels in developing countries and encourage their training institutions to meet international expectations. The new standards also challenge crew-supplying countries and their training institutions to address existing limitations.

#### New Responsibilities for the Flag States

Under STCW 78, certificates of international crews were simply recognized by the flag states; these administrations were not required to ensure the competence of those crews or the validity of certificates. However, since training and certification criteria differ from country to country, crew competence varies. So, under STCW 95, flag states must now verify that holders of certificates issued by another party comply with STCW 95 requirements. To confirm this, maritime administrations may inspect training facilities; examine training procedures and requirements concerning standards of competence; and review the issuance and endorsement of certificates and all recordkeeping.

In addition, flag states must submit a document to IMO that explains what provisions have been made to ensure effective implementation of STCW 95. This document details compliance procedures and measures taken (e.g., a clear statement of the education, training, examination, competence assessment and certification procedures and other implementation matters). In turn, IMO publishes a white list that reports which flag states have successfully demonstrated compliance.

Port state control is another new provision designed to ensure that safe, efficient operational practices are followed in order to reduce human error. Under this provision, the port state may assess seafarer competence and intervene should any deficiencies be deemed a danger to persons, property or the environment. To focus ship owner and flag state attention on seafarer training, STCW 95 has signficantly expanded port state control powers of inspection to ensure that owners/managers fulfill their responsibilities.

STCW also places new responsibilities on shipping companies. Key among them is the duty to ensure that seafarers assigned to ships are properly certified; that ships are manned in accordance with flag state safety manning requirements; and that detailed records are maintained for all seafarers. The 1995 amendments also permit administrations to prosecute companies or individual seafarers for violation of convention requirements.

In addition, a company must ensure

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that all seafarers newly employed on board have an opportunity to become familiar with the work environment and receive training if necessary before being assigned to perform their duties. The company is also responsible for crew coordination. This is designed to ensure that a crew can effectively communicate—and port state inspectors can request that this ability be demonstrated. Although this should be a standard vessel management practice, ensuring that such activities take place will only help seafarers perform their work properly, particularly in emergency situations.

### *English Language Requirements*

STCW 95's requirements for deck officer English competence are unchanged from STCW 78. However, the amendments include new requirements for the English language competence of engineering officers; this mandate is designed to ensure that these officers can use engineering publications, perform key duties, and communicate clearly and understandably. Such requirements will certainly reduce human error due to poor communication among international crews and in ship-to-ship and ship-to-shore situations.

### *Modern Technology & Training*

As noted, STCW 95 stresses skill-based (rather than knowledge-based) training. Due to quick turnarounds and small crew size, traditional learning methods may no longer be effective. This problem is only compounded by inadequate training facilities.

Sea training consists of facilitating the transfer of knowledge and skills from experienced senior staff to trainees. Personnel managers must ensure that the crew they supply is "trainable," which requires sound management ashore and effective shipboard training. Thanks to modern technology, the time has come for the shipping industry to re-examine the manner in which seafarers are trained.

For example, simulators are an effective way to imitate various situations of vessel operation for officer training, and their use is allowed under STCW 95. In many cases, it is difficult for seafarers to obtain the operational opportunities needed to learn vessel navigation and control skills. Simulator training can help them acquire these skills in a risk-free environment. Full-mission simulators mimic all operations in great detail and are excellent for training crew on shore. However, these devices are expensive and, thus, are not commonly used in less-advanced nations.

In addition, self-study materials can be enhanced when used in conjunction with interactive computer-based training programs. Such methods hold great potential for providing skill training to a large number of seafarers.

All formal training must include some form of assessment and recordkeeping. This is another advantage of computer-based systems. In addition to individual self-testing, these systems can, with proper supervision and safeguards, be used to assess trainee knowledge.

The Internet is another viable training alternative. Cost-effective transfer of data between ship and shore may produce many changes in the way that the ship/shore information interface is used. This technology can also allow crew members to consult online with an independent center, such as a scientific consultation research center, to obtain vital safety information.

## SCIENTIFIC APPROACHES FOR DEALING WITH HUMAN ERROR IN SHIP OPERATIONS

In many industries, safety regulations have evolved from prescriptive mandates to performance-oriented standards—from "tell me what to do" to "show me how to do it" to "involve me in it." For example, in the offshore industry, it is the operator's responsibility to establish and justify the basis for managing the risks of offshore operations. Such a shift is likely in the shipping industry in the future as well. In the authors' opinion, this will involve use of scientific approaches to handling human error in the context of marine training and education.

### *Task Analysis*

Task analysis is a universal term for various techniques used to collect, organize and apply information about tasks in order to make various design and operation judgments (Mitchell and Bright). The primary objective is to compare system demands with operator capabilities and, if necessary, to change those demands to reduce the potential for human error and improve human performance. Task analysis is a process of data collection, representation, analysis and simulation.

The training process for seafarers may also be improved by performing task analysis. The balance between workload and manning level may also need to be assessed in order to reduce human error. Task analysis can also be used to address specific human factors issues, such as person specification, job organization, task and interface design, skills and knowledge acquisition, and performance assurance.

Adoption of formal task analysis techniques may be a realistic goal for the marine industry. The detailed method of analysis and the scope of its application will vary based on the goal of the analysis and the issues to be addressed. Hierarchical task analysis (HTA) and task decomposition analysis (TDA) are two common techniques. HTA is used to represent the relationship between tasks and subtasks, recording system requirements or functions, and how these are to be achieved. It is often used to develop a framework within which other task analysis techniques are applied.

TDA is used to expand on a basic description of activities that make up each task element. It requires a set of basic task descriptions, often developed via HTA. Other task analysis techniques include charting and network techniques; interface surveys; influence diagrams; questionnaires and structured interviews; timeline analysis; and walkthroughs (Mitchell and Bright). In many circumstances, no single technique will meet all analysis requirements; thus, some combination of techniques will be necessary.

### *Human Reliability Analysis*

Human reliability analysis may involve the following factors:

- environmental (physical, organizational and personal);
- internal error (training, experience, toleration by supervisor and lack of supervision);
- technical error (lack of sufficient instruction, poor concentration, feasibility of the product design and various unforeseen causes);
- unknown or undetermined causes.

Human error rates for various forms of activities may be needed to perform quantitative safety analysis involving human error. Although these rates may be obtained from a failure and repair data-collection program, this can be a difficult task for several reasons.

- Low probabilities of human error require a large amount of experience.
- Most data-collection programs con-

centrate on recording events rather than analyzing causes.

•Many large organizations have not committed resources to the collection of human error data (Smith).

As a result, human error assessment models may need to be formulated in order to assess human error rates with respect to factors such as task complexity, level of training and experience of personnel involved. Several models are currently available:

•HEART (Human Error Assessment and Reduction Technique, developed by J.C. Williams);

•THERP (Technique for Human Error Rate Prediction, developed by A.D. Swain and H.E. Guttmann).

•TESEO (Empirical Technique to Estimate Operator Errors, developed by G.C. Bellow and V. Colombari).

To select the appropriate model, one must compare them and determine which is best-suited for the task at hand based on factors such as accuracy, consistency, usefulness and resources. Once human error rates have been estimated for various situations in ship operations, attention can be focused on areas where these rates are too high. A cost-benefit analysis can also be conducted to compare the cost of training and education with the benefit—reduced human error.

## CONCLUSION

Each catastrophic disaster is preceded by a unique set of circumstances. For such an event to occur, many things must go wrong at the same time.

However, statistics on marine casualties indicate that a common "signature"—that of human error—is present in most maritime disasters. To address this problem, the marine industry must strive to minimize poor human decisions that contribute—directly or indirectly—to a casualty or pollution incident. Education and training are an effective way to achieve this goal.

The industry must focus on addressing the problems that affect maritime education and training, particularly in developing countries which are a major provider of mariners. Stakeholders must form stronger alliances in order to better train seafarers, and training institutions must be evaluated to identify and correct their weaknesses.

In addition, competence in practical skills must be given higher priority. This can be achieved by revising training programs to meet STCW 95 requirements. Onboard training programs and practical training activities must also be enhanced, as must the English language qualifications of seafarers.

STCW 95 is a giant step in the maritime community's efforts to improve seafarer qualifications and eliminate human error. In the authors' opinion, STCW 95 will substantially improve the current situation in the world's shipping industry; ensure uniform application of its requirements; and significantly improve the standardization of maritime competence worldwide, which can only enhance the safety of shipping operations and better protect the environment. ■

## REFERENCES


Alam, M.Z. "Training of Seafarers: Key Issues and New Strategies for the Future." Presentation at the Second International Maritime and Training Conference, Singapore. Oct. 12-13, 1992.

American Bureau of Shipping (ABS). "ISM, ISO, STCW and the Human Element Seminar Workbook." Houston: ABS, 1996.

Anderson, D.E., et al. "Influence of Human Engineering Manning Levels and Human Performance on Ships." *Naval Engineers Journal.* Sept. 1997: 67-76.

Cowley T. "The Concept of the ISM Code." *Proceedings of Management and Operation of Ships: Practical Technology for Today and Tomorrow.* London: Institute of Marine Engineers, May 1995. 1-13.

Goulielmos, M.A. "An Emergency Decision Support System Online for Captains." *Proceedings of IMAS 97.* London: Institute of Marine Engineers, 1997. Paper 16.

Metevelis, E. "Managing Human Error in Ship Operations." MSc. Dissertation. London: Centre of Maritime and Offshore Operations, Liverpool John Moores University, 1997.

Millar, I.C. "The Need for Structure: Towards Reducing Human Factors Errors in Marine Accidents." *Maritime Policy & Management Journal.* 1980.

Mitchell, K. and C.K. Bright. "Minimizing the Potential for Human Error in Ship Operations." *Proceedings of Management and Operation of Ships: Practical Techniques for Today and Tomorrow.* London: Institute of Marine Engineers, May 1995.

Ministry of Justice and Police (MJP). "*Scandinavian Star* Disaster 1990." Norwegian Official Report. Oslo: MJP, 1995.

Sidin, J. and S. Sarma. "Officer Training: Old Style/New Style—What Is Different, What Works Best?" *Proceedings of the Second International Manning and Training Conference.* Singapore, Oct. 1992.

Smith, D.J. *Reliability, Maintainability and Risk.* 4th ed. London: Butterworths-Heinemann Ltd., 1992.

Stranding, B. "The Human Factors: Hard Lessons from Tanker Disasters." *Fairplay Journal.* March 1986.

U.K. P&I Clubs. "A Report on Manning." London: UKPIC, 1995.

Wang, J., T. Ruxton and C.R. Labrie. "Design for Safety of Marine Engineering Systems with Multiple Failure State Variables." *Reliability Engineering and System Safety.* 50(1995): 271-284.

Wang, J., J.B. Yang and P. Sen. "Multi-Person and Multi-Attribute Design Evaluations Using Evidential Reasoning Based on Subjective Safety and Cost Analysis." *Reliability Engineering and System Safety.* 51(1995): 271-284.

Wang, J., et al. "Safety-Based Design and Maintenance Optimization of Large Marine Engineering Systems." *Applied Ocean Research.* 18(1996): 13-27.

Wang, J. "A Subjective Methodology for Safety Analysis of Safety Requirements Specifications." *IEEE Transactions on Fuzzy Systems.* 5(1997): 418-430.

Wang, J. and T. Ruxton. "Safety Analysis Methods Applied to the Design Process of Large Engineering Products." *Journal of Engineering Design.* 8(1997): 131-152.

Wang, J. and T. Ruxton. "Design for Safety." *Professional Safety.* Jan. 1997: 24-29.

Wang, J. "A Subjective Tool Applied to Formal Safety Assessment of Ships." *Ocean Engineering.* 27(2000): 1019-1035.

Wang, J. and S. McOwan. "Fast Passenger Ferries and Their Future." *Maritime Policies & Management.* 27(2000): 231-251.


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