2001

Identifying and reducing the involvement of human element in collisions at sea

Zhengjiang Liu
World Maritime University

WORLD MARITIME UNIVERSITY
Malmö, Sweden

IDENTIFYING AND REDUCING THE INVOLVEMENT OF HUMAN ELEMENT IN COLLISIONS AT SEA

By

LIU ZHENGJIANG
The People's Republic of China

A dissertation submitted to the World Maritime University in partial Fulfilment of the requirements for the award of the degree of

MASTER OF SCIENCE

In

MARITIME AFFAIRS

(MARITIME SAFETY AND ENVIRONMENTAL PROTECTION)

2001

Dedicated to
my mother who passed away on
12th August 2000

DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Liu Zhengjiang

14 September 2001

Supervised by:
Prof. R.E. McFarland, LCDR U.S. Coast Guard
Associate Professor, Maritime Safety and Environment Protection
World Maritime University

Assessor:
Dr. P.K. Mukherjee
Professor, Maritime Safety and Environment Protection
World Maritime University

Co-assessor:
Mr. Thomas Koester
Psychologist, MA
Danish Maritime Institute

ACKNOWLEDGEMENTS

I would like to extend my heartfelt gratitude to Dalian Maritime University, the Department of Science and Education of the Ministry of Communication, and the Department of International Cooperation of the Ministry of Communications, which nominated me to pursue a course of studies at the World Maritime University.

I am most grateful for DANIDA, Denmark, for having awarded me a scholarship, which made my study in World Maritime University possible.

I would like to express my sincere thanks to Prof. R.E. McFarland, my supervisor, who has been greatly encouraging and put forward invaluable recommendations and comments on my work.

I want to express my profound thanks to Prof. Wu Zhaolin, My supervisor in China, who has initiated my inspiration on the issue studied in this dissertation and give me much valued advice and assistance in the writing of this dissertation.

Mr. Zhao Yuelin, Associate Professor of Dalian Maritime University; Captain Guo Zirui, Mr.Zhou XiuHong, and Mr.Li Jianjun, officers of China Maritime Safety Administration; and Captain C.L. Petersen, Ship Surveyor of Danish Maritime Authority, have given me their hands in questionnaire investigation, I am deeply grateful for their generous assistance.

Deeply thanks will also go to Mr. C. Cole and Ms. I. Battista for who has performed the thankless task of reading the draft of the dissertation to correct the grammar and spelling mistakes in it.

I wish to thank Mr. Y.J-U. Schroeder for his comments and recommendations on the dissertation has been most helpful and are greatly appreciated.

My sincere appreciation also extended to all the staff of World Maritime University, especially to Prof. P.K. Mukherjee, Prof. P. Muirhead, Capt. J. Horck, and the staff at the library of the University. Without their great help in providing idea and information, this dissertation could not have been completed.

I would also like to thank my colleague students especially Mr. Li Zhaoliang, Mr. Xie Hui, Mr. Sha Zhengrong, Mr. Xu Shiming, Ms. Yang Dan, Ms. Meng Fang, Ms. Liu Jie, Ms.Yan Hong, Ms Xu Chunfeng, Ms Chen Ailing for inspiring me with some beneficial idea and helping me in typing and editing the dissertation.

My particular gratitude goes to all my colleagues and friends in China for their firm support and great help to me.

Last but by no means least, I would like to express my heartfelt gratitude to my beloved wife, Jiang Yingjie, who has not only been supporting and encouraging me all the time, and sacrificed a lot due to my study abroad but also helped me in data calculation, and to all my family members and friends who have been taking care of my wife and my daughter, Liu Zhiyuan while I was away.

Abstract

The dissertation is a study of the human element in collision at sea; both the human elements that may be involved in maritime collisions and the countermeasures that are applicable in reducing the involvement of those human elements are identified and analyzed.

The meaning of the phrases “human error”, “human factors”, and “human element” in the context of maritime system are differentiated based on the comparison of the definitions proposed by various researchers and organizations. Thereby the application scope of “human element “ is defined for the purpose of the dissertation.

The commonly used human element classifications are examined. Based on these examination, a new human element classification for storing and gathering the human element data in maritime collision is proposed, taking into account of the direct causes, the underlying causes, and the external influencing factors leading to collision at sea.

The human element involved in collision at sea are identified by two approaches: in one hand, existing written accident reports are analyzed and the human elements involved in these accident cases are picked up; in the other hand, seafarers and exports’ view on the human elements involved in marine collisions are interviewed by questionnaires. A comparison between the results get from the two approaches is made. Mathematical tools such as fuzzy sets have been used in dealing with the data collected by questionnaires.

Faced with the identified human elements, countermeasures against these elements are examined, taking into account of the measures recommended by researchers, organizations, and seafarers.

The concluding chapter summarizes the main findings concerning the identified human elements, countermeasures, and the approaches used in the study. A number of recommendations are made relating to the need for further research in the subjects.

KEYWORDS: Human element; collision at sea; accidents; maritime investigation; countermeasures; classification.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

APPA	Automatic Radar Plotting Aids
BRM	Bridge Resource Management
CASMAIN	marine casualty database
CM	chief mate
COLREGS	the International Regulations for Preventing Collisions at Sea
CQS	close-quarters situation
ETA	expected time of arrival
FSA	Formal Safety Assessment
GMDSS	Global Maritime Distress and Safety System
HEART	human error analysis and reduction techniques
HE	Human Element
HKMP	Hong Kong Marine Department
HOE	Human and organizational error
ILO	the International Labors Organization
IMO	the International Maritime Organization
ISM	International Safety Management
JMAIAJ	Marine Accident Inquiry Agency of Japan
JMRI	Maritime Research Institute of Japan
MAO	Maritime Administration Officer
MIIUA	Maritime incident Investigation unit of Australia
NM	Navigation mate
PG	post graduate
Ro-Ro	Roll-on---Roll-off
SBAI	Swedish Board of Accident Investigation
SHEL	Software, Hardware, Environment and Live-ware
SSC	staff of shipping company
STCW	Standards of Training, Certification and Watchkeeping
NZTAIC	Transportation Accident Investigation Commission of New Zealand
TSBC	Transportation Safety Board of Canada
UK MAIB	Maritime Accident Investigation Branch of UK
USCG	the United States Coast Guard
VTS	Vessel Traffic System

CHAPTER 1
Introduction

1.1. Background

According to maritime accident statistics, the collision is one of the most significant casualties occurring at sea (IMO, 1997; Lloyd's Register of shipping, 1997, p.16). Collision avoidance has been a hot topic in the maritime industry since the 19th century. The work on collision avoidance has mainly focused on three areas: establishing regulations and strengthening traffic control; improving and enhancing the technical level of seafarers; studying and promoting collision avoidance automation (Zhao, Wu & Wang, 1992). Examples of the achievements resulting from these efforts are: the adoption of the International Regulations for Preventing Collisions at Sea; the establishment of a vessel traffic management system; the use of radar and ARPR. However, accidents, including collisions, still occur at a high rate every year; even when competent navigators are controlling the ship (Gray, 1996,4; IMO, 1997). So, what is still the matter?

It is the human element that plays a main part in maritime accidents. Research into the maritime casualty area reveals that 96% of all collisions were attributable to the human element (MAIB, 1991, p.4; UK P&I Club, 1999; Grime, 1996, p.260). Kuo's (1998, p.108)'s study concluded that 60% of all accidents are directly caused by human error, while a further 30% accidents have the human element as indirect contributory cause.

The human element as involved in maritime casualties, including collisions, has attracted much concern from all parties in the maritime industry. Researchers from various countries especially from Europe and the USA have done a great deal of work on this matter. The International Maritime Organization (IMO), as an inter-governmental organization, has played an active and leading role in human element research work. It coordinates and harmonizes the research activities among member States.

Research on the human element covers quite a wide scope. The major emphases of these research include: the classification of human and organization errors; the systematic survey of factors influencing crew performance; data gathering and analysis relating to human factors; method of improving man-ship interface; system failures; the management of human element; and quality and reliability of human element (Kuo, 1998, p.109; Moore & Bea, 1995, p.184; Williams, 1994; Eriksson & Mejia, 2000, p.8; IMO, 1997).

Research on the human element as involved in collisions has a long history. Indeed, research on the human element in collisions at sea may be traced back to the collection of statistics of accidents at sea in the mid 18^{th} century (Smeaton, Morton, & Dineley, 1996, p.260). The achievement of these accident statistics is the outcome of the International Rules of the Road at Sea which is still the basis of the current International Regulations for Preventing Collisions at Sea (Cockcroft & Lameijer, 1996, xiv). However, the intensive study of the human element involved in collisions was started at the end of the 1980s when IMO shifted its attention to the human element in maritime casualties.

The research in this field mainly focused on three aspects: the investigation of collision causes (Drager, Kristiansen, Karlsen & Wrencke, 1981, p.22; Cahill, 1997); risk analysis (Hinsch, 1995, p.389; Wennink, 1992, p.80); and watch keeper collision avoidance behaviour (MSA, 1995; James, 1994, p.259; Zhao, Price, Wilson & Tan, 1995, p.425; Zhang, 1998). Considerable progress has been made: some frequently occurring unsafe acts in collisions have been roughly identified; collision risk incorporating human factors has been estimated quantitatively; navigators' customary behavior in collision avoidance has been mathematically modeled. This progress has made a great contribution to collision avoidance and promoted safety at sea.

However, very little is known about the human element and the reasons why mistakes are made (O'Neil, 1996, p.4). Poor look out, failure to comply with regulations and fatigue are causes leading to collisions (Smeaton, Moreton & Dineley, 1996, p.260; Cahill, 1997, p.229). But, what caused the fatigue? Why is a navigator negligent when on look out? These questions need to be answered. Only when the underlying human elements leading to the unsafe acts in collisions are identified, can proper countermeasures against these errors be made.

1.2. Objectives

- Identify the human elements involved in collisions at sea.
- Identify the measures for reducing the impact of the human element in collisions at sea.

1.3. Methodology

The method used in this dissertation consists of the following steps:

- Constructing a classification for collecting and storing the data of human elements involved in collisions at sea.
- Gathering data of human elements involved from various sources especially from current written accident reports.
- Interviewing maritime safety related persons using questionnaires.

- Establishing a mathematic model for data analysis.
- Analyzing the information from written accident reports and questionnaires.
- Identifying the human element involved in marine collisions.
- Identifying the measures for reducing the human element involvement on the basis of identified human element and perspectives of related parties.

1.4. Dissertation structure

Chapter 1 provides the background and problem definition for the research. Seven steps of methodology describing the scope of the dissertation are defined.

Chapter 2 provides the definitions for the terms “human element” and “maritime system”; there is an attempt to clarify the difference between such phrases as “human element”, “human factor”, and “human error”. The human elements frequently observed in marine collisions are also presented on the basis of the current maritime accident statistics reports.

Chapter 3 proposes a classification for storing the human elements involved picked up from written accident reports. Some currently used classifications are reviewed.

Chapter 4 analyses the information and data gathered from written accident reports and questionnaires. Some most significant human elements involved in collisions are identified or confirmed.

Chapter 5 reviews the existing measures for human element reduction, and analyses the measures proposed by respondents of questionnaires. Based on this analysis, some recommendations on the reduction of human elements involvement are made.

Chapter 6 is a conclusion for the whole dissertation.

Referred literature and written accident reports, blank questionnaires, and original data for analysis are found in the Appendices.

CHAPTER 2

Human Elements in Collision at Sea

What does "human element" mean? When a glance is thrown on a piece of literature or document dealing with the safety and casualty, phrases such as "human element", "human factor" and "human error" will get into your sight. Even in the same paper, these terms are often used alternatively. The mixed use of these phrases leads to the reader's confusion on their meaning. For the purpose of this dissertation, a better understanding of the terms "human element", "human factor", and "human error" is needed.

Chapter 2 is devoted to defining and clarifying the meaning of "human element" in maritime systems. Based on the comparison of their meaning and the application scope, definitions for "human element", "human factors", "human errors" are proposed respectively. The components of human element implicated in maritime systems are explored. Human errors frequently observed in ship collisions are roughly examined based on the casualty statistics. Finally, based on the proposed maritime system, the scope of the human element to be discussed in this dissertation is defined.

2.1. Defining the human element, human factor and human error

The phrases "human element", "human factor", and "human error" are increasingly used in literature in particular when it is associated with human performance and safety. Some writers use them alternatively without any differentiation in the same paper. They mean the same thing, human failure, with any of these three terms. Indeed, they have different meanings in different uses.

2.1.1. Human error

The term "human error" has a longer history than the other two phrases. It can be traced back to 1931 when it had its birth with Heinrich (Petersen, 1996,xiii). It was introduced as a "people problem" into the causation sequences. Since then, human error has been recognized as a basic cause behind all accidents and incidents. What does " human error" mean? Peters (1966) defined it from three aspects:

> In theory, … human error consists of any significant deviation from a preciously established, required or expected standard of human performance.
>
> In practice, term may have any one of several specific meanings depending upon the nature of contractual agreement, the unique requirements of a particular program, the customary error classification procedures… and the emotional connotations involved with the use of a term which might be incorrectly perceived as possibly placing the blame on individuals or their immediate supervision.
>
> In the reality of situation where arguments of precisely what is or is not a human error are of less importance that what can be done to prevent them.

J. Reason (1990; 1997,61) defined "human error" as "the failure of planned action to achieve their desired ends –with out the intervention of some unforeseeable event."

Rothblum (1996) described the human error as " an incorrect decision, an improperly performed action or an improper lack of action /inaction".

A definition given by IMO (2000e) is:

> "A departure from acceptable or desirable practice on the part of an individual or group of individuals that can result in unacceptable or undesirable results."

Whichever of these definitions you prefer, they all convey such an impression that "human error" is the failure of planned human performance which can result in unacceptable or undesirable results. The focus is lighted on the failure of human actions.

2.1.2. Human factor

Comparing with the term "human error", human factor is a neutral phrase. It may have several meanings depending on the area it applies to. It may be used as a discipline under the title "ergonomics"; thus, it means "the scientific study of man in his working environment " as defined by Stockbridge (1975). In other case, it may means "human engineering" when talking about man-machine interface in the application of computers (Kuo, 1993, p.639).

In the context of the safety of maritime systems, "human factors" covers "a wide range of elements involves in the interaction between individuals and their working environment (Feyer & William, 1998, p.56.9), the phrases "human factors" means (UK Health and Safety Executive, 1989):

> The perceptual, mental and physical capabilities of people and the interaction of individuals with job and working environments, the influence of equipment and system design on human performance, and, above all, the organizational characteristics, which influence safety, related behaviour at work.

Kuo (1993) pointed out “the term ‘human factors’ is concerned with the interfacing of a set of personal capabilities and characteristics with a combination of hardware, software, working environment and operational culture in the effective performance of a task”

Both the above-quoted definitions cover the human beings’ capabilities, jobs and working environment, the effects of system designs on human performance and organizational characteristics. The later one even treats the above-mentioned factors into two distinct groups. Gordon (1998,p.97) quoted Wilpert’s “human factors” definition as “organizational group and individual factors”. Apparently, the term “human error” only shows human factors’ negative sides.

2.1.3. Human element

Comparatively speaking, the term “human element” is much “younger” than the term “human error” and “human factor”. It was not frequently used until the end of the 1980s, when a research report, submitted by the UK government (Marine Directorate of Department of Transportation, 1991) to IMO, claims that “the human element was found to be present in over 90 percent collisions and groundings, and in over 75 of contacts and fires/explosions”.

The UK report (Marine Directorate of department of Transportation, 1991) questioned the use of the term “human error” such as 80-90 percent of all accidents are caused by “human error” as misleading. It was not accurate. They thought that since human beings were popularly treated as just one system component amongst many others, and “human error” thus was an example of component failure. “Human factor” and “human element” were better alternatives. They stated further that both “human element” and “human factor” “can be used quite flexibly without necessarily imputing any sense of failure or transgression”.

Here, some important information is conveyed. First, human beings are treated as a component of a system. In this system, there are still some other components. So the term "human element" may be used to refer to human beings' functions and performances in the system. Second, "human error" is only an example of human elements' failure in the system. Third, "human element" has the similar meaning to "human factor".

IMO (1997a) interpreted the meaning of the term "human element" as "a complex multidimensional issue that affects maritime safety and marine environmental protection"; it "involves the entire spectrum of human activities performed by ship's crew, shore-based management, regulatory bodies, recognized organizations, shipyards, legislator, and other relevant parties".

Based on the discussion above, it could be concluded that the terms "human error", human factor" and "human element" sometimes may be used to refer to the same issues associated with maritime safety. They have different meaning more or less but "human element" emphasizes more on the "function of human being as a "component" of a system. When discussing the issues of maritime system, it is better to use "human element". "Human error" is only one dimension of "human element": human failure. To decrease its occurrence possibility is the aim of consideration of human element matters.

2.2. Human elements in maritime systems

As mentioned above, human element is a component of a system. For the task of exploring the impacts of human elements involved in ship collisions, it is necessary to identify all human elements involved in the system.

2.2.1. Maritime system

A system may be defined as "an organizational array of components designed to accomplish a particular objectives according to plan"(Clench, 1995,p.195). The system approach can offer a framework within which the human element may be put in context (Drager et al, 1981, p.23; Gu, 1992, p.5; Rothblum, 1996,).

Gu (1992, p.5) established a maritime safety system with three subsystems: operator, ship and environment. The relationships among the three subsystems are shown in Figure 2. Apparently, this system is structured from the point of view of the ship operator.

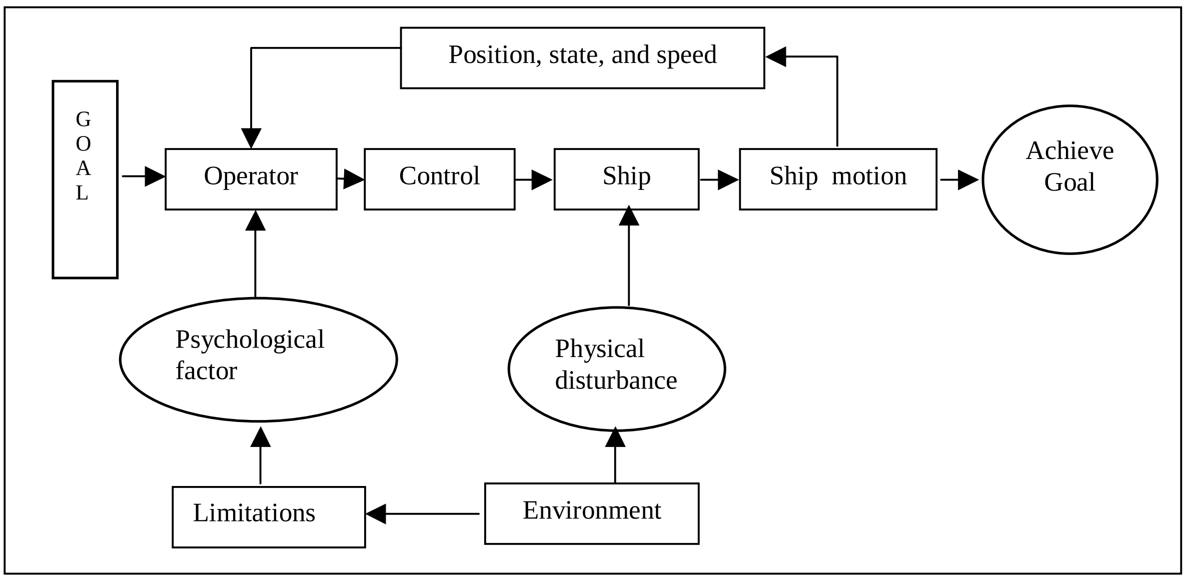

Figure 2.1 Relationship among operator, environment and ship

Source: (Gu, 1993)

Drager's (1981, p.23) system also consists of three subsystems: ship, society and environment. In this system, ship refers to the following components: technical equipment and system, crew organization on board ship, and man machine communication. The subsystem of a society covers a very wide scope including owners, shipbuilders, maritime administrators, education, health authorities, and classification society. (See Figure 2.2.)

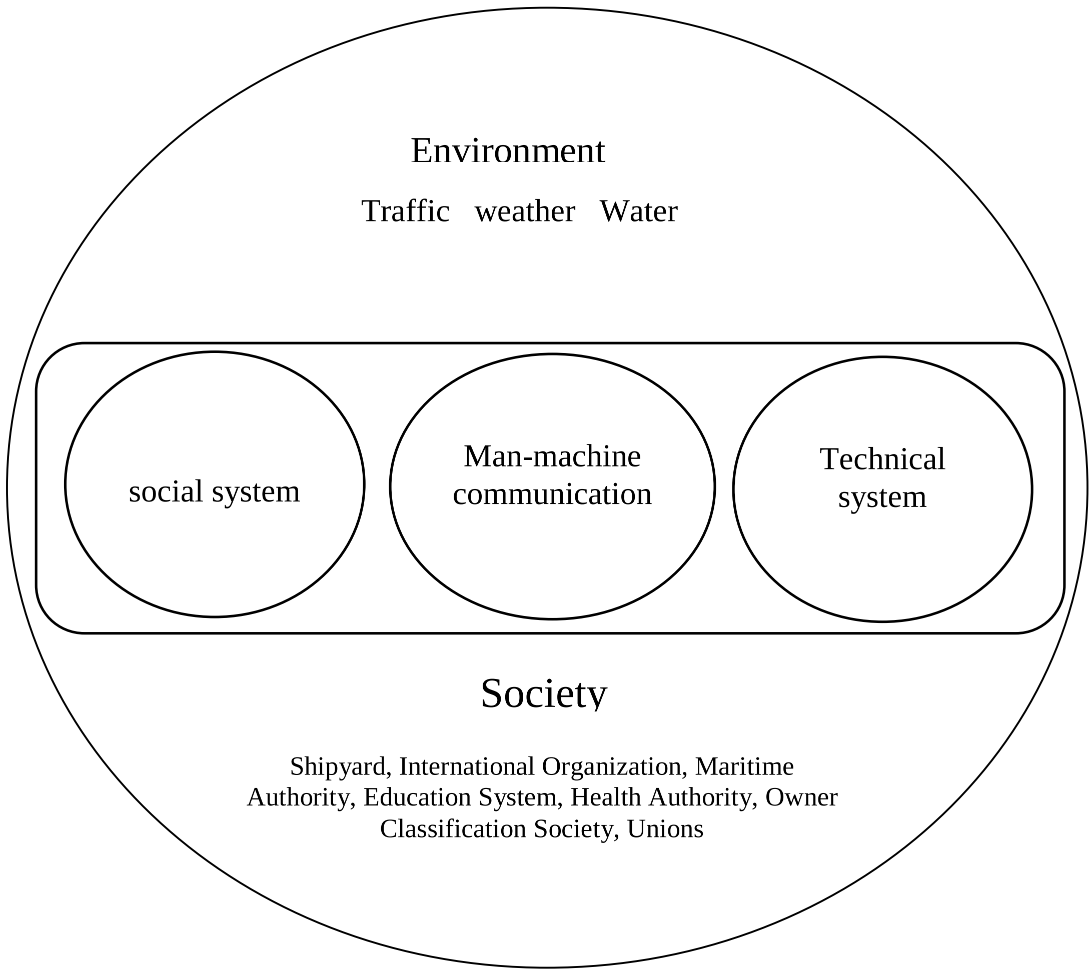

Figure 2.2 Illustration of project

Source: Drager, 1981

Rothblum (1996) stated that the maritime system is a people system (as shown in Figure. 2.3). People interact with technology, the environment and organizational factors. In this system people include the ship's crew, pilots, dockworkers, vessel traffic service operators and others. Environment includes weather environment, physical work environment and the regulatory and economic climates. Technology refers to the design of the ship and the equipment of the ship that may have some kind of impact on people's performance. Organization refers to crew organization and company policies.

Each of these system structures has its characteristics. Some of them cover a wider scope, but people (operator, man), ship, and environment are common components they contain.

2.2.2. Human elements involved

In the maritime system established by Rothblum (1996), people related human elements include knowledge, skill, abilities, memory, motivation and alertness; the effects of technology on people include perception, decision-making, and performance. The effects of the environment on people include physical and mental performance, fatigue, risk-taking; the organization on people includes fatigue, knowledge & skill, work practices, teamwork, and risk-taking. Among all these factors, the three largest problems were fatigue, inadequate technology knowledge, and inadequate communication and coordination between pilot and bridge crew (USCG, 1995).

Clench (1995) identified 9 kinds of human elements in the maritime system: training, work load, fatigue, manning, selection, language, management, knowledge, and automation. These elements are further grouped into four categories: competency, organization and methods, design, and communication.

Kuo (1993, p.640) incorporated the following human elements into safety systems: personal capabilities including both intellectual capabilities and physical capabilities; the influence of personal characteristics (such as personality, response to stress, attitude and leadership and teamwork qualities) on performance; the influence of hardware, software, and the working environment on human beings' performance; and the impact of the operational culture on human beings' behaviour.

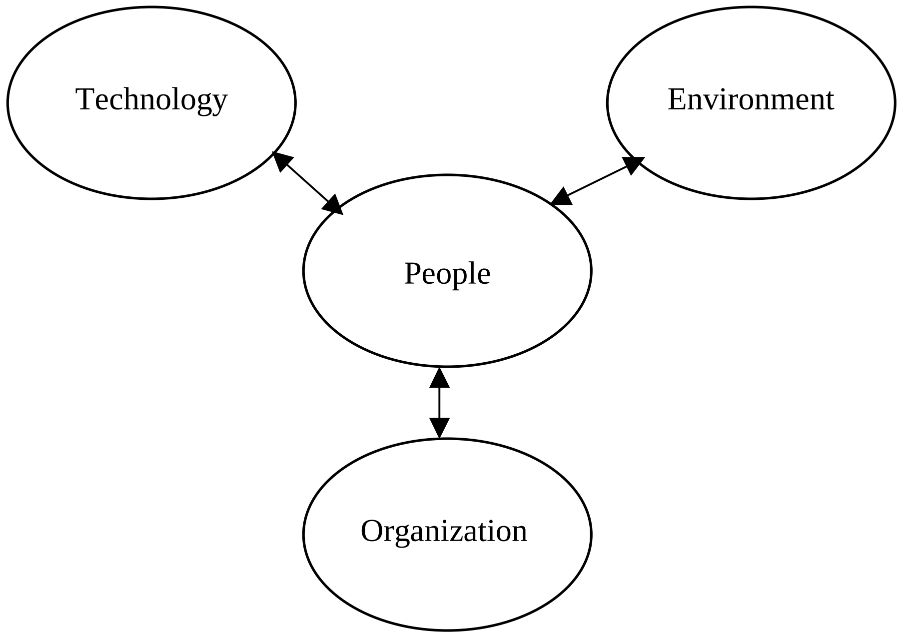

Figure 2.3 the Maritime System

Source: Rothblum, 1996

Clearly, the human elements commonly identified in maritime system by these researchers are people abilities and limitations, the influences of environment, hardware, software, and organization on people.

2.3. Frequently observed human element in ship collisions

What are the most frequently observed human elements present in collision? As a start of this research, some statistical data are quoted as the following:

After an indepth analysis on twelve selected collisions, the Marine Directorate of the Department of Transports (1991) reported that the following human elements or human errors are frequently present:

Carelessness/ overconfidence	7
Lack of attention	6
Communication failure	5
Lack of knowledge	3
Excessive speed in poor visibility	3
Sheer interaction between ships	2
Steering failure	2

Dragger et al (1981) analysed the collision accidents involving Norwegian ships for the period 1970-1978. The results revealed that external conditions and “navigational error” are of high significance in collision accidents. For vessels above 1599tgr, the result of the statistics is:

External conditions	26.8%
Technical failure	6.6%
Inadequate navigational factors	4.1%
Navigational error	17.1%
Non-compliance	6.8%
Other ship	38.5%

The Transportation Accident Investigation Commission (TAIC) of New Zealand’s (2000) statistical overview on accidents that happened during 1998-1999 demonstrates that the largest single human factors which was a cause of the accidents was error of judgement. The following is a list, which shows the occurring frequency of each kinds of causing factors:

Error of judgement	90
Lack of knowledge	71
Improper watch-keeping	53
Failure to comply with regulation	22
Ship handling	15
Failure to obtain ships position and course	13
Drug & alcohol	9
Misconduct or negligence	8
Physiological	4
Overloading	3
Fatigue	1
Adverse weather	56
Adverse current	6
Mechanical failure	26
Inadequate maintenance	12
Other	37

The Australia Marine Incident Investigation Unit (MIIU) (1996) analysed 8 collision cases and got the present frequency of human factors as the following:

Poor or no lookout	8
Poor passage plan	1
Change of watch	1
Incorrect lights	1
Unqualified person	2
Rough weather	1
No radar reflectors	2

The Japan Marine Accident Inquiry Agency (JMAIA, 1999) made a review on collision cases from 1994 to 1998 and found that 12 human elements were frequently present in collisions:

Improper lookout	410
Non-compliance with Steering and sailing rules	194
Failure to sound signals	89
Improper commercial & sequence of Duties	71
Improper selection of speed	45
Improper reporting or hand over	36
Failure to post lights and /or shapes	30
Dozing off	22
Improper ship handling	9
Improper ship operational control	6
Insufficient consideration to weather	30
Failure to check ships position	1

Based on the above quoted statistical data from various sources, a brief conclusion on human elements in collisions may be made. The most frequently observed human errors are

- Improper or poor lookout
- Non-compliance with COLREGS
- Error of judgement
- Lack of knowledge
- Unsafe speed in restricted visibility
- Failure to sound and post signals

It is necessary to point out that most of those revealed human elements are unsafe acts committed by front-line crews. For the purpose of reducing their future occurrence, the underlying contributors to collision behind those unsafe acts are needed to be explored.

2.4. Proposing structure of maritime safety systems and application of "human element"

2.4.1. Structure of maritime safety system

As mentioned above, each of the quoted structures of maritime systems has its scope of application. For the purpose of identifying human elements in collisions, a new maritime system structure is proposed as shown in Figure. 2.4.

In establishing the structure of a maritime system, the components such as operator, ship environment and society are considered. Accident occurrence has also been included into the system structure. If safe measures or defences are broken, the ship will proceed into an accident.

Operator mainly refers to crewmembers, pilots, and even VTS operators who directly conn the ship.

Society mainly includes the ship owner, the shipbuilder, the administrator, the classification society, and the international organization. Organizational culture is included in this category.

Environment refers to the external climate and traffic situation such as adverse weather condition, visibility, fairway condition, and other ships.

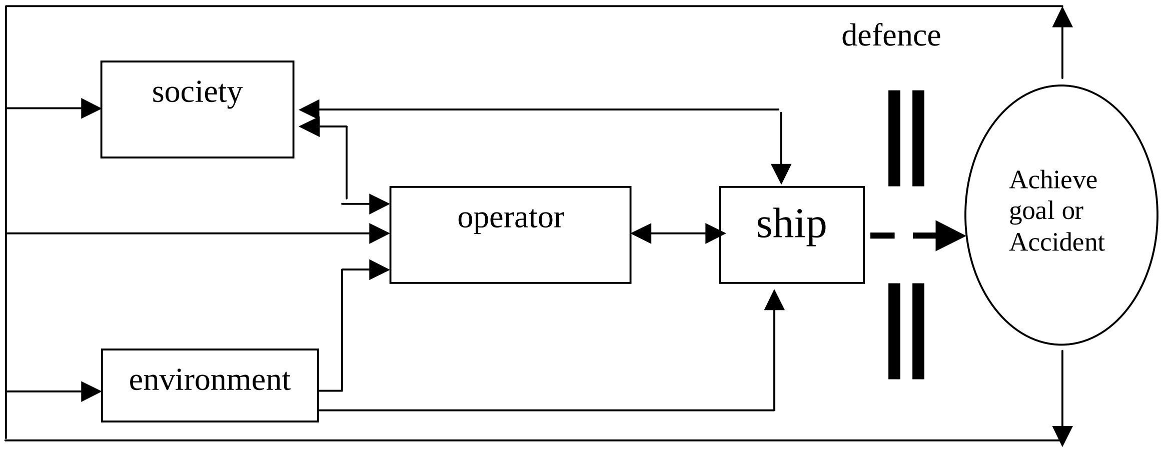

Figure 2.4 Maritime System

The ship itself is also a subsystem; it includes the ship equipment, ship hull, ship maintenance, ship manoeuvrability, and also the operating environment it provides to the operator.

2.4.2. Application of "human element"

Taking into account of the characteristic of marine collision, the human element to be explored in this dissertation mainly focuses on the unsafe acts of operators, and the underlying contributors such as the operators' personality that have a deep influence on the operator's performance. The external elements including the environment, the society and ship itself that have a direct contact with operators will also be deemed as one aspects of the human element. The detail of these human elements will be discussed in chapter 3-classification.

2.5. Summary

The light of this Chapter is thrown on defining the term “human element”, “human factors” and “human errors”, exploring frequently observed human elements in collisions, and proposing the structure of a maritime system, for the purpose of setting the scope of “human element” to be studied in the following chapters.

The meaning of the term “human element” covers a wider scope than the term “human error”. “Human element” represents a component of maritime system while “human error” is only an example of human failure in the system.

Frequently observed human element present in collisions are poor lookout, error of judgement, non-compliance of regulations, selection of unsafe speed and lack of knowledge. Strictly speaking, most of these revealed human elements by accident investigation report can only be called “unsafe act” of front-line operators. To reduce the future occurrence of those unsafe acts, underlying contributors to collisions should be explored.

The proposed structure of a maritime system mainly consists of operators, ship society, and external environment. Based on this maritime, the human element to be studied in the dissertation will limited to the unsafe acts, navigators personal characteristics, and the external influencing factors from society, natural environment and ship’s own operating environment

CHAPTER 3

Classification of Human Elements in Collisions at Sea

The focus of this chapter is to develop a classification framework for systematically identifying and characterizing human elements involved in collisions at sea. For this purpose, various human element classifications used in different accident reports and databases will be reviewed. Some literature about human elements will be studied and references will be made to IMO documents about human element investigations. Based on this study and analysis, a practical and compatible classification for identifying the human elements involved in collision will be proposed.

3.1. Existing marine collision related human element classification

The human element classification is commonly used in marine casualty database and, accident reports, and casualty statistical reports. For the purpose of this Chapter, the human element classification used in casualty database and casualty statistical reports will be reviewed.

3.1.1. Human element classification used in marine casualty database

Two typical human element classifications are introduced in this section: MAIB Human element classification and CASMAIN human error class.

3.1.1.1 MAIB Human Element Classification for Marine Accidents

The classification of Marine Accident Investigation Branch (MAIB) of UK (Gorden, 1998, p.100) classifies the human elements into 6 subcategories: external bodies liaison; company and organization; crew factors; equipment; working environment; and individual (See table 3.3.1). Each subcategory includes some human elements, which have similar natures. Some elements such as communication, training, skill and knowledge appear in different categories repeatedly, but they have different concerns in different subcategories. Take “communication” for example, it may mean the communication between the company and crew, the communication between external bodies and crew, the communication between crew and crew, the communication between external bodies and the company and so on.

Table 3.1 MAIB Human Factors Classification Summary

External Bodies Liaison a. Non compliance b. Communication c. Equipment design-manufacturer d. Training, skills, knowledge e. Working environment/workplace f. Incorrect installation/defective Equipment **Crew factor** a. Communication b. Management and supervision Inadequate c. Allocation of responsibility Inappropriate d. Procedures inadequate e. Manning (rotation / watches) f. Training g. Discipline crew/passengers h. Unsafe working practice **Working environment** Performance affected by: a. Noise b. Vibration c. Temperature d. Humidity e. Visual environment/visibility f. Ship movement weather effects g. Poor housekeeping h. Layout unsuitable for task i. Accommodation	**Company &Organization** a. Company standing orders inadequate insufficient, conflicting etc. b. Manufacture’s instructions c. Communication d. Pressures- organizational e. Inadequate resources f. Training, skill, knowledge **Equipment** a. Equipment misuse b. Equipment not available as needed c. Equipment poorly designed for operational use d. Equipment badly maintained e. Personnel unfamiliar with equipment/not trained in use f. Automation means crew not trained in use of manual alternatives **Individual** a. Communication b. Competence & skill c. Training/inexperience, knowledge d. Violates procedures e. Health drugs/alcohol medical condition f. Domestic issues g. Fatigue and vigilance h. Perceptual abilities i. Poor decision making/ information use j. Perception of risk k. Workload

Source: Gorden, 1998, p.100

3.1.1.2 CASMAIN human error classification

Table 3.2 CASMAIN human error classifications

Bypass available safety devices	Inattention to duty
Intoxication (alcohol-drugs)	Calculated risk
Carelessness	Error in judgment
Lack of experience	Lack of training
Lack of experience	Operator error
Fatigue	Smoking
Open flame	Stress
Physical impairment	Psychological impairment
Failed to comply with rules, regulations or procedures	Inadequate supervision
Improper casualty control program	Improper safety precautions
Failed to account for current weather	Failed to account for tide
Failed to use available navigation equipment	Failed to ascertain position
Failed to use charts and publications	Failed to use radio telephone
Relied of floating aid to navigation	Failed to yield right way
Failed to establish passing agreement	Failed to keep to right of channel
Failed to proceed at safe speed	Failed to stop
Failed to keep proper lookout	Improper faulty lights-shapes
Improper missing whistle signal	Improper maintenance
Used defective equipment	Design criteria exceeded
Service condition exceeded	Improper loading
Preventative maintenance not done	Improper cargo storage
Improper securing- rigging	Improper mooring –towing
Inadequate fire fighting equipment	Inadequate lifesaving equipment
Inadequate controls	Inadequate displays
Inadequate statutory-regulation requirements	Inadequate owner-operator
Inadequate owner-operator safety program	Inadequate manning

Source: Dynamic Research Corporation, 1989

The marine casualty database (CASMAIN) (Dynamic Research Corporation, 1989) is a database which was developed by the USCG to document both vessel and personnel casualties. It consists of two categories: Nature and Cause. The Nature categories include collisions, disappearances, explosions, fires, groundings, and material failure. Under each of these subcategories, some more detailed descriptions are provided. Take collision for example. Under these subcategories, two headings are provided: Meeting Situation and Objects. Meeting situation includes head-on meeting, overtaking, and cross meeting. Object means something that the ship collides with. It includes ice, aid of navigation, submerged object, floating object, fixed object, dike, lock, bridge, dock, pier, and dam etc. The Cause category provides the reasons for each nature(event) of accident. Table 3.2 shows the Cause category called "the human and organizational error classification" used in the CASMAIN.

3.1.2. Human element classification used in marine casualty statistical reports

There are a lot of kinds of marine casualty statistical reports that have mentioned more or less about human elements. In this section, only the human element classifications used in TAIC's maritime statistical overview and JMAIA's statistical reports are reviewed for they introduce the human elements in a more systematic way.

Table 3.3 New Zealand TAIC's Classification of Factors Involved in Marine Accidents

Human factors	**Environment factors**	**Technical factors**
• Error of judgement • Lack of knowledge • Improper watch keeping or lookout • Failure to comply with regulation • Ship handling • Failure to obtain ship'sposition or course • Other • Drugs and alcohol • Misconduct or negligence • Physiological overloading • Fatigue	• Adverse weather • Submerged object • Adverse current • Other • Debris • Navigation hazard • Ice • Lighting	• Mechanical failure • Other • Inadequate Maintenance • Electrical failure • Wear and tear • Structural failure • Corrosion • Steering failure • Inadequate stability • Insufficient fuel • Improper welding • Inadequate firefighting/lifes saving equipment

Source: TAIC of New Zealand. (2000)

3.1.2.1 TAIC Maritime Statistical Overview

New Zealand Maritime Accident Investigation Commission (MAIC) classified the Causes of accidents into three main types: Human, Technical and Environmental (Maritime Safety Authority of New Zealand, 2000). Under the heading of human factors, about eleven human elements are listed; most of them are direct causes of collisions at sea.

3.1.2.2 JMRI and JMAIA 's classification of Causes of Marine Accidents

The Maritime Research Institute of Japan (JMRI) identified 26 kinds of accident causes and classified them into eight major division (Nagatsuka, Seiji, 1993,) such as sub-standard ship operation control, sub-standard ship-handling, non-compliance with navigation rules, lack of due attention to weather conditions, imperfections of equipment and instruments, improper handling of machinery and tools, inadequate operation by seamen, and *force majeure* as shown in Table 3.6. Obviously, most of these divisions are connected with the human element except *force majeure*. The Marine Accidents Inquiry Agency of Japan's (JMAIA) accident statistical report (1999) did not make any kind of sub-division, but put all these phrases in the same column with some phraseology adjustment and thus make the phrase more like those used by seaman (See table 3.4).

3.1.3 Comments

The reviewed classifications, both in database and in statistical reports, provide a basis for establishing statistical model for analysing human elements. Each of them has its characteristics. The classification used in database includes more elements and is more systematic. It is used to gather and store the human element data not only for collision but also for other kinds of maritime casualties. The classification used in statistical reports is easier to be understood for the phrases used in it are closer to seamanlike words than that in databases. So it is widely accepted by those work in front-line.

Table 3.4 MAIA's Classification of Causes of Marine Accident

Major division	Sub-division
Sub-standard ship operation control	Inadequate ship operation control; Improper preparations for departure; Improper selection of waterway and non-stability of the ship's course
Sub-standard shiphandling	Inadequate shiphandling ; Non –confirmation of the ship's position Less alertness to lookout; dozing
Non-compliance with navigation rules	Not carrying lights and shapes; Failure to blow sound signals; Non-compliance with Law for the Prevention of Collisions at Sea; Regulations, and Mode of Navigation
Lack of due attention to weather condition	Lack of due attention to weather and sea phenomena; Inadequate anchorage and mooring; Inadequate measures for storm
Imperfections of equipment and instruments	Imperfections of the structures of hulls and engines, and of the materials used; improper maintenance and handling of steering equipment and instruments
Improper handling of machinery and tools	Improper maintenance, inspection and handling of main engines; Improper maintenance, inspection and handling of auxiliary engines; Improper inspection and handling of fuel oil and lubrication oil; Improper inspection and handling of electric equipment
Inadequate operation by seamen	Non-compliance with seaman's ordinary duties and procedures; Inadequate on-deck and cargo work; Improper loading of passengers, cargo, etc.; Inadequate command and supervision over the services of seamen; Inadequate reporting and transfer of business; Improper handling of fire
Force majeure	*Force majeure*, etc.

Source:JAMIA.(1998).

However, as reviewed, there are still some common drawbacks lying in those widely used casualty and accident databases and reports in terms of human elements classification. In Marton's and Purtell's (1990) words to make a comment on this issue:

> (1). No comprehensive, standardized, validated and commonly accepted classification of human factors to adequately identify human factors involved in collision process;

(2) No standardized, hierarchically organized, concept or format for identifying human factor casualty data to identify and correlate direct error causes to the underlying and contributing factors that shape the behaviours responsible for error and collision events.

3.2 Some theoretical researches results on human element classification

For developing a suitable classification framework that maybe used in identifying the human elements in marine collision, it is necessary to view the researcher's works on human failures and errors. This may give some help and inspiration.

3.2.1. Reason's classification

Reason (1990,1993) classifies human failures into types and tokens. As shown in Figure 3.1, failure types are further subdivided into source failure types and unsafe act tokens. Failure types are found at the management level and failure tokens are founded at the front line crew level.

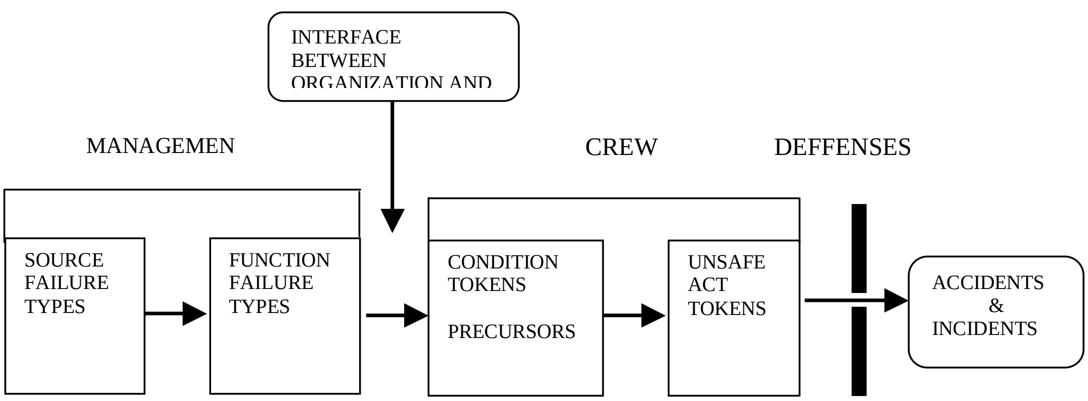

Figure 3.1 The basic elements of safety information system
Source: Reason, 1993

Unsafe acts are violations and results of motivation, individual and management attitudes and cultures, which are founded at higher levels in the organization (Reason, 1990). Unsafe act tokens are categorized as slips, lapses, mistakes and violations (Reason, 1996, p.18).

The next level in Reason's safety information system scheme is the condition tokens. Condition tokens are psychological and situational precursors to accident scenarios. They are elements which contribute to unsafe acts such as working environments, training, design, hardware, maintenance, communication and the like (Reason, 1996, p.18). The root causes of each of these condition tokens are found in critical underlying contributing errors.

Functional failure types are made at the line management level. It can be categorized into: inadequacies in operating procedures and conditions; system defects and inadequate defences; communication failures; design failures; and poor maintenances.

Source failure types are decisions made at the strategic level of the organization; this can be directed at top-level management commitments to safety competence in addressing problems or lack of cognisance of the nature of the problem.

3.2.2. Moore and Bea's classification

Moore and Bea (1993, p.3-10) categorized human element related casualty causes into 13 categories: commitment to safety; resources; human-system interface; knowledge /experience /training; maintenance; physical/mental lapses; violation; morale/incentives; job design; regulating/policing; operation policy; communication/information; and manning. The meaning and scope of these categories are given and defined as the following:

Commitment to safety is determined by the level of commitment of available resources and cognisance of potential problems to the safety of the operational system from top-level managers to front-line operating crews.

Resources pertain to money and expertise used to heighten operational safety.

Human-system interface encompasses failures and shortcomings of human actions resulting from inaccurate or insufficient information or from an inaccurate or insufficient response of control systems and control system display.

Knowledge/experience/training pertains to human or organizational failures and shortfalls resulting from insufficient or improper knowledge, experience, or training of the system under normal or extreme operating conditions.

Maintenance refers to the impact on ship operations as a result of improper, insufficient or a failure to conduct adequate maintenance, which is important to the normal and emergency operating systems.

Physical/mental lapses, slips and mistakes pertain to physical or mental lapses, attention failures, memory failures and rule based mistakes, which cause or contribute to fail or inadequately manned functions or performances under normal or extreme operating conditions.

Violations refer to intended unsafe acts as routine and exceptional violations or acts of sabotage.

Morale refers to individual behavioral attributes while incentives pertain to the differences in goal and preferences at different levels in the organization that lead to inadequately manned functions or performances.

Job design encompasses the inappropriate match of personnel characteristics with job or inadequate job descriptions.

Regulating/policing refers to the insufficient, inaccurate regulatory and policy making system or failure of organizations and regulatory bodies in continually maintaining or monitoring the integrity and reliability of the operating system.

Operating policy pertains to organizational policies and procedures from top level to front-line management, which are conducive to the implementation of safety of the operating system.

Communication/information refers to the incorrect, incomplete, or failure of the transfer of information between individuals, organizations, regulators, and systems.

Manning embodies the inadequate manning in terms of number or expertise of individuals (Moore &Bea, 1993, p.3-10).

Moore and Bea (1993) establish three stages of accident events: underlying or contributing events, direct events, and compounding events. Consequently, the causes contributing to the accident scenarios are also classified as underlying /contributing causes, direct causes, and compounding causes (as shown in Figure 3.2). Underlying/contributing causes represent latent errors in technology, organizational management, regulation, or immediate underlying causes for the specific error events. Direct causes are accident initiating errors or active errors by front-line crews, which directly affect the primary accident event. Compounding causes are latent errors in organization regulations, technological systems that enhance the casualty factors. For example, Figure 3.2 demonstrates the basic events of a potential vessel collision. Each of the events is influenced by particular human elements. (1) Vessel proceeds at an extreme high speed (contributing event), (2) the ship collides with other ship (direct event), (3) ship is damaged (compounding event).

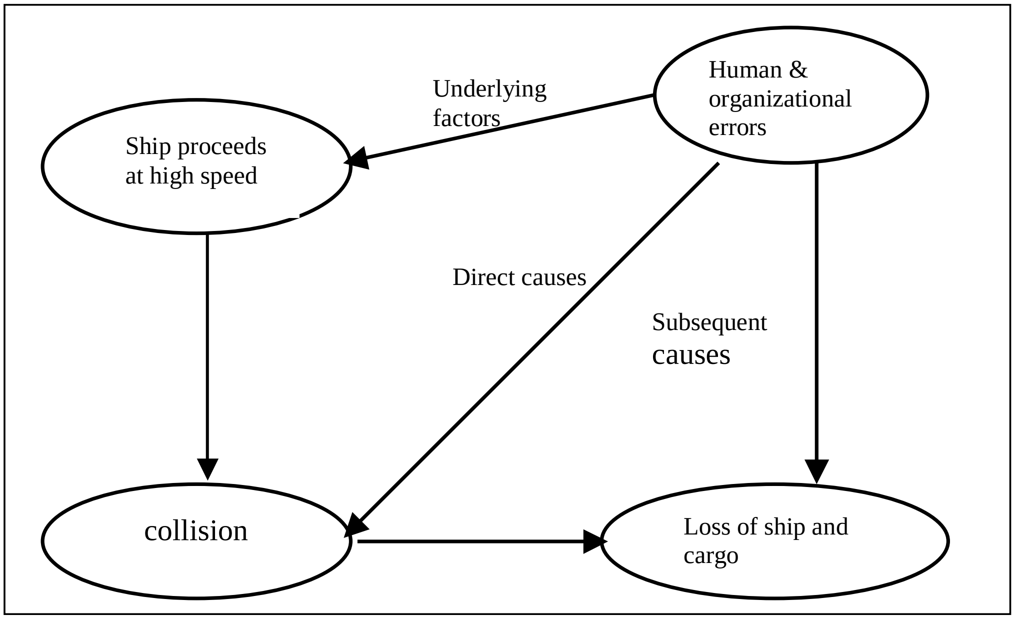

Figure 3.2 Accident event dependencies on HOE factors for ship collision

To examine the effects of external operating environments on error events and causes at the various stages in an accident sequences, Moore and Bea (1993, p.3-14) make a distinction between operating conditions (man-made or environmental) and error causes. The operating conditions are further differentiated into external and operational factors. Operational factors are specific to the operating environment. The external operating environment may contribute to events, decisions, actions or human errors. Vibration, noise, air quality, vessel traffic and smoke are classified into operational factors. External factors pertain to the external environment such as temperature, fog, rain, snow, wind, waves, time of day, ice and so on.

3.2.3. SHEL Model

The SHEL model was developed by Edward and modified by Hawkins (1987). It consists of four components: **S**oftware, **H**ardware, **E**nvironment and **L**ive-ware. Furthermore, each two of these four components forms four interfaces between them:

live-ware/live-ware, live-ware/hardware, live-ware/software and live-ware/environment as shown in Figure 3.3.

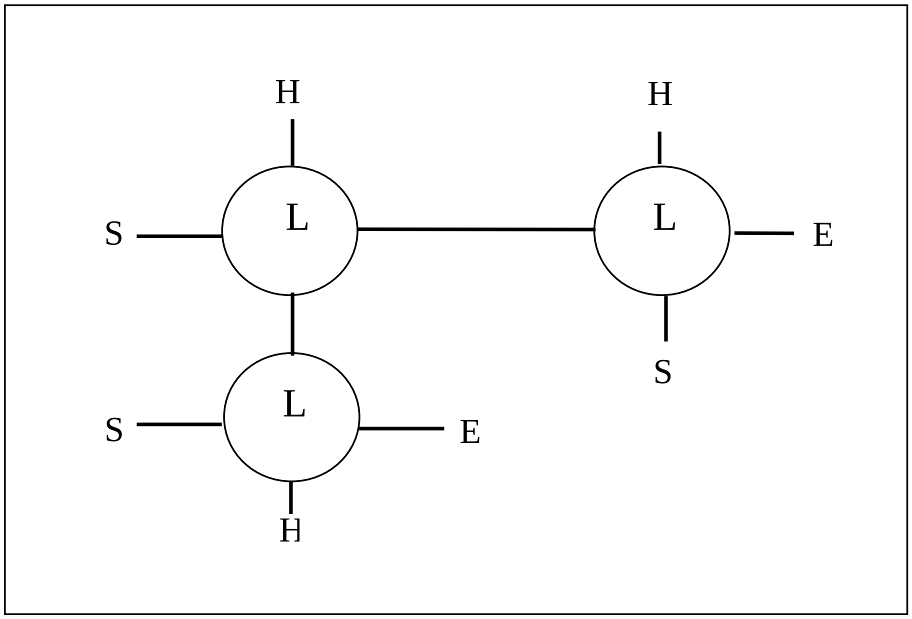

Figure 3.3 SHEL Model

Source: Hawkins, 1987

The most valuable and flexible component placed at the centre of the SHEL model is the live-ware, the human element (Schroeder, 2001). This component includes factors relating to the individuals under consideration: physical, physiological, psychological and psychosocial. Physical factors are those that limit the capacity of the individual to fulfil the designated tasks. Apart from the physical characteristics such as height, age, sex and strength of a person, sensory limitations such as needs for glasses or hearing aids are also included in this category. Physiological factors refer to the factors that could affect the individual's physiological abilities. Health, lifestyle, fatigue, duty, consumption of alcohol/drug and incapacitation are listed in this column. Psychological factors are those factors concerned with the individual's

Mind and thoughts. They include perceptions, attention information processing capacity and attitude towards specific tasks. Other aspects affecting the psyche of a person such as personality, knowledge, training, planning of operation, confidence, and emotional status are also included in this category. Psychosocial factors result from the individual's social situation. Personal problems such as mental pressure, interpersonal conflict, personal loss, financial problems, significant lifestyle changes, cultural differences and family pressure are usually taken as psychosocial factors; they may restrict capacities of a person in a crisis situation. (Schroeder, 2001).

Around the central live-ware, there are hardware, software, and environment. Hardware refers to the equipment part used in a transportation system. It includes displays, controls, and ergonomic aspects of workstations. Software is the non-physical part of the system including organizational policies, procedures manuals, checklist layout, charts, and advisories and computers programs. Environment includes the internal and external climate, temperature, visibility, vibration, noise and other similar factors, which constitute the conditions within which people are working. Sometimes the broad political and economic constraints under which the particular ship operates are included in this element. The regulatory climate is a part of the environment in as much as its climate affects communications, decision-making, control and coordination. The persons around the individual under consideration are dealt with as peripheral live-ware. It talks about human-human interactions. This may include factors such as management, supervision, crew interaction and communication, and labour relations (Schroeder, 2001).

Indeed, four interfaces mainly deal with the external and internal influences including ship, workplace, technology, human beings, weather, and fairway on the individual under consideration. Live-ware/live-ware or person-person refers to human interactions and communication covering the following aspects: oral communication (for instance, noise interference, misinterpretation, rate of speech, language barrier, and read back and hear back); visual signal (for example: hand signal, body language); crew interactions (for instance: supervisor, briefings, coordination, compatibility/team, resource management, task management, personality, and experience), controllers (for instance: supervision, briefings, and coordination), passengers(for example: behaviour, briefing, knowledge of ships, and procedure), labour relation (for example: employee/employer management, and industrial action), worker-management relations (for example: hierarchy, and Bridge Team Management), pressures (for instance: mental pressure, morale, and peer pressure), and regulatory agency (for instance: regulation, standard, implementation, inspection, monitoring, audit, and support).

Live-ware/hardware refers to human-machine interaction. Design limitation in workstation configuration, instrument and workspace can affect the performance of the system and the individual; factors relating to the person to machine interface are included in this category.

Live-ware/software refers to the factors relating to the person to system interface. It mainly focuses on the information transfer between the human and supporting systems. These factors usually include written information (for instance: manuals, checklist, publication, regulations, charts and publications, instruction, and standards), computers software and automation extent of the system. Regulatory requirements such as qualification, certification, medical certificate, license are also belong to this column.

Live-ware/environment means the factors relating to the person to environment interface. It is usually divided into three parts: internal, external and infrastructure or supporting services. Internal part includes hear, cold, humidity, ambient pressure, illumination, glare, motion of vessel, noise interference, vibrations, air quality, pollution etc. External part refers to weather. Wind, fog, sea state, temperature, visibility and so on are belongs to this category. Infrastructure refers to port facilities, support equipment, company facilities and equipment and so on. Some other factors such as time of day, other traffic, and lighting glare are also classified into this category.

The first focus of the SHEL model is on the individual and his abilities and condition. His interactions other than at work are also here. The second focus is on the different interfaces that can have an effect on overall performance of the individual.

3.3. The human element classification recommended by IMO

For the systematic investigation of human factors in marine casualty thus to determine accident causes, identify contributing factors and draw lessons, the 21st IMO general assembly adopted resolution A.884 (21)(IMO, 2000a) which amends resolution A.849 (20)(IMO, 1997 November 27) by adding the Guidelines for the Investigation of Human Factors in Marine Casualties and Incidents and designated it as Appendix 2 of the Code. Both the SHEL model and Reason's Hybrid model are recommended by these guidelines as tools for collecting and storing human elements in marine accidents.

Apparently, the SHEL model has provided a highly organized place to store information regarding unsafe situations (Landsburg et al, 1999, p.21) and human elements. The model can be used as a basis for determining the causes and probabilities, for it has taken into consideration of all the important work system elements and the interrelationships between the work system elements and has focused on the factors which influence the human performance by relating all peripheral elements to central human elements.

The Reason's model is established on base of the discovery that accidents usually are not caused by mistakes done by the front-line operators alone, and has considered the circumstances that persons not directly involved in a accident may contribute to the accident through creating a certain environment for the accident. It is deemed as an excellent tool for analysing the data from the SHEL model (Ferguson et al, 1999). The data collected in an investigation can be organized using multiple components of the SHEL model, into a framework surrounding an occurrence template, based on the Reason (1990) model. Causal factors are thereby identified.

The classification model, such as the SHEL and Hybrid model recommended by IMO provides a good backbone standard taxonomy, but when it is applied to the actual accident investigation and causation analysis, there are still some further work needed to be done. Some terms used in the model are not included in the vocabulary of the average mariners on a daily basis, which brings about the difficulties for common mariners' use.

3.4. Classification of human elements in marine collisions

The classification used in this dissertation is established on the basis of the SHEL and Hybrid model. References to some research reports (Moore and Bea, 1993; Rothlum, 1996; Reason, 1996) and accident reports (MAIB, 1999,2000; TAIC, 2000; MIIU, 1996; MAIA, 1999) have also been made. The scope of human elements to be involved in the classification has been defined in chapter 2.

3.4.1. Consideration in establishing the human element classification

First of all, the goal of the classification should be considered. The main objective here is to systematically identify collision related human elements and analyse the accident causation. The classification must be complete enough for collecting and storing the relevant element data.

Second, the preferences of users should be considered. Hopefully the dissertation may have reference values to collision avoidance researchers, marine accident investigators, shipping managers and operators, regulators and mariners, thus their preferred elements should be included.

Third, the complexity of the classification should be weighted against the preferences of the user. Standard vocabulary of interpretation should be used thus it could be easily understood and grasped by professional mariners and investigators who used to be mariners.

Fourth, the compatibility of the classification should be considered. The classification should be such a taxonomy that could be adopted and at the same time permit sharing and storing of data not only for collision accident but also for other maritime accidents.

Finally, for further development, the classification model recommended by IMO should be put in a priority position.

3.4.2. Structure of the classification

The classification consists of three areas: unsafe acts and failure, underlying human elements, and influence factors and conditions. Figure 3.4 demonstrates the structure of the classification. Table 3.5 gives the human elements involved in the classification in detail.

Unsafe acts and failure refers to errors committed by front-line watch keepers, crews, pilots and the like that directly lead to the occurrence of collision. Based on analysis results of collision accident reports (see appendix A), the following failures and unsafe acts that frequently occurred and lead to collisions are included into the following classification:

- *Poor lookout*: includes no lookout and improper lookout because of dozing off, lack of experience or change of watch.
- *Poor passage plan*: this item may refer to improper preparation for departure, lack of knowledge of the fairway and passage.
- *Failure to take early action*: the action taken for collision avoidance is too late and leads to collision.

- *Failure to obtain ships position and course*: deviate from its own road without awareness.
- *Failed to comply with regulations*: violate the requirements of COLREG, non-compliance with the rule for the prevention of collision at sea;
- *Error of judgement*: failure in judging the meeting situation and circumstances and take an improper action based on this error judgement.
- *Unsafe speed*: select an extreme speed that is too fast or too low under the current circumstances.
- *Improper ship handling*: handle the vessel in improperly because of lack of skill of ship handling and knowledge of ship manoeuvrability and thus lead to collision.
- *Failure to compliance with seaman's ordinary practice*: no attention has been paid to good seamanship.
- *Misinterpreted communication*: misunderstanding between crew and pilot, ship and shore, ship and ship, crew and crew.
- *Failure in using radar and ARPA*: defective inspection, maintenance, handling and interpreting electronic navigation and collision aids, especially misinterpreting the information given by radar and ARPA.
- *Failure to post lights or shapes*: failure to blow sound signals.
- *Violation*: acts of sabotage.

In most instances, collisions are caused by more than one unsafe acts and failures (Rothblum, 1996). In addition, there are also more than one human elements behind these unsafe acts and failures. The human elements listed in the following classification are particularly focused on:

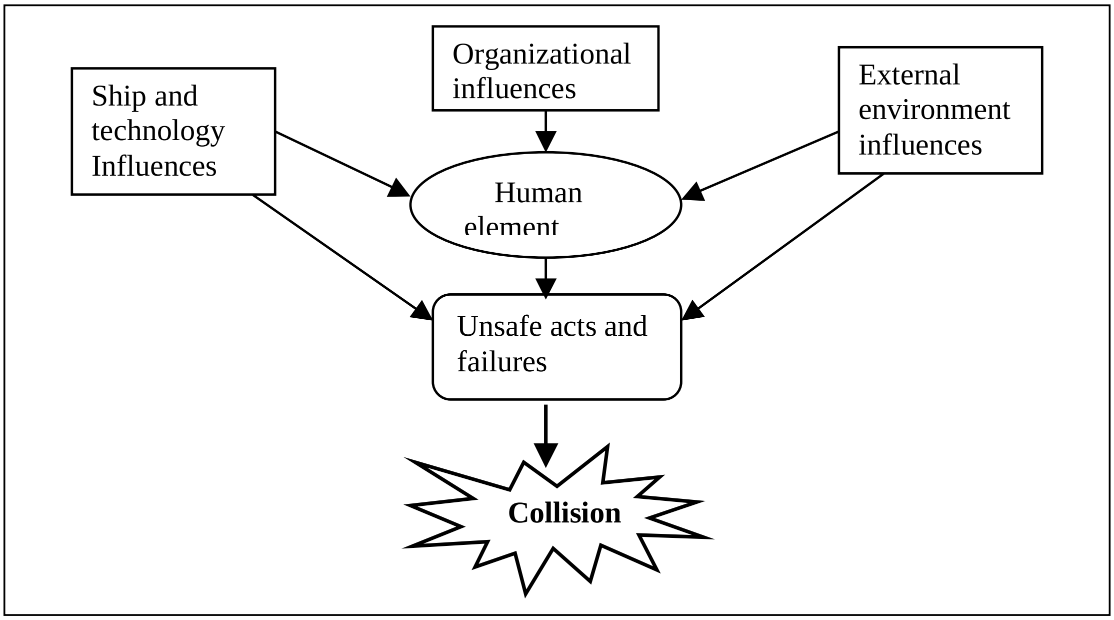

Figure 3.4 Structure of human element classification for collision analysis

- *Physical factors*: sensory limitation, including visual, hearing, touching and smelling limitation.
- *Physiological factors*: fatigue, including sleep and duty; health including life style; drug and alcohol;
- *Psychological factors*: attitudes, attention, judgement, workload, experience/knowledge/training, mental/emotional state, personality (such as withdraw, aggressive, show off), confidence (such as over confidence);
- *Psychosocial factors*: pressure from social and family, crew interaction.

External factors which may have a positive or negative influences on crews' performance daily are listed in the right column of Table 3.5, They are categorized into three areas: organizational factors, operating environment, and external environment.

Organizational errors are created by top-level decision makers. They may take the form of under-manning, unworkable procedure, excessive time pressure, poor supervision and other workplace factors likely to promote human errors.

Table 3.5 Human Elements Classification

Unsafe acts and failure	Human elements	Influence factors
➢ Poor look out ➢ Poor passage plan ➢ Failure to take early action ➢ Failure to obtain position and course ➢ Failure to comply with ➢ Regulation ➢ Error of judgement ➢ Unsafe speed ➢ Misinterpreted communication ➢ Improper ship handling ➢ Failure to comply with Good seamanship ➢ Misuse radar, ARPA etc. ➢ Failure to display visual and sound signal	➢ Sensory limitation ➢ Health ➢ Fatigue ➢ Drug and alcohol ➢ Attention ➢ Information processing ➢ Workload ➢ Experience/knowledge/ training ➢ Mental emotional state ➢ Personality ➢ Communication ➢ Social pressure	❖ Organizational factors ➢ Manning ➢ Commercial pressure ➢ Supervision ➢ Safety culture ➢ Labour relation ❖ Operating environment ➢ Equipment layout ➢ information display ➢ maintenance ➢ automation ➢ Written information ➢ Noise and vibration ➢ Motion of vessel ❖ External environment ➢ Adverse weather ➢ Visibility ➢ Current and tide ➢ Fairway ➢ Other traffic ➢ Time of day ➢ Lighting glare

Operating environment focus on noise and vibration on board of ship, motion of vessel such as pitching, rolling and heaving, equipment layout, information displaying, maintenance of the vessel, automation, for they have impacts on crew's decision-making ability to certain extent. Some literature also takes it as technology factors (Rothblum, 1996) or ship environment (Huang, 1999, p6).

External environment mainly consists of weather, traffic and fairway conditions. These factors such as adverse weather, restricted visibility, congested traffic, confined waters; time of day, and background of light may all have negative influences on seafarers' physical and mental performance, and therefore reduce their ability in judgement.

3.5. Summary

In this chapter, the most commonly occurred unsafe acts and failures in collision accidents were reviewed with reference to various casualty reports, safety digest, and accidents statistics and research literature. Based on the SHEL and Hybrid model recommended by IMO (2000), supplemented by the error classification given by Moore and Bea (1993) and incorporating the results given by current casualty reports and statistics, a human elements classification is developed which is particularly applicable for collecting the data of human element involved in collision at sea. The human element classification consists of three areas: unsafe acts and failures; underlying human elements; and external influence factors. Unsafe acts and failures include the front-line crew errors, which initiate the events of collision. Underlying human elements include individual's physical, physiological, psychological and psychosocial states, which form the preconditions of crew's unsafe acts and failures. External influences come from organization, ship and natural environment.

CHAPTER 4
Identifying the Human Elements Involved in Collision

The focus of this chapter is to identify the human elements involved in collisions at sea. Existing available written reports of collision accidents will be carefully analyzed. Seafarers and experts from various sections of the shipping industry will be interviewed by questionnaires. The results of these two approaches will be compared and discussed thereby to reach our goal.

4.1. Identifying the human elements from the written accident reports

4.1.1. Collision data search

The written collision accident reports are selected as the main source for collecting the human element data involved in collision at sea. There are several kinds of formats for storing casualty data. Written reports and database are the primary form among them. However, computerized casualty database is usually limited in documenting accidents, which brings about the difficulty in finding the underlying causes leading to unsafe acts and failures. (Moore & Bea, 1993, p.2-1). Although the existing written accident reports also have this or that kinds of drawbacks, for example, there is no uniform description format and recording system and the accuracy of the reports are strongly influenced by the competence of investigators, they are still the most invaluable materials available for they provide an approach to look at the accidents themselves and the causes leading to the accidents. They allow researchers to examine the sequence of causal factors, which would be difficult to determine and identify by other means (Reason, 1990; Moore & Bea, 1993 p.2-1). They also provide researchers with a great deal of information to examine the effects of contributing errors, factors and the limitations of human performance under various operation conditions.

The written accident reports studied in this dissertation are mainly collected form the Internet and some printed publications. 13 out of the 100 collected accident reports come from the Marine Accident Investigation Branch (MAIB) of the United Kingdom, 32 reports come from the Marine Incident Investigation Unit (MIIU) of Australia, 2 of them come from the National Transportation Safety Board of the USA; 2 of them are written by Hong Kong Marine Department (HKMD); 21 of them come from the Transportation Safety Board of Canada; 1 comes from the Transportation Accident Investigation Commission (TAIC) of New Zealand; 1 comes from the Swedish Board of Accident Investigation(SBAI); the remaining 28 cases are taken from the Lloyds Law Report and the American Maritime Cases which have been quoted by Captain Cahill (1997). A comprehensive list of the collision casualty information is found in Appendix 2. Table 4.1 summarizes the sources of collision accident reports.

The written reports are selected at random without any special attention to type of ships, time of day, and site of occurrence. All collected accidents occurred from the beginning of the 1980's to present. Most of them occurred in the 1990's.

Table 4.1. Source of the used written accident reports

Source	Number of used accident reports
ATSB	32
MAIB	13
TSB	21
TAIC	1
HKMD	2
NTSB	2
SBAI	1
Lloyds Law Report and American Maritime Case Quoted by Cahill	28

4.1.2. Results derived from the written reports

By analyzing the written accident reports carefully, the human elements involved in these accidents are roughly identified. These elements are classified into three subcategories: unsafe acts; underlying human elements; and external influencing factors, based on the classification system provided in Chapter 3.

4.1.2.1 Unsafe acts

As shown in Figure 4.1, the most frequently involved unsafe acts in collisions are poor lookout. 71% of the researched accidents are attributed to poor lookout. The second frequently involved unsafe acts are error of judgment. Failure in use of radar and ARPA ranks at position 3 of the frequency list. Half of the analyzed collision accidents have more or less relations with misuse of radar and ARPA. Failure to comply with the requirements of regulations, failure in communication and failure to display and sound signals rank at position 4 of frequently involved unsafe acts together. 41 of the 100 collision accidents are more or less caused by these unsafe acts. The rest frequently involved unsafe acts are ranked in the following orders: improper ship handling (35%), failure to take early actions (30%), unsafe speed (30%), failure to comply with good seamanship (24%), failure to take position and course (20%), poor passage plan (8%) and violation (8%).

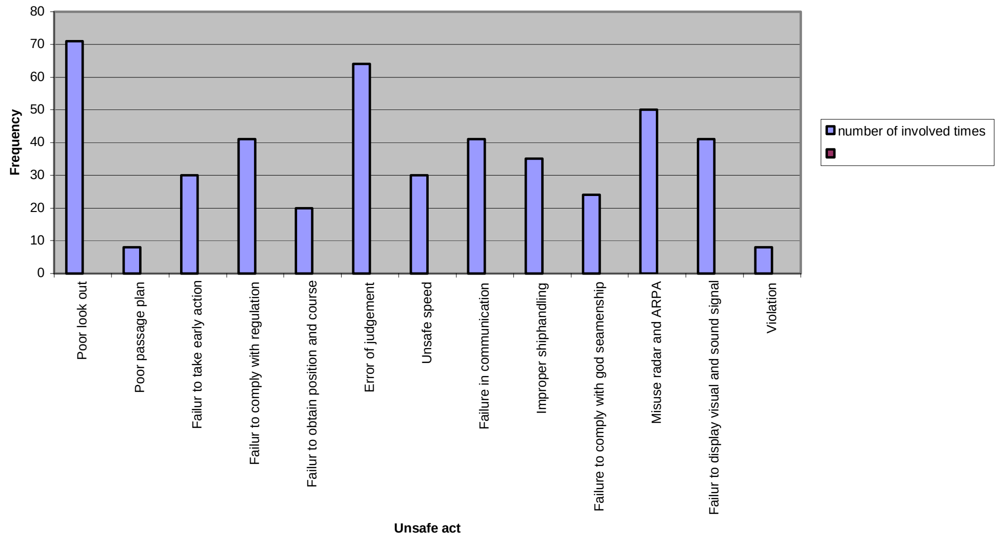

Figure 4.1 Unsafe acts found in written reports

Poor lookout refers to no lookout and improper lookout. These unsafe acts occurred in these collision accidents are considered as poor lookout: no lookout man is arranged at proper position, especially in restricted visibility conditions; the number of lookout men is not enough in prevailing circumstances; the duty of lookout is not properly conducted; all available means appropriate including the effect use of available instruments and equipment are not properly used; the situation is not fully appraised; anchor watch is not properly kept (Cockcroft & Lameijer, 1996, p.37; Cahill, 1997, p.210).

Error of judgment refers to failure to judge the meeting situations and circumstances. The following acts have been classified as error of judgment: assumption on scanty information; lack of judgment to differentiate between situations when it is safe to follow the routine and when circumstances require its suspension; judgment was made based on the old experience; failure to ascertain the situation in respect to whether or not the safe situation exists (Cockcroft & lameijer, 1996, p.37; Cahill, 1997, p.210).

Failure in using radar and ARPA includes defective inspection, maintenance, handling and interpreting electronic navigation and collision aids. The acts that have been considered as failures in the use of radar and ARPA include the flowing: no operational radar on board ship; radar and ARPA are not at their optimum settings; the range scale is not properly set; the display is not properly chosen; the bearing and distances of approaching vessels are not taken at regular intervals and carefully evaluated by plotting or by some equivalent method; no continuous observation on radar and ARPA; too great reliance on radar and ARPA without a full, appreciation of its possible inaccuracies (Cockcroft & Lameijjer, 1996, p.40; Cahill, 1997, p.54).

Failure to comply with regulations covers much broader scope in general. All acts that deviate from the requirements of regulations may be considered as failure to comply with regulations. In this dissertation, it is limited to the unsafe acts that were not explicitly listed in the classification. For example, these acts will be deemed as failure to comply with the regulation: failure to give sufficient sea room to stand on vessel; action is not sufficiently bold to be ready apparent to other; failure to use available means to determine risk of collision; relied exclusively on the passing arrangement made on VHF R/T contrary to procedures as defined in COLREGS; make a succession of small alteration of course and /or speed in collision avoidance. Ignoring the requirements of local regulations has also been considered as failure to comply with regulations (Cockcroft & Lameijer, 1996, p.6; Wu, 2000, p.36).

Failure in communication not only refers to misunderstanding between crew and pilot, ship and shore, ship and ship, but also includes no communication and failure in making use of all available means for communication. Those acts involved in collect cases have been deemed as failure in communication: misinterpreting the meaning of other ships, pilots, and masters; failure to exchange information between pilot and master; failure to report to master and pilot the information concerning the situation; failure to establish a communication by VHF between VTS and ship, ship and ship; failure to communicate in time.

Failure to display and sound signals is also a very common unsafe act in the studied cases. The acts that failed to post and display required lights and shapes under way and at anchor, and failed to exchange sound and light signals with other ships during collision avoidance action have been deemed as failure to display and sound signals. For instance, a vessel restricted in her ability to maneuver failed to show the relevant lights and shapes, a stand on vessel failed to sound short blasts to warn the give-way vessel that failed to take early action, and an overtaking vessel failed to sound signals to inform the overtaken vessel from the side she intended to overtake.

Improper ship handling refers to ship maneuver that did not adapt to the prevailing situation and even worsened situation. The following acts occurred in the studied collision cases have been categorized as improper shiphandling: miscarrying out the shiphandling order given by pilot and/or by master; handling the vessel without considering the effects of winds, current, bank, shallow water and other external disturbances.

Failure to take early action is also a violation of International Regulations for Preventing Collisions at Sea, (COLREGS) (Cockcroft & Lameijer, 1996, p.48). The give-way vessel failed to take early action and the stand-on vessel failed to take action at the moment when it is permitted by COLREGS are deemed as failure to take early action.

Unsafe speed refers to the speed that makes vessel unable to take proper and effective action (Cockcroft & Lameijer, 1996, p.26). It may be too high or, in some special circumstances, too low. The following acts have been deemed as using unsafe speed: a vessel in fog without operational radar proceeded full ahead; a vessel reduced speed to such an extent that the steering became ineffective. (Cockcroft & Lameijer, 1996, p.26).

Failure to comply with good seamanship (Cockcroft & Lameijer, 1996, p.6) refers to the act that deviate from the customary ways which have been practiced by experienced seafarers for a long time and have been proved to be proper to navigation safety. The following acts occurred in the collision cases are deemed as failure to comply with good seamanship: failure to prepare anchor for emergency use when sailing in narrow channel; over relying on other vessels keeping out of their way when a vessel is underway but stopped; failure to take shallow water effects into account when sailing in confined waters; overtaken vessel failed to clear the path of the overtaking vessel.

The following acts have been considered as *failure to obtain position and course*: failure to fix her position regularly in anchorage thus leading to collision because of dragging anchor; failure to fix her position and unawareness of the facts that the vessel was on the wrong side of the channel.

This phenomenon in the collision reports has been deemed as *poor passage plan*: the master know nothing or little about the local condition such as the tide, current, and the characteristics of the fairway when the ship is proceeding in confined waters or pilotage waters; there is no emergency plan on board ship for collision.

Violation refers to the acts of sabotage. For instance, the act that a duty officer leaves the bridge for meals without any substitutes for help has been deemed as violation.

Two points need to be mentioned here. First, all collisions studied were always caused by a combination of several factors. For instance, several unsafe acts may be found such as poor look out, error of judgment, improper shiphandling, and failure to comply with regulations involved in one collision case simultaneously. Second, one unsafe act sometimes may be classified into several categories at the same time. For example, the act “to make decision on the scanty radar information” may be deemed as poor look out, improper use of radar and error of judgment. Indeed, there is no crisp boarder between each category in some cases; the classification is really a fussy set.

4.1.2.2 Underlying human elements

Behind each unsafe act there must be some kinds of underlying human elements that initiate it. Unfortunately, it is very difficult to gather the cues to those underlying human elements from the collected written reports. Some of the reports disclose more about underlying cause while others only give the information limited to direct cause. This situation impedes this study in depth on underlying human elements.

Figure 4.2 demonstrates the frequency of the underlying human elements involved in the collected collision cases. The obtained data seems meager, but some valuable cues about the underlying human elements can still be obtained from it.

The most frequently mentioned underlying human elements in accident reports are "experience, knowledge/training" or competence. 54 out of the 100 written reports have indicated that unsafe acts were attributed by incompetence of navigators, that is to say, lack of experience; knowledge and training play an important role in collisions. Lack of local knowledge, lack of knowledge of regulations and shiphandling, lack of sea experience, lack of training in use of radar, ARPA and other electronic navigational aids are commonly found from the written accident reports.

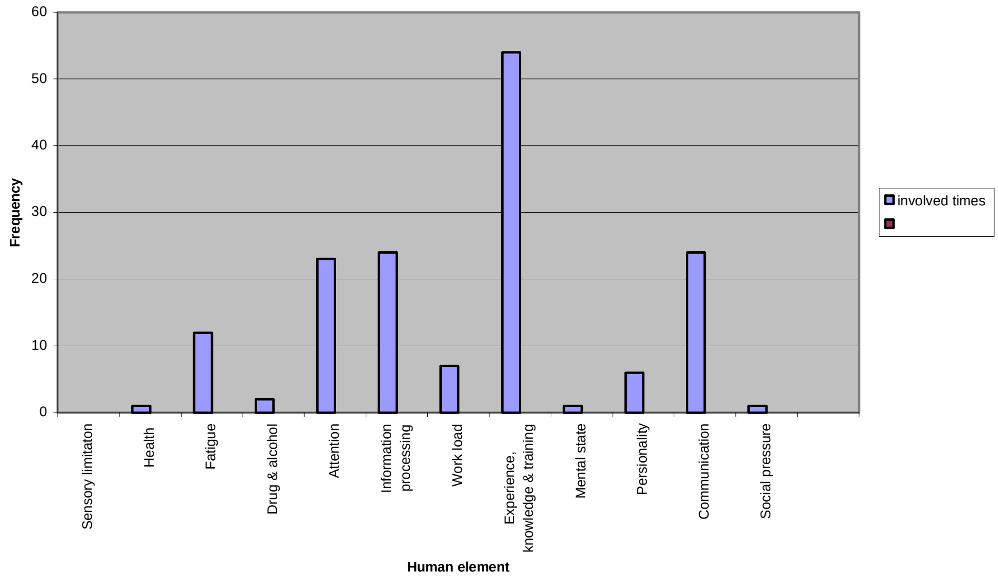

Figure 4.2 Underlying human element involved in collisions

Information processing capacity and communication rank at position two of the list of human elements involved. Information processing capacity is usually closely connected with the error of judgment. The higher the information processing capacity, the less the error of judgment. If a navigator failed to deal with the information exposed to him properly and thus lead to the error of judgment, it would by deemed as problems of information processing capacity. Communication refers to the communicating ability of navigators. The following factors leading to unsafe acts are deemed as communication elements: language barrier, misinterpretation, read back and hear back(Cole, 1999).

Inattention is also a serious issue in collision accidents. The following phenomena are considered as attention problems: navigator focused his attention on maintaining his schedule rather than on a meeting with an approaching vessel; a prolonged period of overtaking involving no immediate risk of collision reduced navigators awareness of the potential eventual collision.

Fatigue has already been considered as a major human element involved in maritime casualties (IMO, 1993; USCG, 2001; Hanson, 1997; Scott, 1998), but the data that collected from the 100 collision cases cannot fully evidence it. Only 12 of them may be traced back to fatigue. According to those reports, fatigue is mainly caused by overload and lack of rest and sleep. Further more, overload and lack of rest are caused by prolonged poor visibility and lack of working hands.

Personality of navigators is seldom mentioned in the written reports. The author has tried to find the cue from the description of the reports word by word. For instance, in one report, it is narrated that a third navigation officer who used to take small and late alterations in collision avoidance especially in front of new crews. According to this description, he deemed that the third mates' personality belongs to the show off type.

Some reports pay particular attention to drug and alcohol issues; however, only two collisions may be traced back to this factor. Health, mental emotional state, social pressure and sensory limitation are almost not mentioned at all in the collected reports. But, it does not mean that there are any such kinds of human elements involved in collision. The reasonable explanation for this result is that the investigator who wrote the report did not pay special attention to these aspects.

4.1.2.3 External influencing factors

While human elements directly affect navigators' actions, the external factors have deep influence on human elements. The most frequently reported external factors in collected reports are fairway, visibility, team working, manning and supervision, as shown in Figure 4.3.

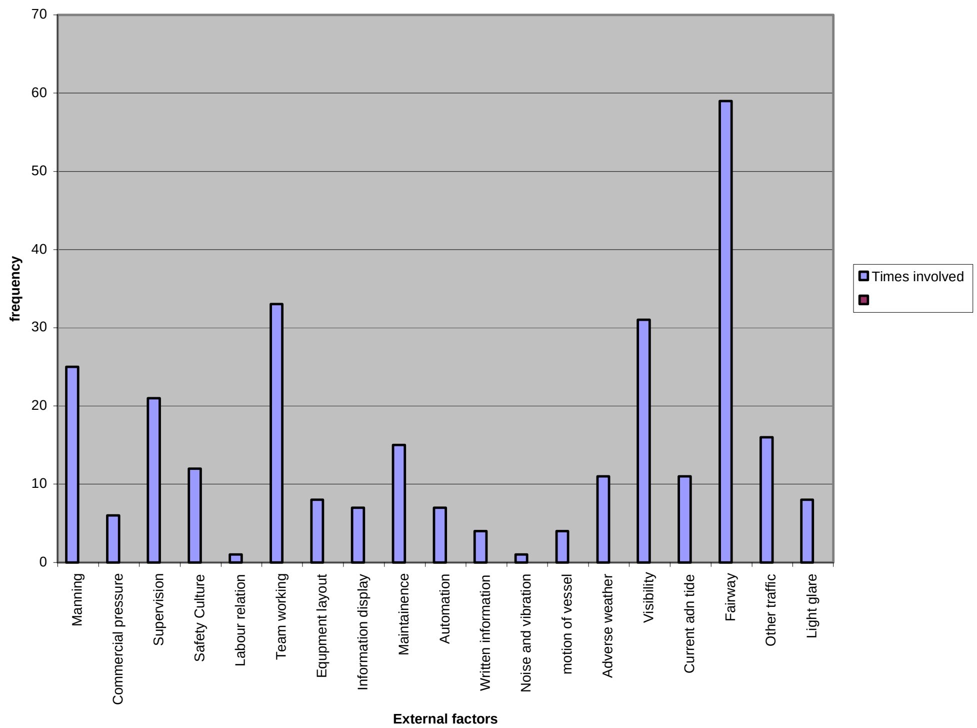

Figure 4.3 External factors involved in collision

Manning and team working are the most frequently involved factors. The following acts and phenomena are considered as influenced by manning factors: no adequate hands maintaining look out tasks; duty officer with no appropriate certificate; master without local knowledge conning vessel in pilotage waters. Team does not refer to an act by one person but a continuous adaptation of all the team members to fulfill the team roles that they have been assigned (Swift, 1993, p.7). The following weakness found from the collected reports are deemed as a team working issues: ambiguity in ship position, navigation order, duty of team member; distraction from the duty of collision avoidance; internal and external communication break down; improper con and look out arrangement; non-compliance with plan.

Supervision comes from the upper level. The following performances have been classified as lack of supervision: the absence of any guideline to owners and operators by the flag Administrations. The absence of instruction to masters by the vessel operators: lack of instruction and navigation warning from VTS and port control. If ship owners failed to see that their instructions were in fact carried out, it has also been considered as a supervision problem.

Safety culture may be defined as "a clear understanding of the system and its features, positive attitudes towards safety measures, and incentive system that encourages safety in operations" (Håvold, 2000, p.81). The problems in manning, teamwork, communication, and commercial pressure have more or less reflected the level of a company's safety culture. In this research the author only considers those collision accidents, which were caused by the navigators' negative attitudes as cases, which have safety culture involved.

Commercial pressure has never been mentioned in any of the collected reports, the author only makes the assumption on information whether the ship owner had asked for the expected time of arrival (ETA) from master and whether the owner had instruction about the ship speed in restricted visibility and narrow channels.

Very little information about the operating environment could be picked up from the accident reports. No comments have been made on equipment layout except that of fishing and recreational boats. No information about noise and vibration on navigators' performance except one case in which the pilot's order was misinterpreted because of the sound interruption. Equipment failure caused by improper check and use has been considered as a maintenance issue. Automation influences occurred in the reports are mainly of the failure in transfer of steering gear from auto mode to manual mode.

It is easier to pick up information about influence of the external environment on human elements from the written reports. Nearly 60% of the collisions happened in confined waters, fairway, and harbor and nearby. 31% of the collisions occurred in restricted visibility. The time of day also plays an important role in forming human being's performance. Figure 4.4 shows the relationship between watch-keeping time and the frequency of collision. Nearly half of the collision occurred in the period from 2000 to 0400 of the day. Only 20% of collisions happened in the period during 0800 to 1600 of the day.

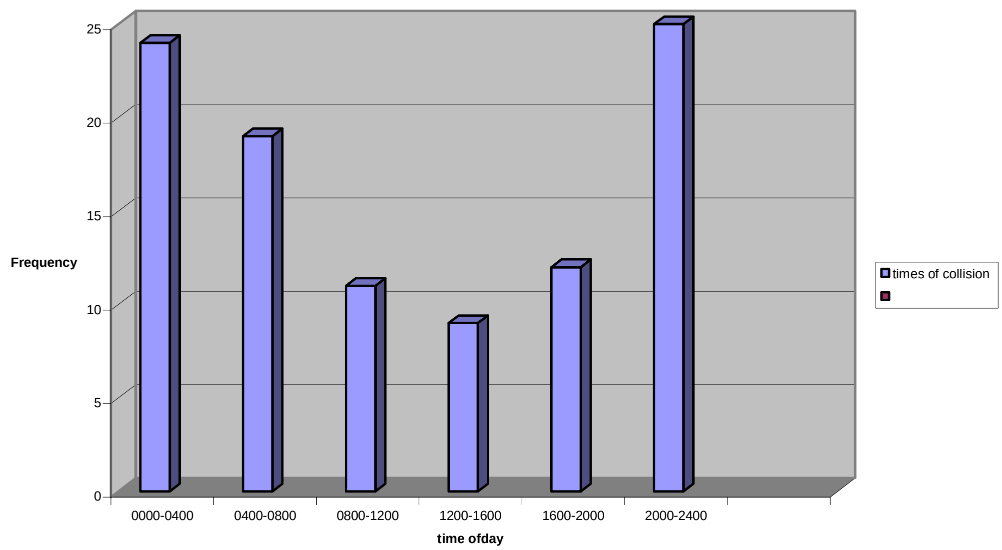

Figure 4.4 Relationship between collision and time of day

Other types of traffic, adverse weather, current and tide also have some influence on human performance to a certain extent. In studied collision cases, adverse weather brings about difficulties to lookout, both visually and by radar; other types of traffic have an influence on the navigators' decision ability. Unawareness of the existence of current and tide usually caused navigators to loss their awareness of the ship's position in fairways.

4.1.3. Main findings from written accident reports

1 Poor lookout has been involved in most of collisions. It was embedded in the following aspects: lack of competent lookout men; improper lookout methods;

improper use or no use of all available means. Poor lookout usually was caused by: lack of experience, knowledge and training; poor communication; manning problem; poor equipment layout; problems in safety culture; over workload; poor teamwork organization; inattention.

2 Improper use of radar and ARPA are still a common problems onboard ship. Examples found in the accident reports are listed as the following: misinterpreting the information showing on the radar screen; no patience to keep continuous radar observation; improper set the range scale of the radar; no radar plotting. The underlying human elements include lack of knowledge/experience/training, personality, and fatigue. The organizational factors and operational environment also have an influence to some extent.

3 Error of judgment is another commonly involved human error in collisions. Error of judgment led to improper ship handling, and the further, improper shiphandling resulting in the collisions. The most frequently involved underlying human elements are skill/knowledge/training, inattention, information processing ability and communication. Fatigue and workload have also been mentioned as influencing factors on the navigators' ability of judgment. Although mental state, social pressure and drug/alcohol have been mentioned or referred to as important accident contribution factors (Smeaton, Moreton & Dineley, 1996; TAIC, 2000), few cause records about this factor could be found from the reports. It does not mean that these factors might be deleted from the list of collision causes, but investigation methods need to be improved.

4 Communication problems ranked high in the list of unsafe acts. The most frequently made mistakes are lack of communication and misinterpreting received information. The major underlying human elements found are the reluctance of navigators to exchange information.

5 The main cause for failure in compliance with regulations may be explained as lack of knowledge and understanding of collision regulations and local

rules. Lack of supervision maybe deemed as the main cause. Other underlying human elements seem hard to come by.

6 Failure to take early actions is the main cause of the close quarter situation. It frequently appeared in collision cases. Poor lookout may be explained as one initiating cause. There are still some other explanations; one may be that the navigator needs to get more information about the situation for the nearer the other vessels approaching; the more information becomes available to navigators. Another explanation maybe the torpor induced by the sheer monotony of watch keeping. The navigator thus may take a stress of close encounter as a relief. Personality, for instance, show off, may also be one of the explanation for later action.

7 Apparently improper ship handling, failure to comply with good seamanship, failure to display signals has a close relationship with knowledge, skill, training and experiences. Personality may also play a certain role in this area.

8 Fatigue is commonly deemed as one of the main causes of collision, but only a few direct pieces of evidence could be found from the collected cases.

9 It is hard to come by the evidence of the organizational errors but many unsafe acts. For instance, lack of enough lookout men, chaotic teamwork on bridge, unsafe speed led to take the organizational factors as critical underlying causes. There are serious drawbacks in aspects of manning, supervision and a company's safety culture.

10 Very few direct causes have been found about the influence of the operational environment on navigators' performance. But it cannot be concluded that the working environment has no influence on human performance. More research work needs to be done on this issue.

11 Most of the studied collision reports occurred in port approach, narrow channels, and rivers. The explanation may be: first, this is the water where traffic is densest; second there are some special adverse effects acting on ships in these waters, for instance bank effects, shallow water effects, interaction between ships, tide and currents; third, although there has been

VTS in some of those areas, it seems that their information have frequently failed to get communicated to the ship; lastly, navigation in narrow fairway is really an art, lack of ship handling skill, local knowledge, experience may result in accidents in these waters.

12 Visibility is an important influencing factor in collisions. It is still common that navigators put over reliance on radar and ARPA in poor visibility. Failure to sound signal, failure to arrange appropriate lookout, failure to reduce speed, failure to communicate with other frequently appeared in this situation. The underlying cause maybe conducted with knowledge, training, experience, supervision and manning.

13 Nearly half of the 100 studied collisions happened in the period of 2000 to 0400 of the day, this may have little to do with darkness or light, but could be linked to body rhythms.

14 Since 54% of the collisions were attributed to lack of knowledge, training and experience, how to explain the reason of those collisions caused by unsafe acts performed by well-trained navigators? Inattention, boredom, fatigue may be good reasons for the qualified navigators' poor performance.

15 It is true that the relationship between underlying human elements, human errors and causes of collision at sea is complex. However, it is necessary for collision avoidance to find the human elements that influence the human behavior leading to collision. Except the improvement of investigation methods, more and deep research work in this field needs to be carried out as soon as possible.

4.2. Experts' and seafarers' view

Experts' and seafarers' view on human element involvement may reflect the actual situation to a certain extent. As a means of compensation, their perspectives on human element involvement in collisions are investigated by questionnaires.

Since human beings' view on something is always with more or less uncertainty or "fuzziness", the questionnaires are also specially designed to reflect this characteristic. The interviewees are requested to confirm the given assumed human elements which may be involved in collision accidents or not with one of the four multiple-choices: very unlikely, unlikely, likely, and very likely. The main goal is to get the membership grade of listed human elements to a particular conceptual class, a fuzzy set labeled "involved". If all respondents confirm an assumed element with "very likely", then this element's membership grade to fuzzy sets "involved" will be 1 if all respondents select "very unlikely" for an assumed element, then the membership grade of the element to fuzzy set "involved" will be 0. The membership grade will always fall in the interval of real number from 0 to 1 or [0, 1]. Thus the result is a fuzzy set called "involved". For determining which assumed human elements are involved in collisions, a cut value α is needed, if elements membership grade is larger than this limit α, for instance 0.65, then, an element is "involved" (Klir & Folger, 1988, p.10; Wang, 1995, p.54).

Three hundred eighty seven out of 1000 circulated questionnaires have been recovered. This makes it possible to calculate the membership grade for each assumed human element. Respondents' background has also been investigated by questionnaires, so it is also possible to analysis the influence of backgrounds on respondents' view.

4.2.1. Briefing the background of respondents

One thousand copies of questionnaires were distributed to seafarers and experts in the maritime industry. Three hundred eighty seven of them have been recovered. The interviewee's background is shown in Table 4.2 and Figure 4.5(a-g).

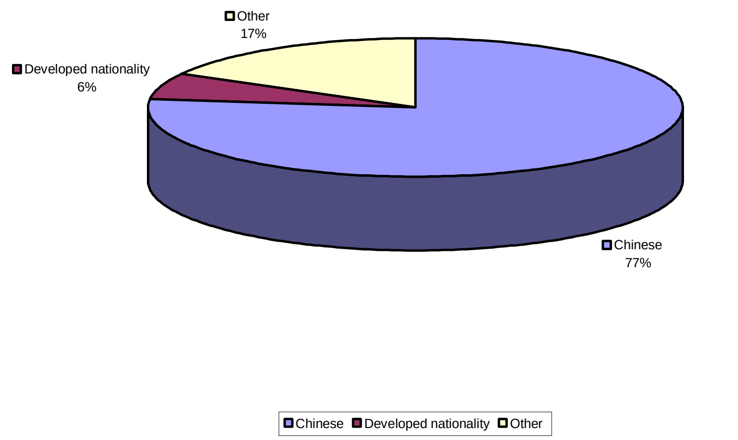

Figure 4.5(a) Background of respondents (nationality)

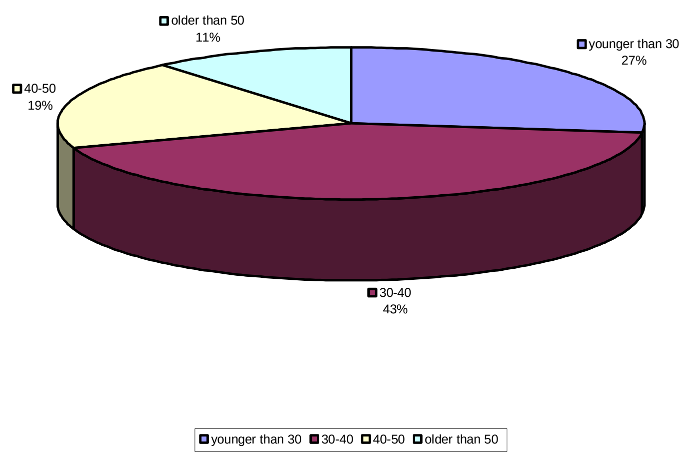

Figure 4.5(b) Background of respondents (age)

For convenience of analysis, respondents are divided into some sample groups based on nationality, education, occupation, sea experience, competence level and experience of collision/close-quarters situation (CQS) respectively. When nationality is considered, respondents are divided into three groups: developed nationalities, Chinese, the other nationalities. When occupations are taken into account, respondents are divided into groups of seafarers, staff of shipping companies, administration of officers, and the other. The "other" group mainly consists of naval architects, staff of ports and nautical lecturers. Since collision accidents are mainly caused by navigational watch keepers, respondents are divided into groups of master, chief mate, navigational duty mate and the other when considering the competence level. Sea experience is divided into groups of no sea experience, less than 5 years, 5-10 years and more than 10 years. Education background is divided according to the education level: post graduate, university, college, and the other.

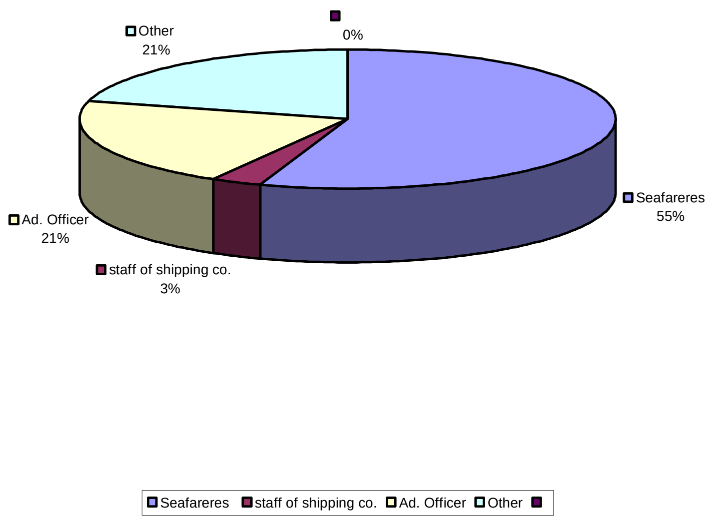

Figure 4.5(c) Background of respondents (Occupation)

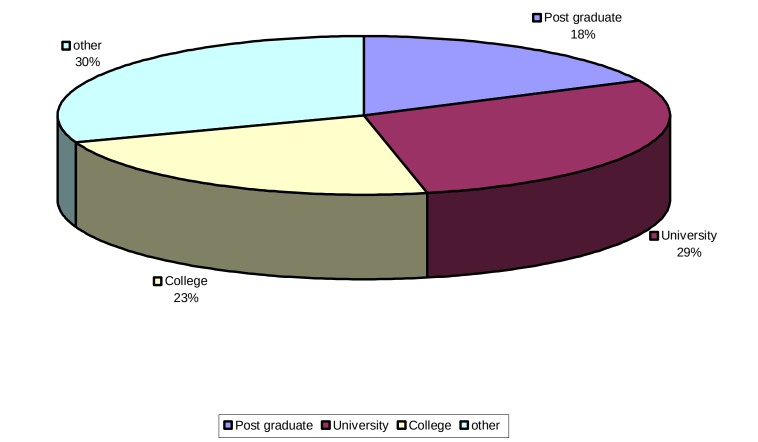

Figure 4.5(d) Background of respondents (Education)

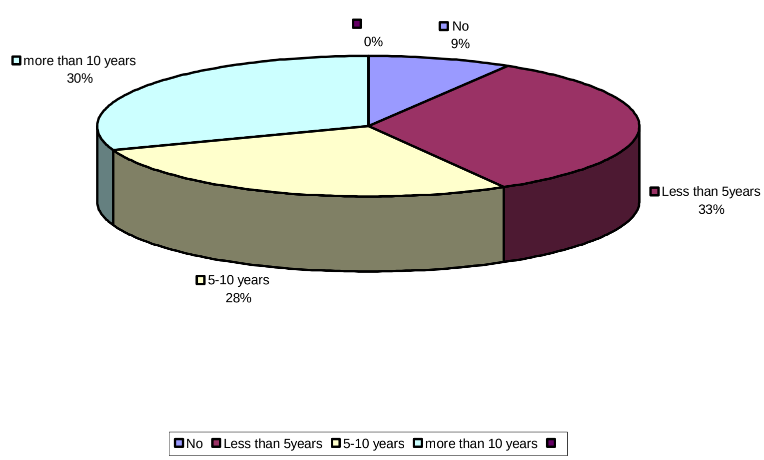

Figure 4.5(e) Background of respondents (sea experience)

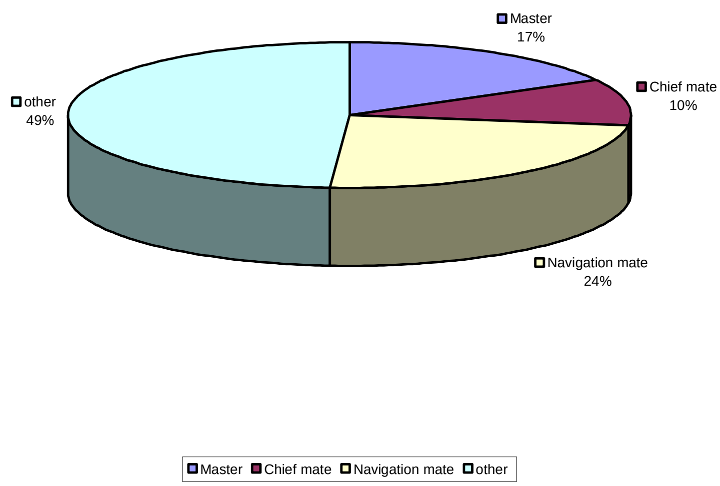

Figure 4.5(f) Background of respondents (competence level)

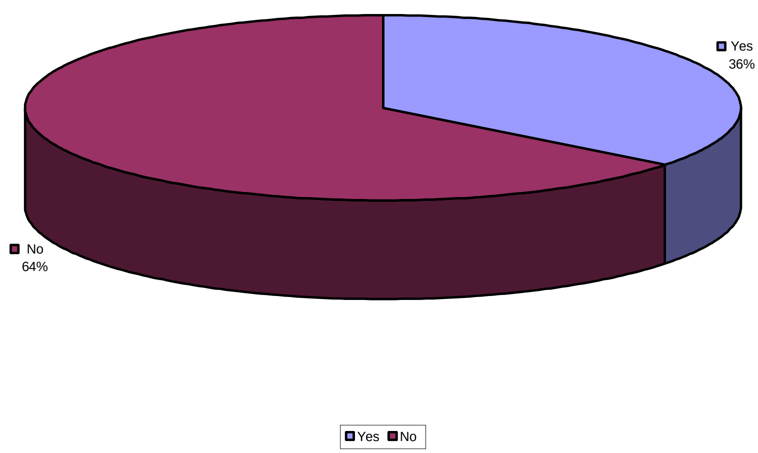

Figure 4.5(g) Background of respondents (experience of collision/CQS)

Table 4.2 Backgrounds of Respondents

Background	Number of respondents and their percentage (%)				Total
Nationality	Chinese	Developed Nationalities		Other	387(100)
	298(77)	23(6)		66(17)	
Age	<30	30-40	40-50	>50	387(100)
	104(27)	166(43)	74(19)	43(11)	
Occupation	Seafarers	Ad. Officer	Staff of shipping Co.	Other	394[1]
	218(56)	82(21)	12(13)	82(21)	
Education	Post Graduate	University	College	Other	387(100)
	69(18)	112(29)	88(23)	118(30)	
Sea experience (years)	No	<5	5-10	>10	387(100)
	33(8)	128(33)	108(28)	118(31)	
Competence	Master	Chief mate	Nav. mate	Other	387(100)
	66(17)	39(10)	93(24)	189(49)	
Collision /CQS experience	Yes		No		387(100)
	138(36)		249(64)		

4.2.2. Fuzzy sets model and calculation of membership grade

4.2.2.1 Constructing fuzzy sets

Let X denotes the universal set, a set of assumed human elements. It will be:

$X= \{x_1, x_2, x_3, x_4 \ldots, x_m\}$, m: number of elements

={Incompetence, error of judgment, improper look out, unsafe speed, failure to take early action, failure to comply with regulations, improper shiphandling, misuse radar and ARPA, negligence or misconduct, communication problem, mental state, anxiety and fear, health fitness, over work loading, fatigue, management, intentional violation, drugs and alcohol}

m=18

Let A denotes the fuzzy sets "involved" which is defined by membership function μ_A. μ_A has following form:

[1] Some respondents have selected two occupations in the questionnaire; for instance, he is both a seafarer and nautical lecturer.

μ_A: $X \rightarrow [0, 1]$

And A is expressed as

$A = (\mu_A(x_1), \mu_A(x_2), \dots \mu_A(x_m))$ m = 18

For the purpose of this dissertation, there is no need for us to model a membership function but to calculate the membership grades of each element in the universal of discourse.

4.2.2.2 Calculating the membership grade

There are lots of means for measurement of membership grade. The commonly used way is to sample the statistical response pattern for the true or false question of the set membership. In the questionnaires, four choices are given; only one choice is required to be chosen. It is different from some traditional statistical methods, which only have yes, or no question. So the author has to reform the calculating method as follows:

$$\mu_{Aj}(x_i) = \lim_{n \to \infty} \frac{n_j}{n}$$

Where,

N—number of respondents, it needs not be an infinite number (Wang, 1995, p.56), but big enough.

n_j—times of x_i belongs to A_j

j = 1, 2, 3, 4

μ_{A1}—very unlikely

μ_{A2}—unlikely

μ_{A3}—likely

μ_{A4}—very likely

Let $$\mu_A(x_i) = \sum_{j=1}^{4} \beta_j \mu_{Aj}(x_i)$$

Where

βj are defined as weight factor on the base of degree of involvement of the human element, for meeting the requirement of normalization, the weight factor is defined as :

$\beta_1 = 0.25$, $\beta_2 = 0.5$, $\beta_3 = 0.75$, $\beta_4 = 1$

The membership grade calculated is shown in Figure.4.6. When $\mu_A(x_i)$ are calculated, the fuzzy sets A will thereby be determined.

4.2.2.3 De-fuzzying

De- fuzzying the fuzzy set A may be done by a α-cut. α-cut of a fuzzy set A is a crisp set Aα that contains all the elements of the universal set X that have membership grade in A greater than or equal to the specified value of α. it can be expressed as

$$A\alpha = \{x \in X \mid \mu_A(x) \geq \alpha\}$$

It is very critical to chose the value of α for it just determines which one will be deemed as the involved element. Since "unlikely" has already been given a weight value 0.5 and "likely" 0.75, it is better to select a value in this interval: 0.5-0.75. Here, α is given value 0.6.

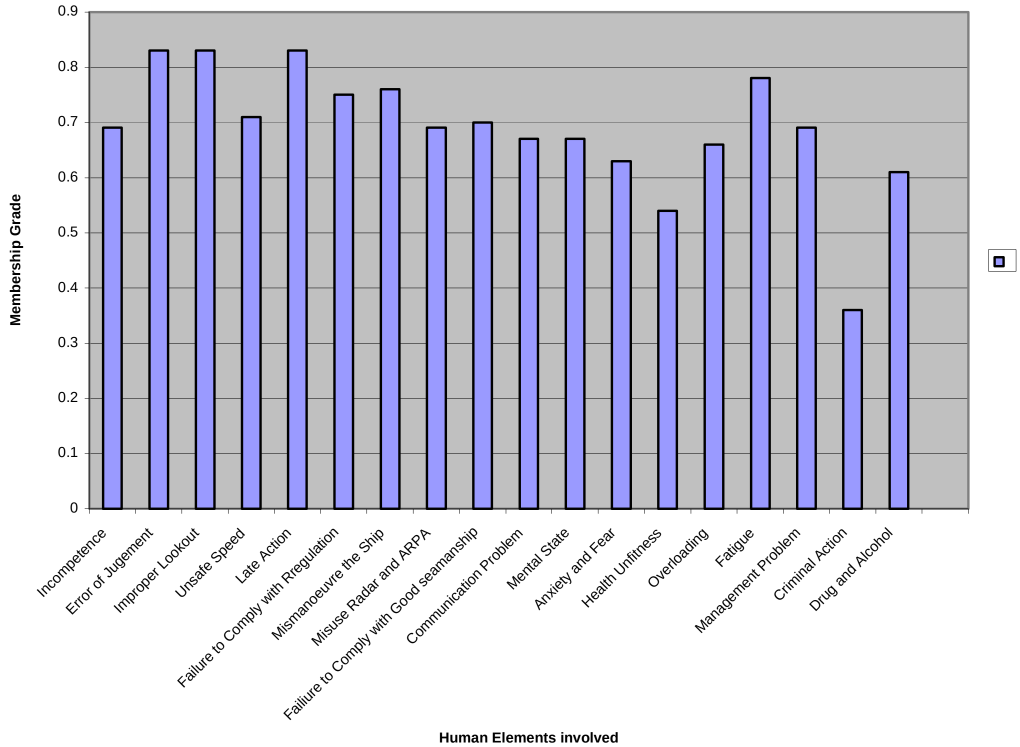

Figure 4.6 Membership Grade of Human Elements Involved in Collision Accidents

4.2.3. Calculated statistical results

Figure 4.6 demonstrates the membership grade of each assumed human element. Obviously the membership grade of violation is only 0.36. This means that it is unlikely that a human element is involved in collision. If $\alpha = 0.6$, assumed elements such as health fitness, anxiety and fear will be eliminated from the set $A_{0.6}$. For $\alpha = 0.7$ more assumed elements, including incompetence, improper ship handling, misuse of radar and ARPA, mental state, drugs and alcohol will also disappear from set $A_{0.7.}$ For $\alpha = 0.8$, only a few assumed elements are left; they are error of judgment, improper lookout, failure to take early action.

Figure 4.7 to 4.12 show the comparison result of membership grade of assumed human elements on base of respondents background, including nationality, occupation, education, sea experience, competency level, experience of collision or close quarter situation.

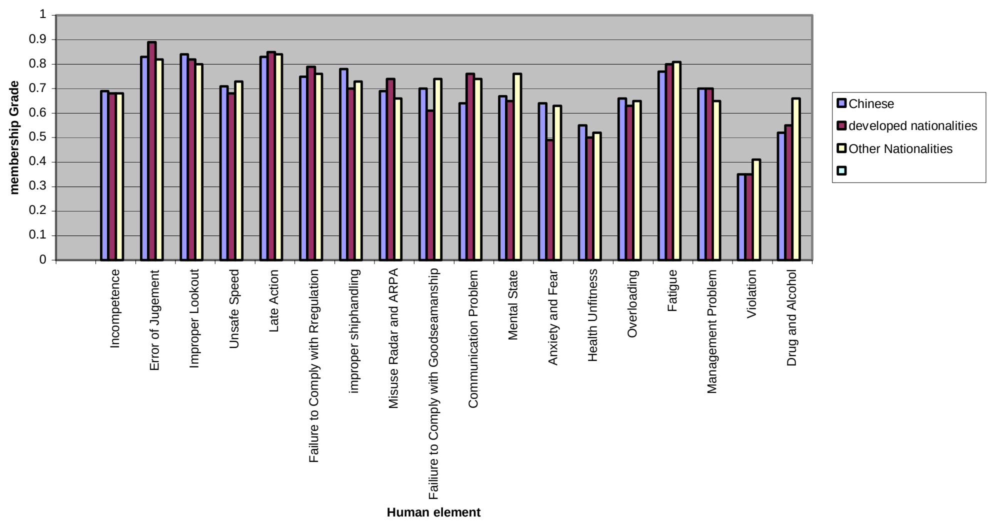

Figure 4.7 Comparison of the View on HE Involved between Nationalities

As demonstrated in Figure 4.7 the perspective of respondents of different nationalities seems similar in general. There is only some minor different opinion on error of judgment, mental state, drugs and alcohol. Although all respondents consider error of judgment as a major factor leading to collisions, those from developed nations view it as a number one human element in collision. The respondents from China and developed countries deem mental states as a less involved human element, but respondents of other nationalities consider it as a likely involved human element. Drugs and alcohol is deemed as unlikely involved factor by the Chinese, west Europeans and Americans, while other respondents view it as a likely involved element.

The comparison results based on occupation are shown in Figure 4.8. It is interesting to see that while seafarers take incompetence as a less involved human factor, staff of shipping companies and others take the factor as a more likely involved one. The perspectives on drugs, alcohol, overload and fatigue may well reflect the occupation background of the respondents. Staffs of shipping companies take drugs and alcohol as a serious issue while the others pay less attention to it. On the contrary to seafarers and the Administration officers who deem overloading and fatigue as likely involved human elements, staff of shipping companies do not take it as a serious issue.

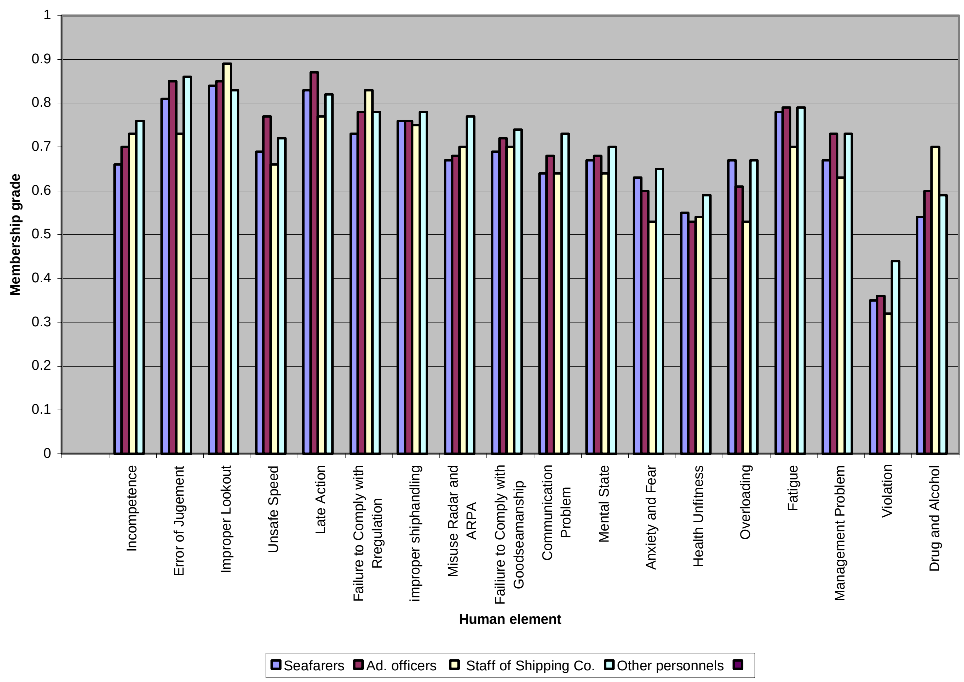

Figure 4.8 Comparisons of the Views on HE Involvement between Different Occupations

Figure 4.9 demonstrates the perspective of persons with different educational backgrounds. The difference of their views on incompetence and failure to comply with regulations has also reflected their educational levels. Obviously the persons with higher educational background put more emphasis on those human elements such as incompetence and failure to comply with regulations.

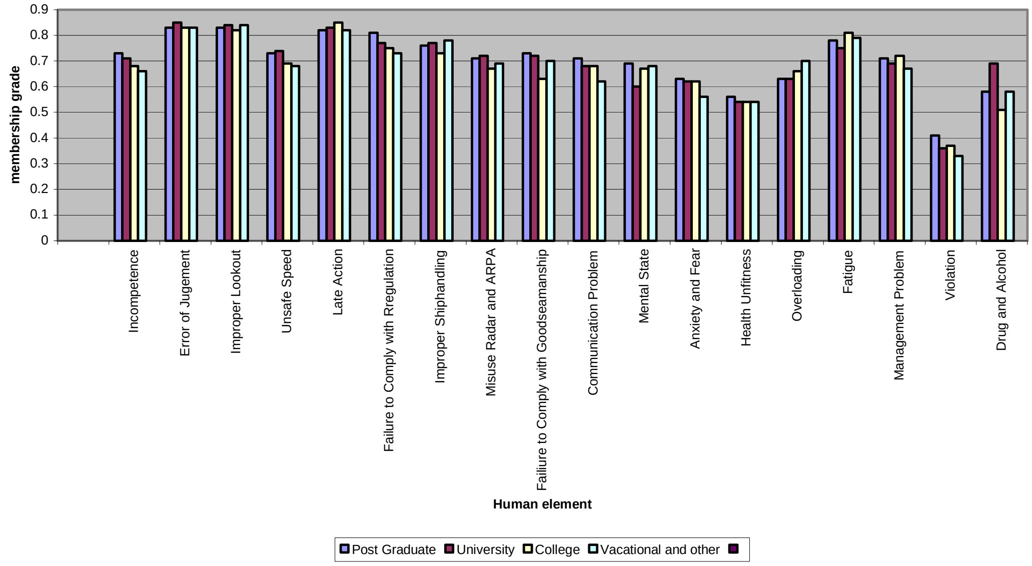

Figure 4.9 Comparisons of Views on HE Involvement between Different Education Level

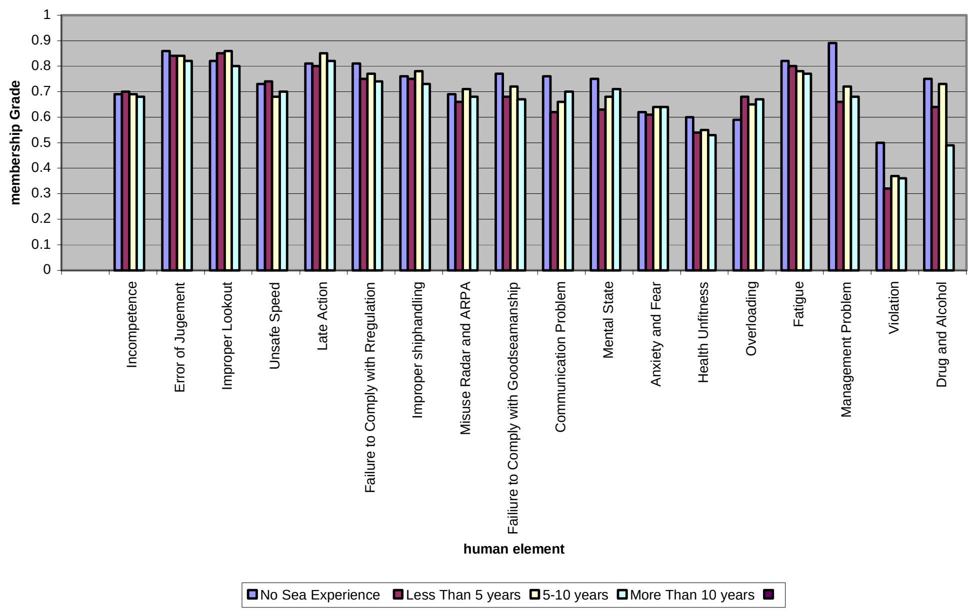

Figure 4.10 Comparison of Views on HE Involvement between Different Sea Experiences

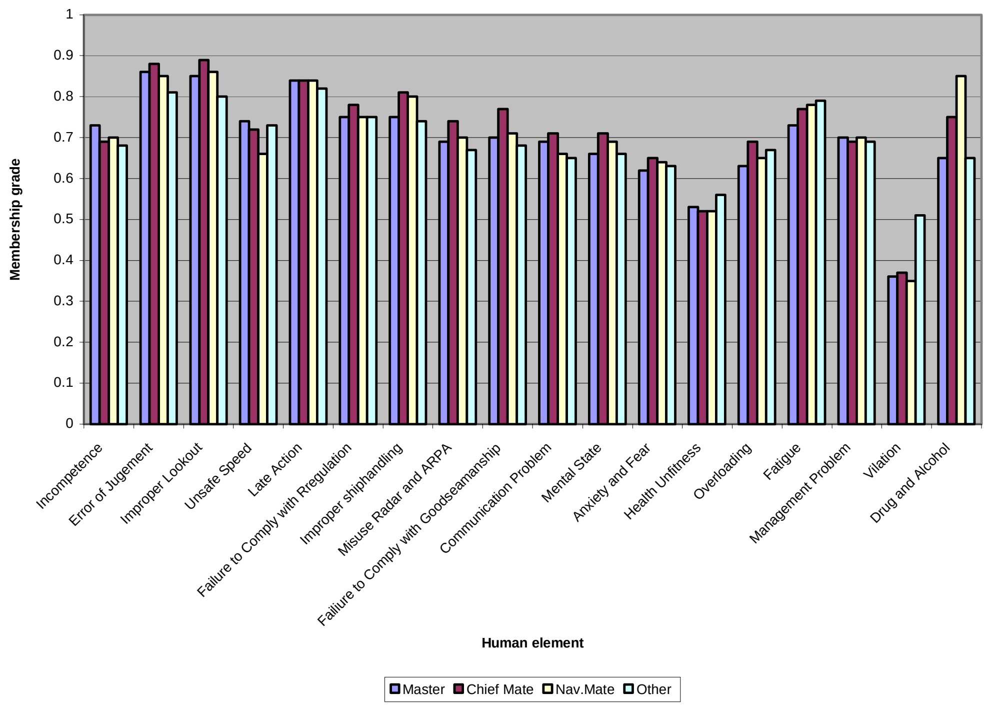

Figure 4.11 Comparison of Views on Human Element Involvement between Different Competence Levels

Figure 4.10 shows the comparison results based on the sea experience. Apparently those who have longer sea experience put more emphasis on management, communication, good seamanship and mental states.

Figure 4.11 demonstrates the perspectives of seafarers at various competent levels. Comparatively, the master emphasizes the competence more than others. Especially navigation mates and ratings, take fatigue as a more involved human element than that of the master's view. Chief officers, with more different opinion than others, pay more attention to judgment, lookout, good seamanship, and workload.

The last comparison is made based on whether the respondents have experience in collision/close quarter situation. In general, there is no big difference between their views. Only minor differences could be found from their perspectives on these factors such as competence, judgment, lookout, safe speed, early action, ship maneuvering, use of radar and ARPA, mental states, and management where the experienced respondents put a higher membership grade than those without experience. See Figure 4.12.

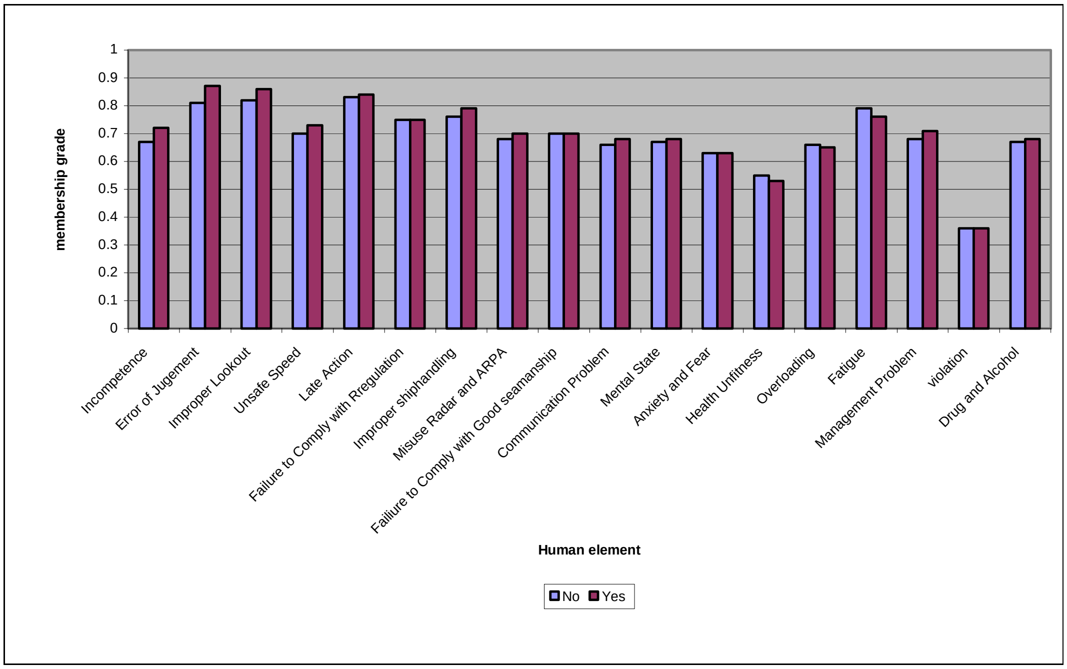

Figure 4.12 Comparison of Views on Human Element Involvement between the Collision/Close-Quarters Situation Experience

4.3. Discussion

Based on the data collected from the written reports and general perspectives of respondents, the author focuses his discussion mainly on the following questions:

- How far are the human beings' perspectives from the actual world?
- What kinds of human elements are mostly involved in collision accidents?
- What should and what could be done next in the research field of human elements?

4.3.1. How far are the human beings' perspectives from the actual world?

For the convenience of comparison, the statistical results got from the written accident reports and the calculated result based on the questionnaire are put together side by side in Table 4.3. It is easy to tell the similarities and differences between them. In general the respondents' perspectives on human elements are roughly identical with the actuality. For instance, respondents view poor lookout and error of judgment as very likely involved human elements in collisions. Indeed the statistical data picked up from written report properly evidenced that.

The inconsistency lies on the perspective towards the use of radar and ARPA, communication, early actions and fatigue. Compared with the actual data, the involvement of misuse of radar and ARPA, communication problems are underestimated while that of failure to take early actions and fatigue are overestimated.

It does not mean that the data from the written reports are absolutely accurate while the membership grade of involvement calculated on the basis of respondents' perspectives are inaccurate. Since human beings wrote the collision investigation reports, and data of human element involvement are extracted from these reports by human beings, there will absolutely be human error in the actual data itself.

In general, the respondents' view reflects the reality roughly; there is still a gap between them. To solve this issue, more research work on both aspects is needed.

4.3.2. Which human elements are most likely involved in collision accidents?

According to the actual data collected from the written reports and the general opinion of 387 respondents, it may be concluded that improper lookout, error of judgment, failure to take early actions, failure to comply with regulations, improper shiphandling, communication, poor management, incompetence, unsafe speed, and inattention are likely involved human elements or errors in collision accidents without hesitation.

Table 4.3. Comparison between Human Beings' View and Actuality on Human Elements in Collisions at Sea

Human elements	Involved times in the written reports	Membership grade (respondents' view)
Unsafe acts		
Poor lookout	71	0. 83
Error of judgment	64	0. 83
Misuse of radar and ARPA	50	0. 69
Failure to comply with regulation	41	0. 75
Failure in communication	41	0. 67
Failure to display proper signal	41	/
Improper shiphandling	35	0. 76
Failure to take early action	30	0. 83
Unsafe speed	30	0. 71
Failure to comply with good seamanship	24	0. 70
Failure to obtain position and course	20	/
Poor passage plan	8	/
Violation	8	0.36
Underlying human element		
Experience, knowledge and training (incompetence)	54	0. 69
Communication	24	0. 67
Information processing	24	/
Attention	23	0. 70
Fatigue	12	0. 78
Workload	7	0. 66
Personality	6	0. 63
Drug and alcohol	2	0. 61
Health	1	0. 54
Mental state	1	0. 67
Social pressure	1	/
Sensory limitation	/	/
External factors		
Organizational	See appendix c & Figure 4.3	/
Operational environment		/
External environment		/

Because of the lack of data in the written accident reports, some other listed human elements especially these underlying human factors, for example, fatigue, workload, personality, and mental state seem not as significant as the above mentioned elements. In conclusion, regarding these elements, more research and study are needed.

4.3.3. What should and what could be done next?

Obviously, there are at least two inherent defects in the collected data. First, the data collected from written reports are incomplete and maybe inaccurate. This problem has already been demonstrated in Table 4.3 where the occurrence rate of some human elements is extremely low, especially those under the heading of underlying human elements and external factors. It does not necessarily mean that these human elements are not involved in collision accidents, but the investigation did not get in touch with these elements.

Second, the data obtained from the questionnaires are also scanty on underlying human elements and external factors. For the convenience of interviewing, a lot of human elements have been omitted from the questionnaires. The direct effect is that the author has no idea about the perspectives of the respondents on these elements. It hinders his further analysis of the involvement of human elements, especially underlying human elements involved.

What could be done and what should be done? To improve the investigation, the collision accident investigation needs to be conducted deeper into the underlying human elements and external factors that may influence human beings' behavior. Fortunately, IMO (1997, November 27; 2000a) has already recognized the issue and provided codes and guideline for investigating human elements involved in maritime casualties. What should be done is to implement the codes and guidelines actively. Assessment of its effectiveness is also necessary.

4.4. Summary

Two approaches are used in identifying the human elements involved in collision. On the one hand, human elements involved in collisions are approached by a written accident report study. 100 collision cases have been carefully studied and analyzed. On the other hand, asking those who are involved in the maritime industry the answer to the human element involvement. A questionnaire for this purpose was specially designed and circulated to them. 387 respondents out of 1000 interviewees of the questionnaires contributed their perspectives on the issue. With these two approaches some commonly involved human elements are identified.

The frequently occurred unsafe acts leading to collisions are poor lookout, error of judgment, failure to take early action, misuse radar and ARPA, failure in communication, failure to comply with regulations, unsafe speed, improper shiphandling, and failure to apply good seamanship. The underlying human elements of these unsafe acts are incompetence or experience/knowledge/training problems, communication barrier, inattention, fatigue and workload. The external factors which may influence the performance of navigators may include manning, supervision, team working, safety culture, confined fairway, time of day, restricted visibility and density of traffic.

Most of the respondents' view on human elements involved in collision properly reflected the actuality. What kind of inspiration will this result give to human beings and researchers? Research work needs to be done on this issue. In addition, the following areas also need to be explored: to identify the underlying human elements behind the unsafe acts of navigators in collisions; to clarify the external factors which may have influences on navigators performance; to conduct research into the interaction between various identified human elements for very few collision are caused by a single factor

CHAPTER 5

Reducing the Involvement of Human Elements in Collision Accidents

Some human elements involved in collisions have been roughly identified in Chapter 4. This chapter focuses on identifying proper countermeasures against the negative influences of the human elements in collisions at sea. Therefore, the following work has been conducted:

- Searching from the present literature for countermeasures against human elements involved in collisions.
- Reviewing the methods and measures for human element reduction proposed by IMO.
- Interviewing the opinion of seafarers and experts on this issue by questionnaires.

Based on this work, countermeasures against human elements are discussed.

5.1. Researchers' perspectives on countermeasures against human errors

The commonly proposed means and measures for reducing the human elements in maritime accidents by researchers are focused on education and training, safety culture, bridge resource management, and research on human elements.

5.1.1. Improving education and training methodology

Since a great many maritime accidents including the collisions are attributed to lack of knowledge/skill/experience, failure in compliance with regulations, failure in compliance with good seamanship, misuse radar and ARPA, problematic communication, training and education will absolutely find its position in reducing the involvement of human elements and improving the standards of safety. The importance of education and training are commonly recognized. The key lies in improving the methodology of education and training. The following is a brief of researchers' achievements (Kuo, 1998, p.170; Hanson, 1997; Peterson, 1996, p.257; Sanders & McCormick, 1987; Hoys & Zimdong,1988, p.188) :

1. Although training and education are closely connected together, they are different in many aspects, therefore, their applications should be differentiated depending on the actual needs (Kuo, 1998, p.170). Training concentrated on human beings efficiency in doing a specific task, while education will also involve developing and changing the attitude, and behavior of those concerned. Training tends to achieve results more quickly, while education tends to take longer to achieve more fundamental outcome (Kuo, 1998, p.171). An example relating to teamwork on the bridge of a ship may properly explain these differences. Training will ensure that all the crewmembers work efficiently; however, education will try to generate a team spirit and a positive attitude towards the carry-out of duty on the bridge. It is easy for a trainee to achieve desired competence by training in short term, but to educate a navigator to keep safe speed in restricted visibility may take very much longer time (Kuo, 1998, p.171). In concern of the collision avoidance, training maybe used for enhancing the competence of navigators in use of radar and ARPA, while changing people's attitudes towards collision at sea, education is needed.

2. The international regulations for preventing collisions at sea include (COLREG) two different kinds of rules in nature; therefore, for properly grasping the nature of the regulations, the use of education and training should be differentiated accordingly (Taylor, 1998, p.69). Some rules in collision regulations contain all of their meaning within the text, whereas rules depends on the meaning and on the knowledge of the system to which they refer and so can not be understood by reference to their task alone. Rules 20 to 38 in the collision regulations belong to the former kinds of rules, while rules 1 to 19 have the nature of the latter situation. For example, rule 23 prescribe in a very simple way lights and shapes to be shown by power driven vessels underway. These can be fully understood and complied with by anyone who knows the meaning of the words, whereas rules 16, “every vessel which is directed to keep out of the way of another vessel shall, so far as possible, take early and substantial actions to keep well clear”, is not easy to be understood by a person who has never been to sea. The phrases such as “so far as possible”, “take early and substantial actions”, “keep clear” are not precisely defined and have an unwritten meaning beyond the words themselves. Clearly both kinds of words can be learned in the classroom, and easily be remembered in parrot-fashion; however, parrot-fashion learning the rules such as rule 16 merely teaches a fairly obvious principle of collision avoidance. It is of little help in distinguishing proper from improper practices. For learning of such kind of rules more practical training on ships is needed.

3. Simulators may be used as an effective means in developing and renewing the navigator’s skill in collision avoidance. It can be operated to train human beings in a stressful situation as well as in a complicated, sensitive or rare situation. Trainers may design collision situations they are going to use during the simulation training, if the causes and collisions of fault actions are known.

4. The content of training courses should be designed according to the trainee’s actual requirements. For example, according to Wollski (1996, p.330) the underlying causes of improper use of radar and ARPA are the navigators’ lack of knowledge about the use of

radar and ARPA, about the limitation of radar and ARPA, and the navigators' over confidence in the data obtained from the radar and ARPA screen. Therefore, it is very important that the contents of training courses should be designed to familiarize navigators with both capabilities and limitations of the radar and ARPA.

5. Since problematic communication is mainly attributed to language barrier, the situation may be improved by properly designed language training. The Seafarers International Research Center at Cardiff cooperated with some partners such as World Maritime University (1999) conducting a study on maritime communication issue and recommended a set of guidelines for the way in which a maritime English syllabus should be created in their project final report. It points out that the ways in which English is used as maritime English is different depending on who uses it; therefore, the methods of delivery for language teaching should also be adjusted accordingly.

5.1.2. Developing a safety culture

Developing a safety culture within an organization is likely to be the most effective measures in accident prevention (Winbow, 1998, p.2). What is culture? The key feature of any culture is the existence of a belief or faith held by the individuals involved which is displayed in practice through their behaviors. (Kuo, 1998,p.167) Kuo defined the safety culture as "the philosophy of safety matters" held by organizations and individuals, which is demonstrated in practice through their attitude, actions, and behavior. Many collision accidents are due to unsafe acts or performance by navigators. These errors or more often violations of ordinary practice of seamen or established rules can really be avoided. Those who make them are often well aware of their errors. They may have taken short cuts they should not have taken. Almost all of the navigators have received education and training in collision avoidance, but collisions still occurs at a high rate. This issue may be attributed to the navigator's attitude towards safety. Since individuals' attitude toward safety is shaped to a large degree by the culture of the company, developing a safety culture in a shipping company is an effective way to deal with this issue. The challenges for company mangers are not only how to instill the skills or knowledge, but also to change the attitudes necessary to ensure the safety objectives are met. (Huo, 1998, p.167; Winbow, 1998, p.2)

Possible ways of implementing good safety practices include definition of the company's corporate safety goals; standards and procedures should be laid down for every task, for instance watch keeping, which has critical safety implications and effective monitoring systems should be developed to check their constant implementation; all individuals should be encouraged to examine and constructively discuss safety issues; a safety information system that collects, analyses and disseminates information from accidents or near misses should be created; a company must possess a learning culture – the willingness and competence to draw the right conclusion from its safety system and implement major reforms when its need is indicated. (Reason, 1997, p.72)

5.1.3. Using human error assessment and reduction techniques

In general human reliability in collision avoidance is constrained by impaired system knowledge, response/processing time shortage, poor feedback information, difficulty in judgment, overall levels of alertness, operational environment, and personality. The application of methods to reduce the impacts of these general sources of failure potential has an active prospect of making the right improvement to man-machine reliability and minimizing the contribution of human error to collision.

Based on the human error analysis and reduction techniques (HEART), Williams (1994, p.9) proposed the following general strategies for achieving effective human performance offshore, which is also applicable in collision avoidance:

1. Provision of adequate training and precise rules of engagement for personnel when confronted by a phenomenon outside their experience.
2. Keeping the information, precisely requirements, as low as possible, without making the rule uninteresting.
3. Providing diverse means of checking information and reversing unintended actions.
4. Providing immediate feedback that operation have succeeded or failed and what the performance standards are in the first place.
5. Providing an incentive to maintain performance and means of knowing that task synchronism is being achieved.
6. Providing an appropriated environment, which will promote high satisfaction, health and performance.
7. Appreciating that humans are not good at diagnosis of failure.

5.1.4. Managing bridge team and resources

An accident, such as collision, is unexpected, but most accidents occur because there is no system in operation to detect and consequently prevent one person making a mistake—a mistake of the type all human beings are liable to make. (Swift, 1993, p.11) Bridge team management is one solution to this issue. Bridge team management of a way of working which recognizes that reliable and consistent standards can only be maintained if navigation is based upon principles and reinforced by effective management.

USCG has developed a team approach to reduce navigational and operational mishaps. (Hanson, 1997, p.4) The approach requires the team to be proficient in seven skills such as leadership, mission analysis, adaptability and flexibility, situation awareness, decision-making, communication and assertiveness. If these requirements are met, the organization's safety culture will ultimately be changed.

The Swedish Club developed a bridge team management (BRM) training course to increase safety at sea. The aim of the programme is to minimize risk by creating positive attitudes towards communication, coordination, leadership and standards of operation procedures. The topics covered in the course are divided into 12 modules: cultural awareness, communication and briefing, challenge and response, authority and assessment, short term strategies, management styles, state of the bridge, attitudes and management skills, leadership in emergencies, human involvement in error judgment and decision making, and workload. (Herngvist, 1996, p.334)

5.2. IMO's work on reducing human element involvement in maritime accidents

It was not until the end of the 1980s that the International Maritime Organization shifted its attention from the development of technical standards in ship design and construction to the human element of daily operation and ship management. The major work IMO did in reducing the human error in casualties include the 1995 amendments to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW 78), the adoption of the International Safety Management Code (ISM), the application of Formal Safety Assessment (FSA), and the adoption of the Guideline for the investigation of human factors in marine casualties and incidents. Special attention of IMO has been paid to fatigue problems. (IMO, 1996a; Eriksson & Mejia, 2000, p.8; Winbow, 1998, p.2)

5.2.1. The STCW Convention

The revised STCW Convention forms a sound foundation for safe ship operation; many of the accidents and incidents, for example collision and close-quarters situations that continue to occur could arguably have been prevented, had seafarers met the minimum standards of competence and owners and managers fulfilled their obligations in the STCW Convention and Code. (Winbow, 1998, p.2) Numerous new provisions that address operational or "human element" aspects have been dealt with by new provisions include communication, working language, medical fitness and prevention and mitigation of fatigue.

Because a high proportion of maritime accidents was contributed by poor communication, STCW 95 requires that everyone involved in watch keeping should ensure that " communication are clear and concise at all times and orders are acknowledged in a seamanlike manner". Since multinational crews man more and more ships, language is becoming an increasingly serious factor in safe operations.

While there is not one standard maritime language, English has been deemed as a lingua franca on board ships by the STCW amendments. Navigators, engineers and GMDSS radio operators are required to "be able to use English in written and oral form"(IMO, 1996a). All ratings forming part of a navigational watch, on the other hand, are required to be able to "steer the ship and comply with helm orders also in the English language".

Since illness is a potential threat and danger to personnel on board ships and safety of ships while medical care is inaccessible at sea, medical fitness is a natural requirement for seafarers. Therefore, STCW 95 requires State party to the convention to establish standards of medical fitness for their seafarers, particularly in the areas of eyesight and hearing.

Fatigue was shown by numerous studies (IMO, 1997d) to be " a contributory factors in 33% of critical vessel casualties". Because of its obvious risk to maritime safety, prevention and mitigation of fatigue have been the focus in STCW 95. It requires that watch systems must be so arranged that watches keeping personnel be not impaired by fatigue. For this purpose, the convention provides a rest hour limits for watchkeepers.

Except the above-mentioned work, another contribution of STCW 95 to reduction of human error in accidents is its help in developing a safety culture. For example, familiarization training for those at sea or new to a specific company, required by STCW 95, is a very effective way in instilling the safety culture in them.

5.2.2. International Safety Management Code

The adoption of the International Safety Management Code is another important step taken by IMO in reducing human elements involvement in maritime casualty. Since the human element is deeply influenced by organizational factors (Reason, 1997, p.71), the role of ship owners and managers in safe shipping operations should also be emphasized. The ISM Code introduces measures designed to improve the quality and accountability of those who are mostly involved with shipping operations (O'Neil, 1996; Eriksson & Mejia, 2000, p.18; Kuo, 1998, p.155). ISM Code emphasizes, "In matters of safety and pollution prevention it is the commitment, competence, attitudes and motivation of individuals at all levels that determines the end result".

The ISM Code's objectives are " to ensure safety at sea, prevention of human injury or loss life, and avoid damage to the environment". To achieve those objectives, the ISM Code requires every company to develop, implement and maintain a safety management system. This system should include a company's safety and environment protection policy, instructions and procedures to ensure safe operation of ships, procedures for reporting accidents and non-conformities, procedures to prepare for and respond to emergency situations, procedures for internal audits and management reviews and defined levels of authority and lines of communication between and amongst shore and shipboard personnel. (IMO, 1993b).

5.2.3. Formal safety assessment

Formal safety assessment has been introduced at IMO as "a structural and systematic methodology, aimed at enhancing maritime safety by using risk and cost/benefit assessments"(Rosmussen, 2000). It is a five-step processing consisting of: identification of hazards; risk assessment; risk control options; cost-benefit assessment; recommendation for decision-making. (IMO, 1995b; Rasmussen, 2000).

FSM formalizes the application of risk-based thinking. A lot of analytical techniques have been arrived at in conducting it. For instance, fault tree analysis, event tree analysis, regulatory impact diagram, failure mode and analysis, hazard and operability studied, especially human reliability analysis and human element analyzing process are commonly used techniques.

Trial application of the FSA methodology on RO-RO passenger ships, high-speed craft, oil tankers, and bulk carriers has already been conducted by some governments and organizations (IMO, 1996b, 1997b, 1998a, b, 1999, 2000c, d; Eriksson & Mejia, 2000, p.23). It is still evolving at IMO, with much research still being undertaken to determine how human factors would be incorporated in a practical and usable manner (Kuo, 1998, p.149).

5.2.4. Casualty investigation

The investigation of maritime accidents and casualties play a very important feedback function in the promotion of safety (Eriksson & Mejia, 2000, p.30). Since careful analysis of casualties "can lead to greater awareness of casualty causation and result in remedial measures…for the purpose of enhancing safety…"(IMO, 1997 November 27), IMO adopted the code for the investigation of marine casualties and incidents in 1997. For further addressing the human elements in casualty investigation, IMO amended the code by adding the guidelines for the investigation of human factors in marine casualties and incidents into its Appendix. (IMO, 1997 November 27, 2000a).

The guidelines offer methods and techniques for the collection and analysis of information, which help the investigator to methodically identify human factors leading to the accident. The objective of the guideline is to alert the maritime seafarers to the contributory role of human elements in causing accidents at sea. This awareness would in turn be beneficial to any programme to mitigate human error, and therefore this would lead to the improvement of safety at sea.

5.3. Experts' and seafarers' perspective in measures for reducing involvement of human elements in collisions

For the purpose of this dissertation, the author specially conducted an interview on a mount of seafarers and experts in the shipping industry for their views on the human elements involvement in collision accidents by questionnaires. 387 interviewees responded to the questionnaires. Some of them even made extra comments and recommendations on methods and techniques that may be helpful and applicable in human error reduction.

5.3.1. Statistical results of respondents' perspectives

Ten assumed measures are listed in the questionnaires. Interviewees were required to confirm the assumed measures with yes or no. Table 5.1 and Figure 5.1 demonstrate the statistical results of the respondents' opinion on countermeasures suitable and applicable for fighting against the impacts of human elements involved in collisions.

82% of the respondents took enforcement of training and education as an effective countermeasure in reducing the involvement of human elements in collisions at sea. 69% of the respondents confirm the measure "to promote and support the research work on human element issues". Improving the management both onboard ship and ashore has also been confirmed by a majority of the respondents. Other assumed measures which have got a majority support are: upgrading and updating the relevant knowledge in time; establishing a quality system; insuring the minimum safe manning; enhancing the international cooperation on training, research and technical issues; equipping the ship with more automated instruments and systems for reducing the work load of human beings.

Other two assumed measures, amending, or establishing international conventions and national legislations and improving ship design, have failed to get majority confirmation.

For convenience of further analysis, experts' and seafarers' opinions are divided into different groups according to their background. Figure 5.2-5.7 shows the different comparison results based on background of nationality, occupation, education, competent level, sea experience and collision/close-quarters situation experience respectively.

Table 5.1 Respondents' View on Countermeasures against HE in Collision at Sea

Countermeasures	Number of "yes"	Percentage (%)
Enforcing training and education both on board ship and ashore	318	82
Upgrade and update the relevant knowledge in time	256	66
Enhancing the international cooperation on training and research	208	54
Amend, establish, and put in order the international convention and national legislation	163	42
Improve the management both ashore and on board ship	263	68
Improve ship design	121	31
Equip the ship with more automated	198	51
Insure the minimum safe manning	243	63
Establish quality system	229	59
Promote and support the research work on human elements	268	69

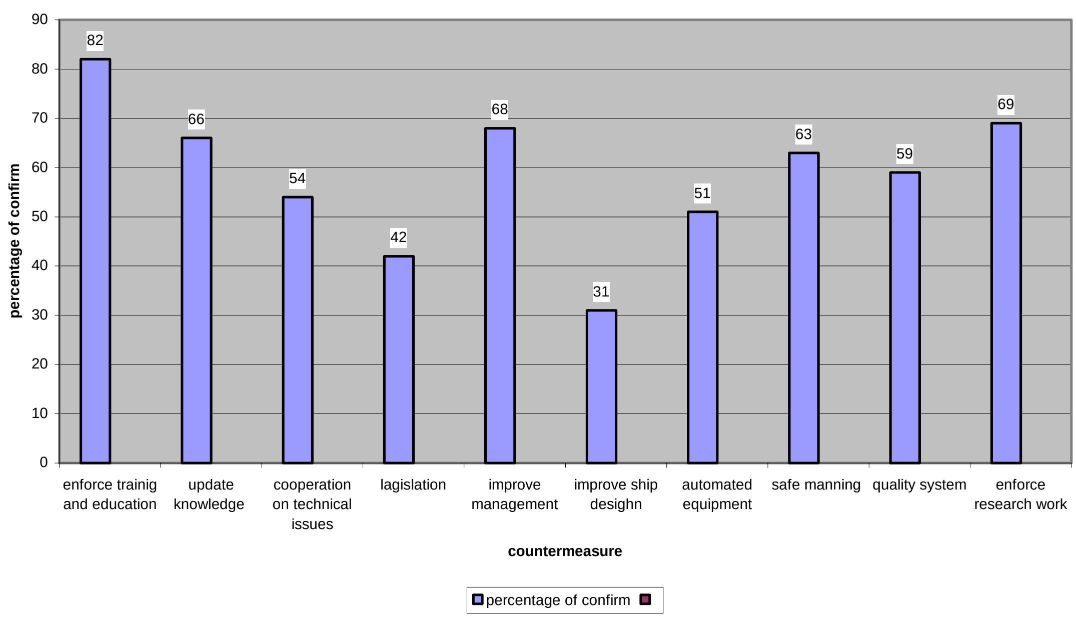

Figure 5.1 Respondents' View on Assumed Measures

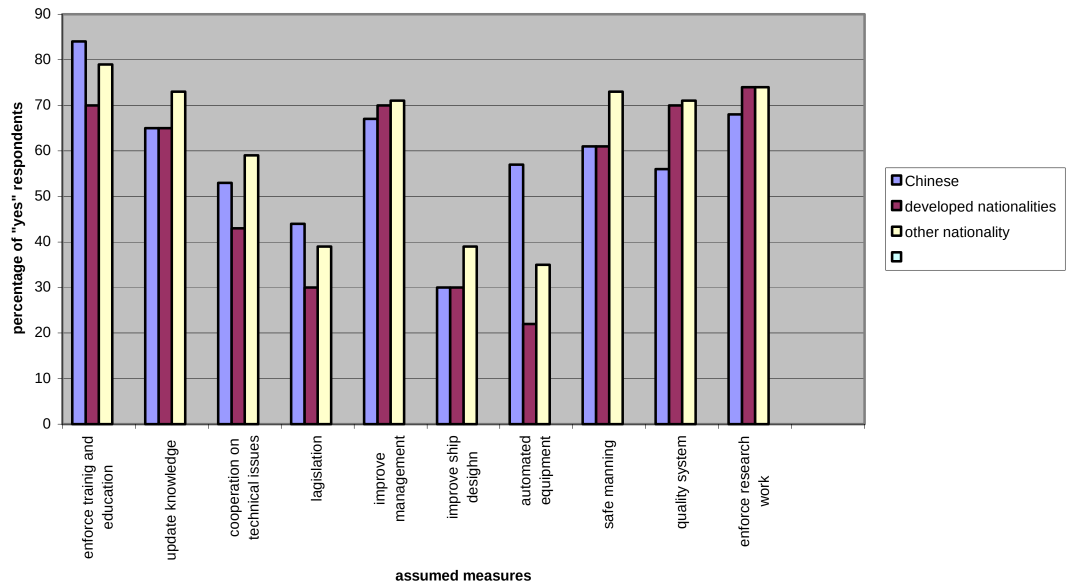

Figure 5.2 Comparison between the Views on Human Error Reduction Measure Based on Nationalities

It seems that the difference in opinion on countermeasures for fighting against impacts of human elements involved in collisions is not very significant. Figure 5.2 demonstrates the opinions of the Chinese, developed nationalities and other nationalities. They share the same opinion of the importance of training /education and enforcement of human element research. The most obvious differences among their opinions are about management, quality system, safe manning and automated equipment. It seems that the respondents from developed nations emphasize more on management and quality systems than the other nationalities did; the Chinese gave a higher priority to automated equipment than others did ; the respondents from other nationalities pay more attention to safe manning than those from developed nations and China .

Figure 5.3 is about the opinions of respondents with different occupational backgrounds. The apparent differences among their opinions are mainly about safe manning automated equipment and legislation. Seafarers put the safe manning, automated equipment, and legislation in a more important position than that of the rest of the respondents did. Particularly, there is a strong contrast between the views of seafarers and staff of shipping companies on safe manning issues.

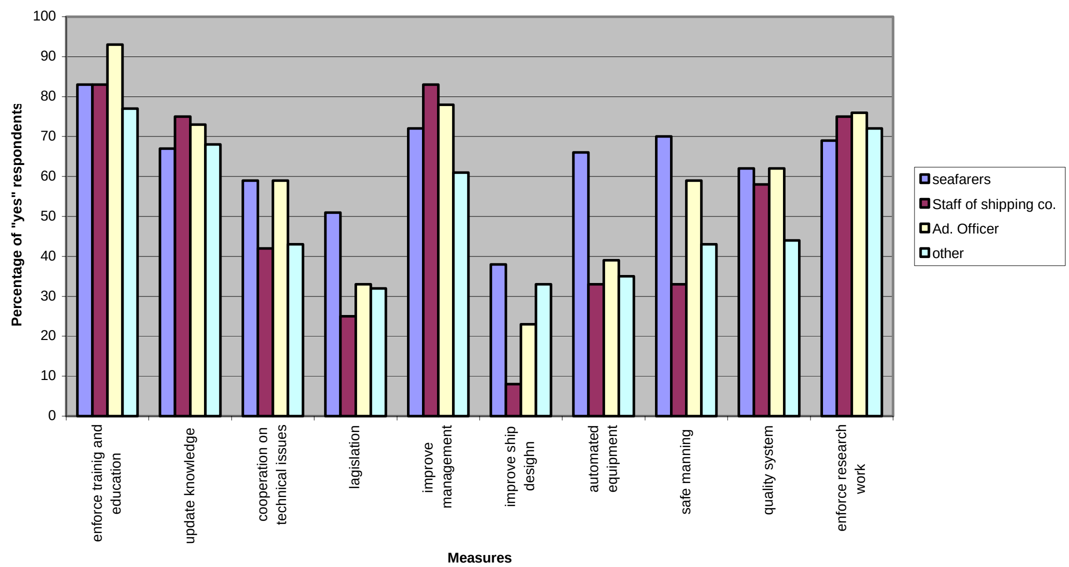

Figure 5.3 Comparisons between the Views of the Respondents on Human Error Reduction Measures Based on Occupation

Figure 5.4 demonstrates the perspectives of the respondents with different educational backgrounds. The main diversity lies on update knowledge in time, safe manning, automated equipment and research on the human element. It seems that people with lower educational background take safe manning more serious while those with higher education background put more emphasis on knowledge updating. It is interesting to see that the respondents with university and college background put more emphasis on research work than those with post graduate background.

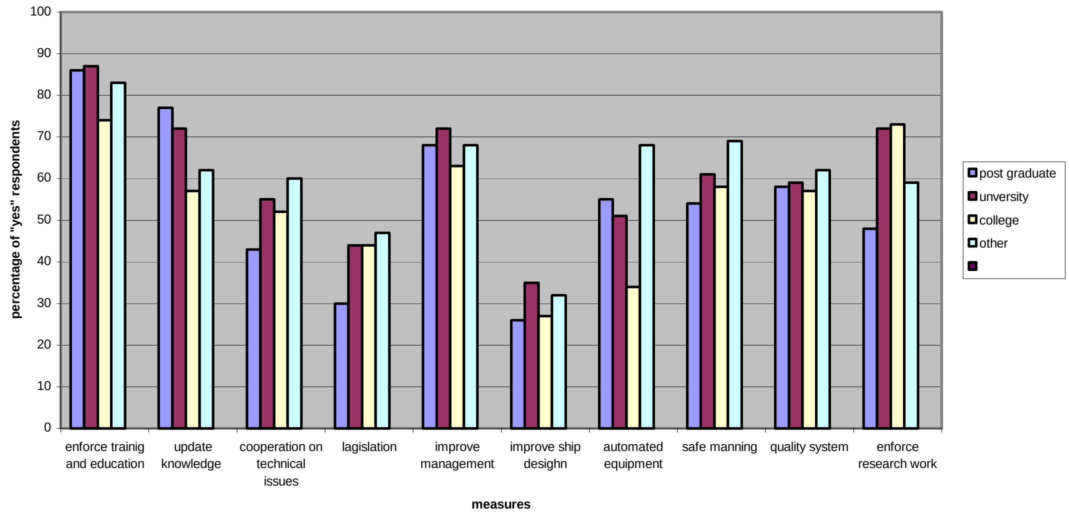

Figure 5.4 Comparisons between Views of Respondents on Human Error Reduction Measures Based on Education Level

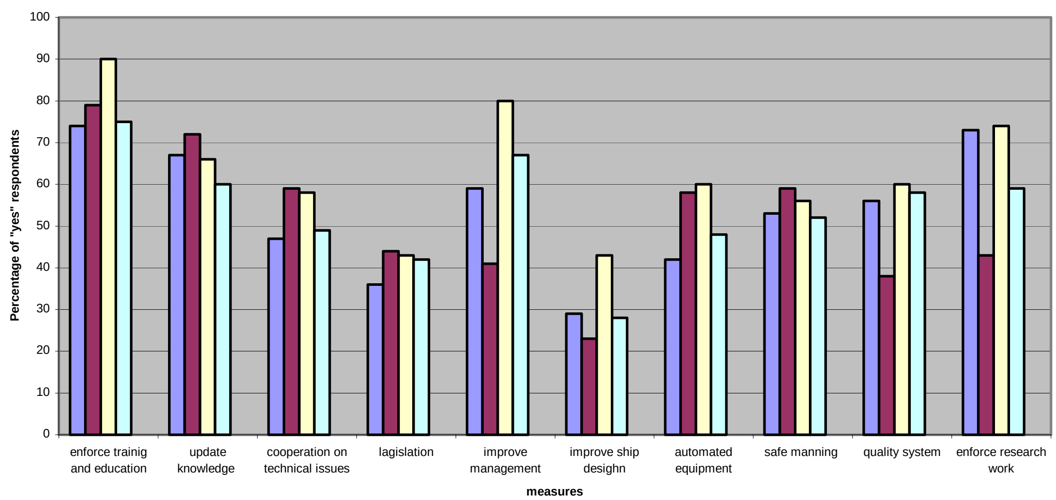

Figure 5.5 Comparisons between the Views of the Respondents on Human Error Reduction Measures Based on Competence Level

Apparently, those with lower education background pay more attention to automated equipments.

Figure 5.5 shows the comparison results on the basis of competent level. In general, the difference of their opinions mainly focused on management improvement, quality system establishment, automated equipment and research. On management and quality system issues, all other seafarers put more importance on it than the chief officer did. The chief mate also paid less attention to research work on the human element, but the chief mate and navigational mate emphasized the automated equipment more.

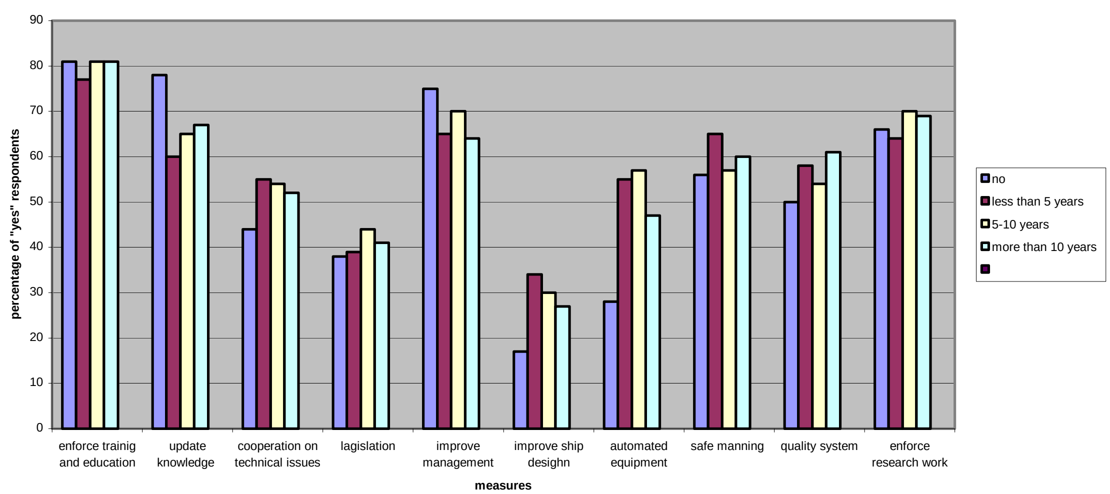

Figure 5.6 Comparisons between the Views of the Respondents on Human Error Reduction Based on Sea Experience

Figure 5.6 gives the comparison results based on sea experience. There is an obvious difference between the view of those with sea experience and those without sea experience. Those without sea experience pay more attention to updated knowledge and management improvement while those with sea experience emphasize more on automated equipment and safe manning.

Figure 5.7. Demonstrates the opinion comparison on the basis of collision experience. Those who have collision or/and close-quarters situation experience emphasize more training and knowledge updating than those without experience.

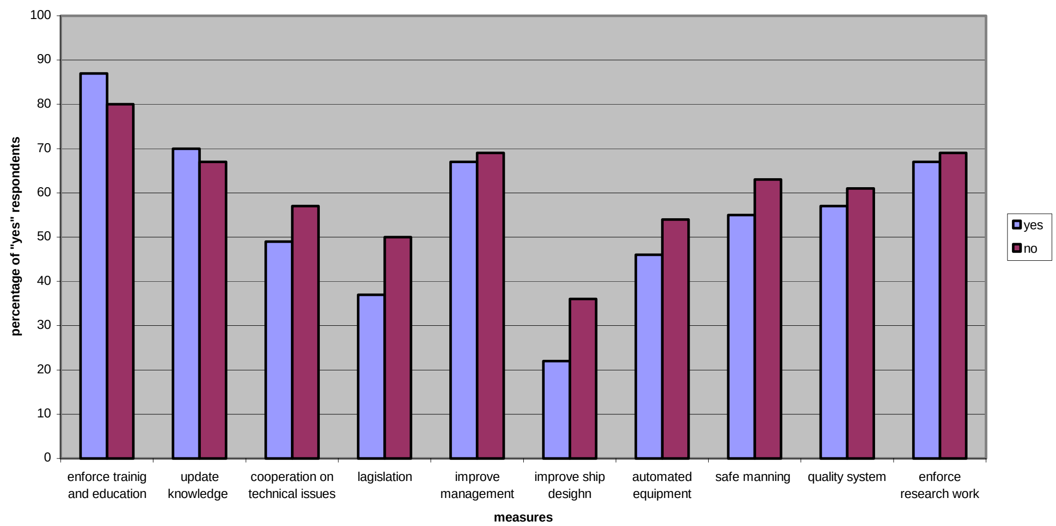

Figure 5.7 Comparisons between the Views on Assumed Measures Based on the Experience of Collision/Close-Quarters Situation

5.3.2. Extra recommendations and comments given by respondents

Besides confirming the assumed measures listed in the questionnaire, many respondents have also made some extra recommendations and comments on countermeasures against the involvement of human elements in collisions. The following is a summary of their extra comments and recommendations.

1. The length of working period on board ship should be limited. Overlong working period on board ship is also a dangerous factor influencing seafarer's performance. It impairs the mariner' ability to perform his tasks safely and effectively. Overlong working period on board ship means seafarers have to endure a long time of harsh working conditions and separation from loved ones. These unfavorable conditions will definitely have a negative influence on seafarers' mental and physical state; thus, deteriorate their ability to perform their duties. There should be legislation at least at national level to stipulate the limitation of the period that a seafarer may work on board ship each time.
2. Seafarers should be properly motivated. Motivation is a very important means, which may affect human beings' attitudes and performance. The effective methods for motivating seafarers on board of ship may include: enhance their salary and allowance in time; provide them a comfortable living and working environment; show loving care for those who work on board ship from the company; reduce the pressure acting on seafarers from various sources such as company, family and crewmates.
3. Education and training should not only focus on upgrading and updating skills and knowledge but also on developing a safety culture. All relevant individuals and organizations should pursue the cultivation of a safety culture continuously and vigorously. Seafarers' professionalism including pride in profession, sense of value and ethics need to be developed. Education and training is an available and practical means for achieving these objectives. All relevant personnel should be made aware of the inherent dangers posed by different situations and the causal effects which can lead to casualties through improved education and training. If people in general have a sound safety consciousness and a positive attitude towards safety, the impact of the human element in all marine accidents and incidents including collisions would decrease.

4. The current regulation should be enforced and properly implemented. No more new regulations are required. The existing regulations are quite good and adequate. The problem is that people intentionally or unintentionally refuse to use them. People do not follow the requirements. To deal with this issue, education is needed. Some kinds of enforcement, for instance punishment on violation of regulations is also needed.
5. Efficient and effective communication between ship and shore, seafarers and their families should be properly maintained. To those who have been separated from society and family for a long time, communication seems critically important in calming their anxiety and improving their performance.

5.4. Discussion

1. Education and training

All parties, whether researchers, IMO, or respondents of the questionnaires, consider education and training as a most effective means even as a sole effective means in certain circumstances (Kuo, 1998, p.170) in reducing the impacts of human elements in maritime accidents. But the following points should be made clear when conducting education and training.

First of all, objectives of education and training are understood as “ to achieve or enhance the competence of individuals for doing a specific task” (Kuo, 1998, p.171). Indeed, it is also playing an important role in changing individual’s attitudes towards safety and profession. Second, trainees should not be limited to seafarers on board ship. All relevant personnel both on board and ashore must be educated and trained on safety issues especially human element involvement. Third, all available means should be used in education and training. It should not be limited in classroom ashore, but on-job training should also be conducted. It should not be limited to books and paper, simulators, computers and other advanced techniques should also be taken advantage of. There is no conflict among them, no reason to replace this one with that one, but integrate them and enhance each other. Lastly, education and training is not a one-day-task. Continuing education and training should be maintained. It is difficult to over stress the importance of upgrading and updating the knowledge, skill and safety consciousness in time.

2. Research work on the human element

Since the end of the 1980s, in the wake of casualties such as Herald of Free Enterprise, the human element has been a hot topic in the maritime industry. Many researchers, organizations, member States to IMO (Eriksson & Mejia, 2000, p.37; IMO, 1995a, 1995b, 1995c, 1996, 1997a, 1997b, 1998a, 1998b, 1999, 2000a, 2000b, 2000c, 2000d; MAIB, 1991; Williams, 1994) focus their energy on the study of the human element in maritime casualties with the aim to determining the most effective means of preventing or mitigating the impacts of human error and thereby to promote safety of life at sea and prevention of marine pollution. Although a great advance has already been made in the human element study field for instance, the successful trial application of formal safety assessment, there are still some issues that need to be solved before even greater progress and breakthrough could be made.

First, cooperation among all maritime States should be strengthened; there should be a general research plan integrating all these States together as a research body. Since shipping is an international industry, multinational crewmembers are used worldwide; it is not enough that only a few developed maritime nations have an interest in the human element research. Only with the efforts of the entire international maritime society, can the goal of reducing human element impacts in marine accidents be achieved. Second, there need be a sound research work agenda. It seems that most of the searchers' attention is focused on formal safety assessment and management of fatigue. How about other issues? For instance, the relationship between each assumed psychological, physical, physiological factors in accidents, the interaction between the various identified hazards, they are an integrated part of the total research work and cannot be overlooked. Lastly, the research attention should also be devoted to devising some more appropriate methodologies or procedures that can assist all relevant personnel to reach the requirements of the modern shipping industry, to be qualified in competence and to have proper attitudes and professionalism.

3. Management of bridge team and resources

Enhancing the safety management and bridge resource management are frequently mentioned in various pieces of literature about the human element. IMO specially provides standards for the safe management and operation of ships by adoption of the International Safety Management (ISM) Code and requirements for establishing a quality system by STCW 95. In the questionnaires, most of the respondents have also confirmed the assumed measures of improving management both on board ship and ashore. Since it is such a widely accepted measure and it has been applied in the shipping industry for a long time, why do accidents including collision caused by poor bridge management still occur at such a high rate? Poor implementation may be one of the explanations to it. Therefore, the author would like to emphasize that implementation is as important as management it self. For real and effective implementation of the ISM Code, a quality system and other safety management systems, their need to be common standards applied throughout the entire maritime industry.

4. Safe manning

Inadequate manning has already been repeatedly evidenced to be one of catalysers to human elements and unsafe acts, for instance fatigue, inattention, poor lookout, poor management and error of judgment, leading to the accidents. This issue has already drawn attention from various parties. IMO (1993,1999) and ILO (1996) issued the principle and requirements on safe manning that the manning level should be high enough to maintain a safe navigational watch. But manning problems still exist. According to the recovered questionnaires, the most repeated complaints are about workload and rest. Respondents who were seafarers complained that they always work overtime since there is not enough hands; they feel fatigue because of the workload and lack of rest. This is why a much higher proportion of seafarer respondents than that of other groups confirm safe manning as necessary countermeasure against impacts of human elements in collisions. To ensure the safe manning, strict implementation of relevant regulations and maintenance of higher manning levels are required.

5. Regulations

Regulations issued by international organizations or maritime States or local maritime authorities have really improved the safety situation at sea very much. This is why where a serious maritime casualty occurs, there is a new regulation or a new amendment of an existing regulation. But, many researchers (Kuo, 1998, p.167), and respondents of the questionnaire hold different opinions. They thought that the removal of human error couldn't be achieved by more legislation. The most effective and practical way is implementing the existing regulations seriously, and improving the education and training to make all relevant personnel be more aware of the human element involvement in accidents.

6. Ship design and automated equipment

The assumed countermeasures, improving ship design and equipping the ship with automated equipment, specially designed to improve navigators' operating environment and to reduce their workload only got a very few respondents' confirmation. In the collected 100 collision accident reports, investigators also rarely mention this issue. Thus it cannot be concluded that properly designing the ship and equipping the ship with more advanced equipment are less important, but more research on this issue should be done. Maybe cost and benefit assessments are needed.

7. Difference among the opinions of respondents

In general, there is no big difference among the perspectives of the respondents except some minor ones. The following are what the author thought valuable to mention here.

First, respondents from developed nations pay more attention to management improvement than others; the Chinese seem to attach more importance to automated equipment. The author is not sure whether it is because of the difference of culture, but some Chinese respondents explained in the questionnaires that automated equipment is helpful in reducing the workload for watchkeepers.

Second, seafarers give higher priority to safe manning. This just properly expresses the minds of front-line operators: it is they not others who suffer the impacts of lack of hands, overlong working hours, fatigue and overload. From the point of view of safety, managers of shipping companies and safety administrators should listen to seafarers' voice and pay more attention to manning issues.

Third, respondents with higher education backgrounds emphasize more knowledge updating than others while those with lower education background pay more attention to safe manning and automated equipment. Perhaps this is because most of those with lower education background are seafarers and front-line operators.

Fourth, chief officers seem to be a special group for their opinion on some of the assumed countermeasures as it is much different from other groups. It seems that they pay more attention to automated equipment and manning than others.

Finally, those with sea experience pay more attention to manning and equipment issues than that of others. The main influence of collision/close-quarters situation put on individuals seems to be that it draws more attention from the experienced one to training and knowledge updating.

8. A question

In addition, one question arises from the comparisons between the researchers' recommendations and the seafarers' and experts' views on human element involved in collision and countermeasures against these involvements. Since seafarers and those involved in maritime industry know very well the human elements involved and effective countermeasures against these human elements, why the maritime accidents including the collisions still occur at such a high rate? There should something behind this phenomenon. Deeper research work on this subject is needed.

5.5 Summary

In this chapter, a brief review has been devoted to the work done by researchers and IMO on countermeasures against impacts of human elements in maritime accidents. A specially designed investigation of the perspectives of relevant shipping personnel on countermeasures for reducing human element involvement in collisions is conducted by the questionnaire. It is commonly agreed that improving education and training, promoting research work and enforcing management both onboard ship and ashore are effective and practical measures for reducing impacts of human elements in maritime accidents including collisions.

CHAPTER 6
Conclusion and Recommendations

6.1. Summary

The objective of this dissertation is to identify the human elements involved in collision accidents at sea and the countermeasures for reducing the impacts of the human elements involved. For this purpose the following tasks have already been completed:

- Studying the background literature, documents and reports relating to the human elements in maritime casualties especially in collisions at sea. Preparing information and materials needed for the research work.
- Working out the research plan and determining the methods and approaches used in this research.
- Establishing a classification for classifying and storing the human elements involved in the collisions.
- Identifying the human elements involved in collisions at sea with determined methods.
- Identifying effective and practical countermeasures for reducing the human elements involvement.
- Providing recommendations on future work on reduction of the human elements involvement in collisions at sea.

The methods used for this dissertation mainly consists of: Collecting actual human element data form current written accident reports; establishing a classification of the human element for collecting and storing the data picked up form the written reports; designing a questionnaire to collect the perspectives of marine safety related persons on human elements involved in collisions; designing a mathematical model for analysing the data collected from the questionnaires.

One hundred written accident reports have been retrieved and analysed. 387 out of 1000 questionnaires circulated have been recovered. A fuzzy set model has been established and used in calculating the membership grade of human elements involvement based on the recovered questionnaires.

The main findings and achievements are:

- For identifying the human elements involved in collision at sea, a classification for collecting and storing the data relating to the human element involvement in marine collision accidents has been proposed. It consists of three subcategories: unsafe acts, underlying human elements, and external influencing factors. The application of this classification in this dissertation proves that it is practical and compatible, although there is still some room for improvement.
- The written accident report is currently most useful and available source for identifying human elements involved in accidents, such as collisions, for it provides more detailed information regarding human performance in accidents which is valuable for searching the underlying human elements involved.
- It is proved that a questionnaire is a valuable and practical method for human element research. The comparison between the data picked up form the written reports and the data calculated on the basis of the questionnaires demonstrates that human beings' perspectives on involvement of human elements in collision are roughly consistent with the actual situation. The questionnaire cannot only provide the opinion of respondents about human elements but also reflects the respondents' attitudes towards safety at sea, which is also valuable information for human element research.

- The perspectives of respondents with different backgrounds on involvements of human elements and countermeasures for reduction of those human elements are roughly identical with the actualities..
- The most frequently involved unsafe acts in marine collisions are poor lookout and error of judgement. Other identified human elements include failure to comply with regulations, improper use of radar and ARPA, failure in communication, unsafe speed, and improper shiphandling and failure to comply with good seamanship. The underlying human elements behind these unsafe acts are experience/knowledge/training, communication difficulty, attention, failure and workload. The most involved external factors include manning, management, team working, safe culture, fairway, visibility and other traffic.
- Nearly all aspects of the marine industry take education and training as a practical and effective way in fighting against involvement of human elements in maritime casualties including collisions. The key points lie in that education and training can not only promote the trainees competent levels but can also change their attitudes towards safety. Both of these effects can help to reduce the impacts of human elements in collisions at sea.
- The prescriptive regulations have already played an important and active role in enhancing safety levels at sea, but to make more regulations for removal of human errors in the maritime industry is not a good and effective way. Improved training and education to make trainees be aware of the weakness of human beings and the inherent dangers posed by different situations maybe more helpful.
- Improving management both on board ship and onshore is deemed as effective and practical for reduction of human elements. Onboard ships, bridge resource management or bridge team management should be improved. Ashore it is necessary to establish a quality system within the shipping company. The ISM Code has well coped with these requirements.

- Introducing the safety culture into the shipping industry is an effective way for reducing the human errors in collision accidents. Many collision cases show that not only the incompetent mariners but also the competent ones make mistakes during collision avoidance. It is difficult to explain the reason for lack of knowledge, experience or training; perhaps mariners' attitudes towards the collision avoidance play a critical part in these cases. Establishing a safety culture within a company and an organization and having people change their attitudes towards safety are thus necessary.

There are still some measures proposed by individuals and organizations, for instance, enforcing research on human elements in collisions, maintaining safe manning level, enhancing technical, research and training cooperation between maritime nations on human element issues may be used in fighting against the impacts of the human elements. Some of them need to be practiced; some of them need more research.

6.2. Recommendations

1. Current available accident reports have provided valuable information about accident events and direct causes leading to the accident. But most of them failed to provide more information about the underlying human element and the role the organization had played in accidents (Moore & Bea, 1993). The depth of investigation strongly depends on experience, knowledge, competence and even interests of the investigators. The formats of the reports are also varied from source to source. These problems bring about difficulties to the author in analysing the indirect causations of accidents. Fortunately, IMO (2000) provides a guideline for harmonizing the investigation of human factors in maritime casualties and incidents, which may improve the situation in future. The questions are: Will the guideline be fully

implemented by all maritime States? Is it effective to cover all kinds of maritime accidents? Will investigation in every maritime member states be competent enough to conduct the investigation? This is not sure. Therefore, it is recommended that:

● trial application of the code and guidelines be conducted and its effectiveness assessed. If it is necessary, further amendments are needed.

● the cooperation among all maritime nations in investigators training, information exchanging, technology and finance supporting be enhanced.

2. There are many kinds of human element classifications available at present. Some of them are comparatively simple while others are too complicated; some of them are designed for universal use while others are just for oriented use (Moor&Bea,1993, 2-4). It is of utmost importance that a practical and sound classification for human element research be developed. The classification should be easily understandable for not only the experts but also seafarers. The classification should be able to address the common human element involved in all marine accidents and specific human elements improved in special types of accidents such as collisions and groundings.

3. The underlying human elements behind unsafe acts leading to collision are still uncertain for lack of information and research. There are two ways to deal with this issue: on the one hand, improving the investigation to get deeper into the accident; on the other hand, enhancing the research work on the issue. Since maritime safety as a research area is crosses disciplinary (Håvold, 2000, p.85; Larson, 1998), the research work demands the combined approaches of several disciplines: psychology, sociology, human resource, management, ergonomics, statistics and epidemiology. Since human elements nest on all levels and all aspects of the maritime industry (Rasmussen, 2000), the research work should not only focus on seafarers, all parties involved in shipping should be taken into account.

4. Since seafarers and those involved in shipping industry have well know the human elements involved in collision accidents and the countermeasures against the involvement of these human elements, it is necessary to explore the answer to the question why maritime accidents including collision still happen at a high rate. It needs the combining efforts of various parties.

5. Although more effective and applicable measures need to be developed, the measures, for instance developing a safety culture, which has already been proved to be effective in reducing impacts of human elements in collisions should be actively applied now. It is recommended that all maritime safety related parties should try to seek ways to develop a new and positive safety culture and make it become an integral part of all personnel activities.

"People are the key to any real efforts to improve safety and pollution"(O'Neil quoted by Mejia, 2000). Identifying and reducing the impacts of human elements in maritime accidents including collisions at sea need all efforts of human being.

References

Cahill, R.A. (1997). *Collisions and their causes* (2^{nd} ed). Austin: Nautical Books.

Chauvel, A-M. (1998). Improving quality and safety at sea. In proceeding of ImarE, new safety culture: Vol.110, 3 (pp. 25-32). London: the Institute of Marine Engineers.

Chen, b. & Deng, H. (1996). The analysis of human element in collision accidents. ". In J. Zhao, P.A. Wilson, Z. Hu & F. Wang (Eds.), *Proceedings of the international conference on preventing collision at sea, Maritime collision and prevention*: *Vol.1* (pp296-300). Epson, Surrey: Chiavari Publishing.

Clench, R.S. (1995). The human component in maritime systems. In P Yakimiuk, & AL Erripidou (Eds), *IMAS'95 Conference & proceeding: Vol. 107(2). Management and operation of ships: practical techniques for today and tomorrow* (pp193-198). London: Institute of Marine engineers.

Cockcroft, A. N. & Lameijer, J. N. F. (1996). A guide to the collision avoidance rules (5th ed). Oxford: Butterworth-Heinmann.

Cockcroft, A.N. (1996). Collision regulations: the argument against radical change at the present time. ". In J. Zhao, P.A. Wilson, Z. Hu & F. Wang (Eds.), *Proceedings of the international conference on preventing collision at sea, Maritime collision and prevention*: *Vol.1* (pp161-165). Epson, Surrey: Chiavari Publishing.

Cole,C.W.(1999, May). The Impact of Multicultural and Multilingual crews on Maritime Communication– *what is (y)our position*? Paper presented at the Workshop on Maritime English 10. Rijeka, Croatia.

Dickson, G.C.A. (1991). Risk analysis (2^{nd}. Ed). London: Witherby.

Dragger, K.H., Kristiansen, S., Karlsen, J.E. & Wrencke, R.M. (1981). Cause relationships of collisions and groundings conclusions of statistical analysis. *Norwegian Maritime Research 3/1981*,20-32.

Dynamic Research Corporation Man-Machine systems Department. (1989). *The role of human factors in marine casualties (final Report).* U.S. Cost Guard.

Embrey, D. E. (1988). Assessment and prediction of human reliability. In A.S. Nicholson & S.E. Ridd (Eds), *Health safety and ergonomics*. (pp. 33-47). London: Butterworths.

Eriksson, P. & Mejia, M. (2000). *IMO'S work on the human element in maritime safety*. Report 2003. Lund: Lund University.

Farthing, B. (1998). A new safety culture. In *proceeding of ImarE, new safety culture: Vol.110, 3* (pp. 51-53). London: the Institute of Marine Engineers.

Feyer, A-M. & William A. M. (1998). Human factors in accident modeling. In J. Saari (Ed): *Accidents and safety management. Encyclopedia of Occupational Health and Safety* (4th ed., Vol. II. pp 56.8-56.11). Geneva: International labor organization.

Goossens, L.H.J & Glansdrop. (1998). Operational benefits and risk reduction of marine accidents. *The Journal of Navigation, 53(3),* 368-381.

Gordon, R.P.E. (1998). The contribution of human factors to accidents in the offshore oil industry. *Reliability engineering and system safety, 61(1998),* 94-108.

Gray, W. O. (1996). Competent error, human factors. America Bureau of Shipping *Survey, 27(3),* 10-11.

Grime, R.P. (1996). Human factors. In J. Zhao, P.A. Wilson, Z. Hu & F. Wang (Eds.), *Proceedings of the international conference on preventing collision at sea, Maritime collision and prevention*: *Vol.1* (pp314-329). Epson, Surrey: Chiavari Publishing.

Gu, W. et al. (1993). *Safety of marine transportation*. Dalian: Dalian Maritime University Publishing House.

Hanson,W.E.(1997). A team approach to reduce human error accidents. In: *SAAMEX International'97, safety at sea and marine electronic conference*. Redhill, surrey: DMG Business Media.

Hawkins, F. H. (1987). *Human factors in flight*. Aldershot, U.K.: Gower Technical Press.

Health and Safety Executive, UK (1989). *Human factors in industry safety*. London: Author.

Hebden, D., Barfield, P. & Sachs, M.(1996). Methodology of collision investigation: past, present and future. ". In J. Zhao, P.A. Wilson, Z. Hu & F. Wang (Eds.), *Proceedings of the international conference on preventing collision at sea, Maritime collision and prevention*: *Vol.1* (pp1-5). Epson, Surrey: Chiavari Publishing.

Hernqvist, M. (1996). Bridge resource management –the importance of the right attitude. ". In J. Zhao, P.A. Wilson, Z. Hu & F. Wang (Eds.), *Proceedings of the* *international conference on preventing collision at sea, Maritime collision and prevention*: *Vol.1* (pp334-338). Epson, Surrey: Chiavari Publishing.

Hinsch, W. (1995). Risk of collision at sea. *The Journal of Navigation, 48(3),* 389-395.

Holder, L.A. (1997). *Training and assessment on board (2nd ed)*. London: Witherby.

Hong, B. (1999). *Safety management*. Dalian: Publishing house of Dalian Maritime University.

Hoyos, C.G.& Zimelong, B. (1988). *Occupational safety and accident prevention*. Amsterdam: Elsvier.

Huang, Y. (1998). *Research on human error in maritime accident prevention.* Unpublished master's thesis, Dalian Maritime University, Dalian, China.

International Labor Organization. (1996). *C180 seafarers' hours of work and the manning of ships convention*. Geneva: Author.

International Maritime Organization. (1972). *The international regulations for preventing collisions at sea, 1972.* London: Author.

International Maritime Organization. (1993a). *Consideration of current safety issues: formal safety assessment* (MSC 62/24/3). London: Author.

International Maritime Organization. (1993b). *International Management Code for the safe Operation of Ships And for Pollution Prevention (International Safety Management (ISM) Code)* (Resolution A 741 (18). London: Author.

International Maritime Organization. (1993c). *Fatigues in manning and safety* (Resolution A. 772 (18). London: Author.

International Maritime Organization. (1995a). *Factors that influence human decision making (*MSC 65/15/1 annex). London: Author.

International Maritime Organization. (1995b). *Formal safety assessment* (MSC 65/24/2). London: Author.

International Maritime Organization. (1995c). *Role or the human element: submission by the United States* (MSC 65/15/1). London: Author.

International Maritime Organization. (1996a). *International convention on standards of training, certification and watchkeeping for seafarers, 1978, as amended in 1995 and seafarer's training, certification and watchkeeping code.* London: Author.

International Maritime Organization. (1996b). *Role of the human element in maritime casualties: study into Fatigue, stress and occupational health of seafarers* (MSC 67/12/7). London: Author.

International Maritime Organization. (1997a). *Human element vision, principles and goals for the organization* (resolutions A.850 (20)). London: Author.

International Maritime Organization. (1997b). *Human error on the bridge, a study by Finnish shipping* (MSC 68/inf. 15). London: Author.

International Maritime Organization. (1997c). *International safety management code and guidelines on the implementation of the ISM code*. London: Author.

International Maritime Organization. (1997d). *World maritime day 1997: Optimum maritime safety demands- a focus on people.* London: Author.

International Maritime Organization. (1997, November 27). *Code for the investigation of marine casualties and incidents* (Resolution A. 849(20)). London: Author.

International Maritime Organization. (1998a). *Formal safety assessment : trail application of the FSA methodology* (MSC 69/14/4) . London: Author.

International Maritime Organization. (1998b). *Formal safety assessment: trail application of the FSA to the transportation of dangerous goods on passenger/ ro-ro vessels* (MSC 69/inf. 24). London: Author.

International Maritime Organization. (1999). *Formal safety assessment: comments to the report of the correspondence group on trial application of FSA to high-speed craft* (MSC 71/14/2). London: Author.

International Maritime Organization. (2000a). *Amendments to the code for the investigation of marine casualties and incidents* (Resolution A. 849(20)), (Resolution A. 884(21)). London: Author.

International Maritime Organization. (2000b). *Decision parameters including risk acceptance criteria for safety* (MSC 72/16 annex1). London: Author.

International Maritime Organization. (2000c). *Formal safety assessment: method for reduction of number of accident scenarios* (MSC 72/inf.24). London: Author.

International Maritime Organization. (2000d). *Interim report of FSA on bulk carriers* (MSC 72/inf.7 annex). London: Author.

International Maritime Organization. (2000e). *Principles of safe manning* (Resolution A. 890(21)). London: Author.

International Maritime Organization. (2000, February 4). *Amendments to the code for the investigation of marine casualties and incidents (Resolution A.849 (20))* (Resolution A. 884(21)). London: Author.

Ioannidis, P.J. (1996). The "human factor". American Bureau of Shipping *Surveyor, 27(3),* 6-7.

James, M.K. (1994). The timing of collision avoidance maneuvers: descriptive mathematical models. *The Journal of Navigation, 47(2),* 259-272.

James, M.K. (1994). The timing of collision avoidance maneuvers: descriptive mathematical models. *The Journal of Navigation, 47(2),* 259-271.

Japan Marine Accident Inquiry Agency. (1998). Causes of marine accidents. Retrieved February 18, 2001 from World Wide Web: http://www.motnet.jp/english.htm.

Karlsen, J.E. & Kristiansen, S. (1980). *Cause relationships of collisions and groundings: Analysis of causal factors and situation dependent factors*. *Report No 80-1144.* Oslo: DNV Research Division.

Kliv, G.J. & Folger, T.A. (1988). *Fuzzy sets, uncertainty and information.* New York: Prentice-Hall international, Inc.

Kristiansen S. (1993). Human factors in marine accidents In: *Wegemt: Vol.1 (9)* (pp1-23). Lisbon: a European association of universities in marine technology.

Kuo, C. (1993). The role of human factors in the safety of marine systems. In *proceedings of the third international offshore and polar engineering conference: Vol. IV* (pp638-643). Singapore: the international society of offshore and polar engineers.

Kuo, C. (1998). *Managing ship safety*. London: LLP Reference Publishing.

Landsburg, A. C., & Ferguson, S. J., & Pillsbury, C., & Ellingstad, V. (1999). Accident causation-based human factors taxonomy. *BIMCO BULLETIN, 94* (1), 20-25.

Larsson, T.D. (1998). Safety science monitor,2(1). Retrieved June 18, 2001 from World Wide Web: http://www.ispo.asn.au/vol2/issue1/w6edvzil.htm.

Liu, Z. (1996). Anti-collision and marine education. ". In J. Zhao, P.A. Wilson, Z. Hu & F. Wang (Eds.), *Proceedings of the international conference on preventing collision at sea, Maritime collision and prevention*: *Vol.1* (pp308-313). Epson, Surrey: Chiavari Publishing.

Lloyd's Register of shipping. (1999*). World casualty statistics*. London: Lloyd's Register.

Marine Accident Inquiring Agency of Japan. (1999). *Statistics of accidents 1994-1998*. Retrieved February 18, 2001 from World Wide Web: http://www.motnet.go.jp/maia/english.htm

Marine Accident Investigation Branch, U.K. (2000). *MAIB Annual reports 1999*. London: Author.

Marine Accident Investigation Branch. U.K. (1999). *MAIB Annual reports 1998.* London: Author

Marine Directorate of the Department of Transport (1991). *The human element in shipping casualties*. London: HMSO.

Marine Incident Investigation Unit. Australia (1996). *Marine incident investigation unit 1991-1995*. Canberra: Transport and Regional Development of Australia.

Marine Safety Agency of U.K. (1995). *Watckkeeper collision avoidance behavior*. Southampton: Author.

Mason, E. (1994). Marine human and organizational error: a data evaluation. Berkeley, CA: University of California at Berkeley.

Mejia, M. (2000).*STCW 95 and the Human Element*. Unpublished lecture handout, World Maritime University, Malmö, Sweden.

Moore, H: H. & Bea, R.G. (1995). Management of human and organizational error throughout a ship's life cycle. In P. Yakimiuk & A.L. Erripidou (eds.), *IMAS 95, international conference on management and operation of Ships, Practical Techniques for today and tomorrow: Vol 107(2)*(pp.181-188). London: the Institute of Marine Engineers.

Moore, W.H. & Bea, R.G. (1993). *Management of human errors in operation of marine systems.* Berkeley, CA: University of California at Berkeley.

Moore, W.H. & Bea, R.G. (1995). Management of human and organizational error throughout a ship's life cycle. In P Yakimiuk, & AL Erripidou (Eds), IMAS'95 *Conference & proceeding: Vol. 107(2).* Management and operation of ships: practical techniques for today and tomorrow (pp181-188). London: Institute of

Morris, L.R. (1996). Collision investigation- a consultant's view. ". In J. Zhao, P.A. Wilson, Z. Hu & F. Wang (Eds.), *Proceedings of the international conference on preventing collision at sea, Maritime collision and prevention*: *Vol.1* (pp11-18). Epson, Surrey: Chiavari Publishing.

O'Neil, W.A. (1996). Responsibility to the human element. American Bureau of Shipping *Surveyor*, *27(3)*, 4-5.

Peters, G. (1966). Human error: analysis and control. *Journal of the ASSE,1/1966*.

Petersen, D. (1996). *Human error reduction and safety management.* New York: Van Nostrand Reinhold.

Porter. S. (1988). Accident Proneness: A review of the concept. In. D.J. Oborne (Ed), *International Reviews of Ergonomics* (Vol 2, pp. 177-206). London: Taylor & Francis.

Pourzanjani, M. (1996). A study of collision avoidance behavior. In*: proceeding of Ninth International navigation Simulator Lecturers' Conference* (pp122-131). Malmö, Sweden.

Rasmussen, J. (2000). *Formal safety assessment*. Unpublished lecture handout, World Maritime University, Malmö, Sweden.

Rasmussen, J. (2000). *Implementation of the ISM Code.* Unpublished lecture handout, World Maritime University, Malmö, Sweden.

Rasmussen, J. (2000). *The international safety management (ISM) code.* Unpublished lecture handout, World Maritime University, Malmö, Sweden.

Reason, J. (1990). *Human error*. New York: Cambridge University Press.

Reason, J. (1993). How to promote error tolerance in complex systems in the context of ships and aircraft. In D. Sounders (Ed.), *The Management of safety in Shipping.* London: the Nautical Institute.

Reason, J. (1996). The human element: a psychological perspective. American Bureau of Shipping *Surveyor, 27(3),* 18-19.

Reason, J. (1997). *Managing the risks of organizational accidents.* Aldershot: Ashgate.

Rothblum, A. M. (1996). Human error and marine safety. Retrieved July 1, 2001 from the World Wide Web: http://www.uscg.mil/hq/g%2Dm/risk/e%2Dguidelines/html/vol4/volum…/humanerr.htm

Rothwell, M. &Chudley, J. (1999). The development and analysis of a navigational incident database for naval vessels. *The Journal of Navigation, 52(3),* 318-329.

Sanders, M.S: & McCormick, E.J. (1987). *Human factors in engineering and design.* New York: McGraw-Hill Book Company.

Schager, B. (1994). Counteracting the human factors by means of focused selection, on-board bridge training and challenging of ingrained attitudes. In *proceedings of 8th IMLA, International Maritime Lecturers Association.* Malmö: International Maritime Lecturers Association.

Schroeder, J-U. (2001). *The IMO / ILO approach to human element investigation in marine*. Unpublished lecture handout, World Maritime University, Malmö, Sweden.

Seijji, N. (1993). *Analysis of world / Japan's shipping casualties and future prospects thereof: relationships between causes of accidents and such factors as safety of mixed crew vessels*. Tokyo: Japan Maritime Research Institute.

Smeaton, G.P., Moreton, M-B & Dineley, W.O. (1996). Collision statistics and human factors—a look beyond "human error". In J. Zhao, P.A. Wilson, Z. Hu & F. Wang (Eds.), *Proceedings of the international conference on preventing collision at sea, Maritime collision and prevention*: *Vol.1* (pp260-270). Epson, Surrey: Chiavari Publishing.

Stockbridge, H.C.W. (1975). *Behavior and the physical Environment*. London: Batsford.

Swift, A.J. (1993). *Bridge team management- a practical guide*. London: the Nautical Institute.

Swindells, N.S. (19959. drug and alcohol screening: a deterrent to reduce people- related ship accidents and damages. In P. Yakimiuk & A.L. Erripidou (eds.), *IMAS 95, international conference on management and operation of Ships, Practical Techniques for today and tomorrow: Vol 107(2*)(pp.199-205). London: the Institute of Marine Engineers.

Syms, R. J. (1996). The fundamental argument for reform-the underlying philosophy and the impact of future technology. ". In J. Zhao, P.A. Wilson, Z. Hu & F. Wang (Eds.), *Proceedings of the international conference on preventing collision at sea, Maritime collision and prevention*: *Vol.1* (pp147-153). Epson, Surrey: Chiavari Publishing.

Taylor, D.M. (1998). Rules and regulations in maritime collision avoidance: new direction for bridge team training. *The Journal of Navigation, 51(1)*, 67-72.

Terano, T., Masui, S., Murayama, Y.,& Akiyama, N. (1987). Human reliability in parallel jobs. In J.C. Bezdek (ed*), Analysis of fuzzy information, Vol2.* (pp. 29-38). Boca Raton: CRC Press, Inc.

Transport Accident Investigation Commission of New Zealand. (2000). *Marine accidents 1998-1999*. Wellington: Maritime Safety Authority.

Transport Accident Investigation Commission. (2000). *Maritime accidents 1998-1999.* Wellington: Maritime Safety Authority of New Zealand.

Transport safety Board of Canada. (1999). *Marine occurrences statistics for 1998*.Quebec: the Author.

UK Health and Safety Executive, (1989). *Human Factors in Industry safety*. London: Author.

UK P&I Club.(1999). *Ten-year trends in maritime risk –analysis of major claims- a digest*. London: Author.

United States Coast Guard. (1995). *Prevention Through People: quality Action Team Report*. Washington, DC: Author.

United States Coast Guard. (2001). *Management of endurance risk factors- a guide for deep draft vessels*. Washington: Author.

Vassalos, D. (1999). Shaping ship safety: the face of the future. *Marine Technology, 36(2),* 61-76.

Walczak, A. (1996). The effects of human factors on frequency of navigational accidents. ". In J. Zhao, P.A. Wilson, Z. Hu & F. Wang (Eds.), *Proceedings of the international conference on preventing collision at sea, Maritime collision and prevention*: *Vol.1* (pp284-290). Epson, Surrey: Chiavari Publishing.

Wang, Q (19929. *Fuzzy sets and its application*. Beijing. Publishing house of science and technology literature.

Wennink, C.J. (1992). Collision and grounding risk analysis for ships navigating in confined waters. *The Journal of Navigation, 45(1),* 80-90.

Whalley, S. (1993a). Identification of causes of human errors .In: *Wegemt: Vol.1 (9*) (pp1-23). Lisbon: a European association of universities in marine technology.

Whalley, S. (1993b). Modeling human errors .In: *Wegemt: Vol.1 (9)* (pp1-23). Lisbon: a European association of universities in marine technology.

Williams, J.C. (1994). Identifying and reducing the contribution of human factors to major hazards. *In proceeding of conference on incorporating the human factor into offshore safety cases: No.34* (pp. 1-17).

Winbow, A. (1998). New safety culture-the STCW 95 contribution. In *proceeding of ImarE, new safety culture: Vol.110, 3* (pp. 1-4). London: the Institute of Marine Engineers.

Wolski, A. (1996). Watch officer training in collision avoidance at sea. ". In J. Zhao, P.A. Wilson, Z. Hu & F. Wang (Eds.), *Proceedings of the international conference on preventing collision at sea, Maritime collision and prevention*: *Vol.1* (pp330-333). Epson, Surrey: Chiavari Publishing.

Wu, Z. (2001). *Collision avoidance at sea and study on safety of maritime traffic*. Dalian: Publishing house of Dalian Maritime University.

Zhang, D. (1998). *Human behavior and collision avoidance*. Unpublished master's thesis, World Maritime University, Malmö, Sweden.

Zhao, J., Price, W.G., Wilson, P.A. & Tan, M. (1995). The uncertainty and uncoordination of mariner's behavior in collision avoidance at sea. *The Journal of Navigation, 48(3)*, 425-435.

Zhao, J., Wu, Z., Wang, F. (1992). The development of ship collision avoidance automation. *The Journal of Navigation, 45(1).*

Appendix A

List of Written Collision Accident Reports Studied.

Marine Accident Investigation Branch, UK. (1996). Collision between a Loaded Tanker and a Trawler. *Summary of investigation*, *96*(2).

Marine Accident Investigation Branch, UK. (1996). Pleasure Yacht Collision with Ferry caused by Interaction. *Summary of investigation*, *96* (3).

Marine Accident Investigation Branch, UK. (1997). Collision with a Discharging Chemical Tanker. *Summary of investigation, 97*(1).

Marine Accident Investigation Branch, UK. (1997). Collision in Fog in the Humber Estuary. *Digest of safety, 97*(2).

Marine Accident Investigation Branch, UK. (1997). Lack of Lookout Leads to Collision in Fog . *Digest of safety, 97* (2).

Marine Accident Investigation Branch, UK. (1998). Collision between a Fast Ferry and a Fishing Vessel. *Digest of safe, 98* (1).

Marine Accident Investigation Branch, UK. (1999). A Collision and Near Miss in the North Sea. Dredgers Involved. *Digest of Safety*, *99* (2).

Marine Accident Investigation Branch, UK. (1999). Collision in Harbor between Dredger and Yacht. *Digest of Safety, 99*(3).

Marine Accident Investigation Branch, UK. (1999). Collision between Coaster and Fishing Vessel. *Digest of Safety, 99* (3).

Marine Accident Investigation Branch, UK. (1999). Collision between a Scalloper and an Angling Boat. *Digest of Safety*, *99*(3).

Marine Accident Investigation Branch, UK. (2000). Collision between Two Fishing Vessels. *Digest of Safety*, *Fishing 2000*.

Marine Accident Investigation Branch, UK. (2000). Lack of Lookout Leads to Collision in Fog. *Digest of Safety, Fishing 2000*.

Marine Accident Investigation Branch, UK. (2000). Small GRP Fishing Vessel Collides with Large Vehicle Carrier. *Digest of Safety, 2000* (1).

Australian Transportation Safety Bureau. (1983). *Konstantin Paustovskiy/ FV Bongaree. Report No 2*. Canberra: Author.

Australian Transportation Safety Bureau. (1984). *Flinders Range/fv Han Gil No 105,Report No 4*. Canberra: Author.

Australian Transportation Safety Bureau. (1984). *Yue Man/Charles H McKay, Report No 7*. Canberra: Author.

Australian Transportation Safety Bureau. (1985). *River Boyne/FV Babirusa, Report No 9*. Canberra: the Author.

Australian Transportation Safety Bureau. (1985). *Iron Cumberland/FV Saltfiord, Report No 10.* Canberra: Author.

Australian Transportation Safety Bureau. (1986). *Lysaght Endeavour/Grunter (Yacht), Report No 12.* Canberra: Author.

Australian Transportation Safety Bureau. (1987). *Great Brisbane/FV Naomi Maru, Report No 17.* Canberra: Author.

Australian Transportation Safety Bureau. (1990). *Metal Trader/FV Tammy-R, Report No 25*. Canberra: Author.

Australian Transportation Safety Bureau. (1990). *Iron Kembla/FV Kasuga Maru,Report No 26*. Canberra: the Author.

Australian Transportation Safety Bureau. (1991). *Jin Shan Hai/FV Kikenni, Report No 31*. Canberra: Author.

Australian Transportation Safety Bureau. (1991). Khudozhnik Ioganson / FV Zodiac, Report No 35. Canberra: the Author.

Australian Transportation Safety Bureau. . (1992). *Longevity/Blue Goose of Arne (Yacht), Report No 41*. Canberra: Author.

Australian Transportation Safety Bureau. (1992). *Antares/Champers, Report No 44.* Canberra: Author.

Australian Transportation Safety Bureau. (1992). *Libra/Sanko Heron, Report No 54*. Canberra: Author.

Australian Transportation Safety Bureau. (1992). FV *Ronda Lene/Fareast, Report No 49*. Canberra: Author.

Australian Transportation Safety Bureau. (1994). *Searoad Mersey / AM Vella, Report No 64*. Canberra: Author.

Australian Transportation Safety Bureau. (1994). *Iron Prince/fv Pisces, Report No 81*. Canberra: Author.

Australian Transportation Safety Bureau. (1996). *Bogasari Dua/Midas,Report, No 91*.Canberra: Author.

Australian Transportation Safety Bureau. (1996). *River Embley/Bronze Wing, report No 94*. Canberra: Author.

Australian Transportation Safety Bureau. (1996). *FV Galaxy/Alam Tenggiri, Report No. 98*. Canberra: Author.

Australian Transportation Safety Bureau. (1996). *Columbus Victoria/Sampet Hope, Report No. 102*. Canberra: Author.

Australian Transportation Safety Bureau. (1996). *FV Nimbus/Maersk Tapah, Report No 103*. Canberra: Author.

Australian Transportation Safety Bureau. (1996). *Ester J, Report No. 104*. Canberra: Author.

Australian Transportation Safety Bureau. . (1996). *GUMBET/F.V. MOONSHOT, Report No 106.* Canberra: Author.

Australian Transportation Safety Bureau. (1997). *RIVER EMBLEY/HMAS FREMANTLE, Report No 112*. Canberra: the Author.

Australian Transportation Safety Bureau. (1997). *FV Exterminator/Unisina, Report No. 116*. Canberra Author.

Australian Transportation Safety Bureau. (1997). River *Yarra/W J Trotter, Report No. 123.* Canberra: Author.

Australian Transportation Safety Bureau. (1998). *Teresa / Atlantis Two, Report No 125*. Canberra: Author.

Australian Transportation Safety Bureau. (1998). *Eternal Wind/FV Melina T, Report No. 131*. Canberra: Author.

Australian Transportation Safety Bureau. (1998). *Barrington, Report No 132*. Canberra: Author.

Australian Transportation Safety Bureau. (1999). *Craig The Pioneer and fishing vessel May Bell II, report No 151*. Canberra: the Author.

Australian Transportation Safety Bureau. (1999). *Ariake and the tug Redcliffe, Report No 153*. Canberra: the Author.

The transportation safety board of Canada. (1991). *Collision between the CCGS "GRIFFON" and the F.V. CAPTAIN K" -Long Point Bay, Lake Erie, 18 March 1991. Report Number M91C2004*. Quebec: Author.

The transportation safety board of Canada. (1991). *Collision between the "SIL VER ISLE" and the SERSOU" near Buoy M140 St. Lawrence River, Quebec, 12 April 1991. Report Number M91L3008*. Quebec: Author.

The transportation safety board of Canada. (1992). *Collision Between the Ferry "QUEEN OF ALBERNI" and the Bulk carrier "SHINWA MARU" Strait of Georgia, British Columbia. 12 March 1992. Report Number M92W1022*. Quebec: Author.

The transportation safety board of Canada. (1993). *Collision between the "AMELIA DESGAGNEs"and the "6E7221" St. Lawrence Seaway, Morrisburg, Ontario, 23 May 1992. Report Number M92L3008*. Quebec: Author.

The transportation safety board of Canada. (1993). *Collision Between the Tug-Barge Unit "ARCTIC AGLU"/"LINK 100" and the Fishing Vessel "BONA VISTA" Strait of Georgia, British Columbia, 21 July 1993. Report Number M93W1050*. Quebec: Author.

The transportation safety board of Canada. (1993). *Collision Between the Bulk Carrier "OAKBY"and the Seiner "PACIFIC CHALLENGER" Juan de Fuca Strait, British Columbia, 04 August 1993. Report Number M93W0007*. Quebec: Author.

The transportation safety board of Canada. (1993). *Collision Between the Bulk Carrier "SEALNES" and the Fishing Vessel "MR. FISSION" in the Approaches to Vancouver Harbour British Columbia, 19 December 1993, Report Number M93W0012*. Quebec: the Author.

The transportation safety board of Canada. (1994). *Collision Between the Loaded Bulk Carrier "FEDERAL OSLO" and the Fishing Vessel "SHELLEY DAWN II" approximately 83 miles south of Halifax, Nova Scotia. 10 April 1994. Report Number M94M0009*. Quebec: Author.

The transportation safety board of Canada. (1994). *Collision Between the Bulk Carriers "ALGONORTH" and "RIXTA OLDENDORFF" in the Canal de Beauharnois 02 August 1994. REPORT NUMBER M94L0021*. Quebec: Author.

The transportation safety board of Canada. (1994). *COLLISION between the passenger vessel "LOUIS JOLLIET" and the pleasure craft "MERLIN" Port of Quebec, Quebec, 24 August 1994. REPORT NUMBER M94L0024*. Quebec: Author.

The transportation safety board of Canada. (1995). *Collision Between the Canadian Sailing Vessel"MOONGLOW" and the Chilean Submarine "THOMSON" Off Sheringham Point, Juan de Fuca Strait British Columbia, 11 September 1994. REPORT NUMBER M94W0078*. Quebec: Author.

The transportation safety board of Canada. (1995). *Collision - Between the Bulk Carrier "ZIEMIA ZAMOJSKA" and the Ro-ro Cargo Ship "CICÉRO" in the Vicinity of Pointe du Lac Lac St. Pierre St. Lawrence River, Quebec. 12 April 1995. Report Number M95L0008*. Quebec: Author.

The transportation safety board of Canada. (1995). *Collision Between the U.S. Fishing Vessel "EAGLE" and the U.S. Rail Barge "AQUA TRAIN" Under Tow of the U.S. Tug "CRAIG FOSS" in Chatham Sound, British Columbia 28 May, 1995. Report Number M95W0021*. Quebec: Author.

The transportation safety board of Canada. (1995). *Collision Between the Container Ships "CAST BEAR" and "CANMAR EUROPE" on Lac St. Pierre, Quebec, 16 August 1995.Report Number M95L0070*. Quebec: Author.

The transportation safety board of Canada. (1995). *Collision Between the Fishing Vessel "ROXANA GLEN" and the Tug-Barge Unit "ARCTIC TAGLU"/"LINK) 100" Fraser River, British Columbia, 31 October 1995. Report Number M95W0187*. Quebec: Author.

The transportation safety board of Canada. (1996). Collision between the tug "BROCHU" and the oil tanker "JADE STAR" at Port-Cartier, Quebec, 22 August 1996, Report Number M96L0112. Quebec: Author.

The transportation safety board of Canada. (1996). *Collision Between The General Cargo Vessel "Mallard" and the Bulk Carrier "Canadian Enterprise" Below Lock No.1, Port Weller, Ontario, 25 November 1996. Report Number M96C0088*. Quebec: Author.

The transportation safety board of Canada. (1997). *Collision Between the Fishing Vessels "NAVEGANTE" and "TERESA MARIA" Near S.E. Shoal, Lake Erie, 09 September 1997. Report Number M97C0057*. Quebec: Author.

The transportation safety board of Canada. (1998). *Collision Between the Self-unloading Bulk Carrier "AGAWA CANYON" and the Tanker "EMERALD STAR" Sault*

Ste. Marie, Michigan, United States. 10 April 1998. Report Number M98F0039. Quebec: Author.

The transportation safety board of Canada. (1998). *Collision Between the Ferry "ANIK" and an Open Boat Ottawa River off Carillon, Quebec. 29 August 1998. Report Number M98L0120.* Quebec: Author.

The transportation safety board of Canada. (1998). *Collision Between The Fast Ferry Catamaran "INCAT 046" and the Fishing Boat "LADY MEGAN II" Yarmouth Harbour, Nova Scotia. 4 September 1998. Report Number M98M0061*. Quebec: Author.

The National Transportation Safety Board. (1999). *Collision between Panamanian Container Ship Ever Grade and U.S. Coast Guard Buoy Tender Cowslip, Columbia River near Astoria, Oregon, May 14, 1997. NTSB Report Number: MAB-99-01*. Washington: Author.

The National Transportation Safety Board. (1999). *Collision of Two Recreational Motorboats on the St. Croix River near Bayport, Minnesota, July 3, 1999. NTSB Report Number: MAB-01-01*. Washington: Author.

Hong Kong Marine Department. (1999). *Collision between "Prompt Win 1" and "93098" in water off Cheung Fat Estate, Tsing Yi Island on 10 January 1999*. Hong Kong: Author.

Hong Kong Marine Department. (1999). *Collision between " Xing Long" and "Quan Tai" 4 miles east of Ninepin Group on 6 March 1999.* Hong Kong: Author.

Swedish board of accident investigation. (1999). *Collision between the Swedish vessel MT Tärnsjö and the Russian vessel MV Amur-2524 on 6 February 1998 at Strömskär, C county, Sweden. Report S 1998:02e.* Stockholm: author.

Transport accident investigation commission of New Zealand. (1996). *Collision between the container vessel Sydney Express and the fishing trawler Maria Luisa, Wellington Heads, 29 December 1996.* Wellington: Author.

The following collision cases may be found from: Cahill, R.A. (1997). *Collisions and their causes* (2nd ed). Austin: Nautical Books.

1981. Hellenic Carrier/Lash Atlantic (USA/Greek), North Carolina Coast (pp. 21-22).

1981. Seiryu/Stena Freighter (Japanese/Cayman Islands). Cape San Antonio (pp.80-81).

1981. St. Louis/Kwai. (US/Hong Kong). Algeciras (pp.196-197).

1982. Blackthorn/Capricorn (USA). Tampa Bag: (pp76-79).

1982. Engedi/Acadia Forest (Israel/Liberian). Gulf of Mexico (pp.83-84).

1982. Filiatra Legacy/Monte Olivia. (Greek/German). Scheldt. (Pp.163-164.

1982. Petroship B/Frigo Las Palmas. (Liberian/Italian). Great Bitter Lake (pp.164-166).

1982. Potomac/Baani (USA. /Bangladesh). Strait of Florida. (Pp.82-83).

1983. Faethon/miaoulis (Greek). Piraeus (pp.132-133).

1984. Eglantine/Credo/Inez (French/Norwegian/Belgian. Dover Strait. (Pp.54-57).

1984. Tan/Iran (Cypriot/Iranian). Khor musa. Channel. (Pp.117-118).

1985 Glucometer II/St. Michael. (U.K./Dutch). English Channel. (pp.220-222)

1987 Regina D/Iran Nabuvat (Panamanian/Iranian) Scheldt River. (pp.133-135).

1987. Nordic Ferry/ San. Salvador (UK. / Spanish), Harwich Harbor. (Pp.49-50).

1987. Professor Vladimir Popov /Da ye .(Russian/Chinese). Port Said (pp.166-168).

1987. Ven Pet/Ven oil. Cope of Good Hope (pp.22-25).

1988. Algosoo/Prestigious (Canadian/Hong Kong). St. Lawrence Seaway. (Pp.148-149).

1988. Century Dawn/ Asian energy (Panamanian/Liberian). Singapore Strait .(pp57-58).

1988. Figaro/Camargue (Swedish/French). Galveston Bay. (Pp.149-151).

1988. John M/ Maloja 11 (Cyprus/Greek), St. Lawrence Seaway. (Pp.25-26).

1988. Wishing Star Van Noort (Anguilan/Dutch). North Puerto Rican Coast. (Pp58-60).

1989. Golden Polydinamos/Devotion. (Greek/Panamanian). Cristobal. P.C. (pp.101-104).

1990. M/T Faith//Tug Independence (Bahamas/US). Delaware Bay. (Pp.204-205)

1990. Rich Duke/Nedrill (Bahamas/Netherlands Antilles). Caribbean (pp.198-199)

1990. Shinoussa/chandy N/Hellespont Faith. (Greek/US/Liberian). Houston Ship Channel (pp.135-138).

1991. Koscierznal (hanjin Singapore (Polish7Korean). Bay of Biscay (p118-121).

1993 British Trent/ Western Winner (U.K./Panamanian). Wandelaar Pilot Station (pp.222-225)

1994. Hua Jin/ Henry Senior/Maunaloa (China/U.S.). Diamond Head (pp.206-207)

Appendix B

Questionnaire
Influences of Human Element on Collision at Sea

23 March, 2001

Dear Sir / Madam:

Thank you very much for your attention to this questionnaire.

According to some marine casualty statistics, more than 96 % of the marine accidents are connected with the human element. For safer shipping and cleaner seas, international organization such as IMO and various governments of maritime nations have already carried out a great mount of research and legislation work on this issue. International conventions and codes such as STCW, SOLAS, and ISM are results of that work, which are playing important roles in reducing the impacts of human errors on marine casualties. Although safety situation at sea has improved recently, marine accidents still happen every year and human elements are involved in casualties repeatedly. Further research work is needed.

In this research project, focus is placed on impacts of human element on marine casualties particularly on collision at sea. We need to identify the human factors that play a major role in collision accidents. We are requesting feedback to find out more effective measures and techniques to prevent the human error in collision avoidance from various maritime sectors worldwide.

Your opinions on human elements involved in ship collision and your recommendations on reducing the impacts of human error on collision accidents will be very valuable and helpful to this project. We need your help very much. Please compete this questionnaire with your valuable experience and return to me by 6 April, 2001. You are not only helping this project, but also helping us better understand how to achieve safer shipping and cleaner sea. Thank you again.

Liu zhengjiang
MSEP 2001
World Maritime University
P.O. Box 500
S-201 24
Malmö, Sweden
E-mail: s01025@wmu.se, or liuzhengjiang@hotmail.com

Questionnaire Influences of Human Element on Collision at Sea

Part 1. Respondent's Personal Particulars

Nationality ________________Language: □ English □ Non-English
(e.g. Chinese, American, Swedes, Danish, etc.)

Age : □ < 20 □ 20 - 30 □ 30 - 40 □ 40 - 50 □50 - 60 □ >60

Occupation: □ Staff of shipping company □ Seafarer

□Administration Officer (government) □ Staff of port

□ Other:__________________

Your job relates to: □ safety □economy □ other

Education level: □ Postgraduate □ University /Undergraduate

□ College Degree □ Other:__________________

Competence level: (for seafarers only)

□ Chief officer □ navigational watch officer
□ chief engineer □second engineer □ engineering watch officer
□ Master □ rating for engineering watch

Sea experience:(if have)

□ <1 year □ 1- 5 years □ 5- 10 years □ > 10 years

Collision /close quarters experience : □ yes □ no

Part 2 Most Probably Incidents

(Check one of the following which you think has the highest occurrence rate)

□ Collision/Contacts □ Capsizing □ Sinking/Foundering

□ Fire and Explosion □ Grounding □ damage Machinery

□ Other:_________________________

Questionnaire Influences of Human Element on Collision at Sea

Part 3 Human Elements Involved in Collision at Sea

(Circle a proper number following each item according to your opinion.)

1-very unlikely involved 2-unlikely involved 3-likely involved 4-very likely involved

Human Element	very-unlikely	unlikely	likely	very-likely
Error in judgment	1	2	3	4
Incompetence	1	2	3	4
Improper lookout	1	2	3	4
Use improper speed	1	2	3	4
Failure to take early action	1	2	3	4
Failure to comply with Regulations	1	2	3	4
Failure in good seamanship	1	2	3	4
Mismanoeuvre the ship	1	2	3	4
Misuse of radar and ARPA	1	2	3	4
Negligence or misconduct	1	2	3	4
Communication problem	1	2	3	4
Anxiety and fear	1	2	3	4
Overloading	1	2	3	4
Fatigue	1	2	3	4
Management problem	1	2	3	4
Violation	1	2	3	4
Drug and alcohol	1	2	3	4
Mental state	1	2	3	4

Questionnaire Influences of Human Element on Collision at Sea

Part 4 Measures Lessening the Influence of Human Elements

(Check the item you agree. Please make more recommendations and comments if you like.)

□ Enforce training (seafarers and shore staff) on both skill and knowledge

□ Upgrade and update the relevant knowledge (nautical and management) in time

□ Enhance the international cooperation on technical (e.g. training, research work) issues

□ Amend, establish and put in order the international conventions and national legislation

□ improve the management both ashore and on board ship

□ Improve ship design

□ Equip the ship with more automated instruments and systems

□ Promote and support research work on human elements

□ other:____

Your recommendations or comments:

Appendix C

Experts and Seafarers' Views on The Involvement of Human Elements in Collision at Sea

Membership Grade of Human Elements Involved (Chinese)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	17	85	141	51	0.69
Error of Judgment	0	27	144	124	0.83
Improper Lookout	2	24	131	136	0.84
Unsafe Speed	15	74	149	56	0.71
Late Action	1	21	157	114	0.83
Failure to Comply with Regulation	4	56	170	60	0.75
Improper ship handling	6	35	174	77	0.78
Misuse Radar and ARPA	15	77	165	36	0.69
Failure to Comply with GS.	13	67	183	31	0.70
Communication Problem	20	106	140	22	0.64
Mental State	22	85	124	43	0.67
Anxiety and Fear	24	99	148	19	0.64
Health Unfitness	44	139	89	7	0.55
Overloading	17	110	120	42	0.66
Fatigue	7	38	162	75	0.77
Management Problem	17	73	151	50	0.70
Violation	203	65	14	8	0.35
Drug and Alcohol	2	7	3	0	0.52

Note:

GS: Good Seamanship
Ad.O.: Administration officer
CQS: Close-quarters Situation
C.M.: Chief mate
N.M. : Navigation officer
Developed N.: Developed nationalities including west European and American.

Membership Grade of Human Elements Involved (developed nationalities)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	2	5	13	3	0.68
Error of Judgment	1	1	5	15	0.89
Improper Lookout	2	1	9	11	0.82
Unsafe Speed	3	5	9	5	0.68
Late Action	0	1	12	10	0.85
Failure to Comply with Regulation	1	2	11	7	0.79
improper ship handling	2	5	10	5	0.70
Misuse Radar and ARPA	1	3	13	4	0.74
Failure to Comply with GS:	4	8	6	4	0.61
Communication Problem	0	5	10	6	0.76
Mental State	4	7	5	6	0.65
Anxiety and Fear	5	13	2	1	0.49
Health Unfitness	4	13	2	1	0.50
Overloading	3	8	6	4	0.63
Fatigue	0	4	10	9	0.80
Management Problem	3	3	13	4	0.70
Violation	15	6	0	1	0.35
Drug and Alcohol	5	7	5	2	0.55

Membership Grade of Human Elements Involved (other nationalities)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	6	16	33	10	0.68
Error of Judgment	3	3	32	27	0.82
Improper Lookout	2	6	34	23	0.80
Unsafe Speed	2	13	37	13	0.73
Late Action	0	5	32	29	0.84
Failure to Comply with Regulation	2	11	33	18	0.76
Improper ship handling	1	16	34	14	0.73
Misuse Radar and ARPA	1	25	38	3	0.66
Failure to Comply with GS	5	12	27	19	0.74
Communication Problem	2	12	36	14	0.74
Mental State	0	14	34	16	0.76
Anxiety and Fear	7	26	20	9	0.63
Health Unfitness	14	21	16	1	0.52
Overloading	6	23	17	12	0.65
Fatigue	1	7	31	24	0.81
Management Problem	5	23	28	8	0.65
Violation	34	20	7	2	0.41
Drug and Alcohol	9	10	24	9	0.66

Comparison of Membership Grade of Human Elements Involved (Based on Nationalities)				
	Chinese	Developed N.	Other Nationalities	
Incompetence	0.69	0.68	0.68	
Error of Judgment	0.83	0.89	0.82	
Improper Lookout	0.84	0.82	0.8	
Unsafe Speed	0.71	0.68	0.73	
Late Action	0.83	0.85	0.84	
Failure to Comply with Regulation	0.75	0.79	0.76	
Improper ship handling	0.78	0.7	0.73	
Misuse Radar and ARPA	0.69	0.74	0.66	
Failure to Comply with GS.	0.7	0.61	0.74	
Communication Problem	0.64	0.76	0.74	
Mental State	0.67	0.65	0.76	
Anxiety and Fear	0.64	0.49	0.63	
Health Unfitness	0.55	0.5	0.52	
Overloading	0.66	0.63	0.65	
Fatigue	0.77	0.8	0.81	
Management Problem	0.7	0.7	0.65	
Violation	0.35	0.35	0.41	
Drug and Alcohol	0.52	0.55	0.66	

Membership Grade of Human Elements Involved seafarers)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	20	71	104	32	0.66
Error of Judgment	4	25	104	93	0.82
Improper Lookout	5	22	101	100	0.82
Unsafe Speed	16	64	100	44	0.69
Late Action	3	19	106	91	0.83
Failure to Comply with Regulation	4	50	130	43	0.73
Improper ship handling	9	31	124	58	0.76
Misuse Radar and ARPA	13	64	124	22	0.67
Failure to Comply with GS.	10	60	125	28	0.69
Communication Problem	18	85	94	25	0.64
Mental State	18	54	76	33	0.67
Anxiety and Fear	24	74	105	18	0.63
Health Unfitness	39	94	58	10	0.55
Overloading	16	81	86	43	0.67
Fatigue	8	31	112	70	0.78
Management Problem	18	68	102	35	0.67
Violation	162	47	11	8	0.35
Drug and Alcohol	9	6	5	4	0.54

Membership Grade of Human Elements Involved (Maritime Administrators)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	5	21	40	16	0.70
Error of Judgment	1	4	40	39	0.85
Improper Lookout	1	3	36	34	0.85
Unsafe Speed	1	11	50	20	0.77
Late Action	0	3	39	43	0.87
Failure to Comply with Regulation	0	13	46	23	0.78
Improper ship handling	1	16	47	21	0.76
Misuse Radar and ARPA	4	25	43	10	0.68
Failure to Comply with GS.	6	17	38	18	0.72
Communication Problem	6	22	40	11	0.68
Mental State	3	14	21	7	0.68
Anxiety and Fear	10	37	26	8	0.60
Health Unfitness	18	39	23	3	0.53
Overloading	6	42	21	10	0.61
Fatigue	0	13	44	25	0.79
Management Problem	3	17	47	17	0.73
Violation	51	25	4	1	0.36
Drug and Alcohol	7	13	12	5	0.60

Membership Grade of Human Elements Involved (Staff of Shipping Company)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	1	2	4	3	0.73
Error of Judgment	1	1	7	2	0.73
Improper Lookout	0	1	3	7	0.89
Unsafe Speed	0	5	5	1	0.66
Late Action	0	1	8	2	0.77
Failure to Comply with Regulation	0	1	6	5	0.83
Improper ship handling	0	4	5	4	0.75
Misuse Radar and ARPA	0	3	7	1	0.70
Failure to Comply with GS.	0	3	6	1	0.70
Communication Problem	1	4	7	0	0.63
Mental State	0	3	3	0	0.63
Anxiety and Fear	2	5	3	0	0.53
Health Unfitness	2	6	0	0	0.44
Overloading	2	6	1	1	0.53
Fatigue	0	3	7	1	0.70
Management Problem	1	4	4	1	0.63
Violation	7	3	0	0	0.33
Drug and Alcohol	0	2	2	1	0.70

Membership Grade of Human Elements Involved (Other Personnel's)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	2	13	39	21	0.76
Error of Judgment	0	5	34	37	0.86
Improper Lookout	1	4	39	31	0.83
Unsafe Speed	3	14	46	12	0.72
Late Action	0	4	46	24	0.82
Failure to Comply with Regulation	1	8	46	19	0.78
Improper ship handling	1	7	48	18	0.78
Misuse Radar and ARPA	2	14	50	26	0.77
Failure to Comply with GS.	2	8	52	10	0.74
Communication Problem	1	16	49	11	0.73
Mental State	0	14	27	5	0.70
Anxiety and Fear	7	22	41	5	0.65
Health Unfitness	5	38	30	1	0.59
Overloading	3	25	38	8	0.67
Fatigue	0	11	39	24	0.79
Management Problem	4	13	42	16	0.73
Violation	36	26	8	5	0.44
Drug and Alcohol	4	14	8	3	0.59

Comparison of Membership Grade of Human Elements Involved (Based on Occupation)					
	Seafarers	Ad.O	SSC	Other	
Incompetence	0.66	0.7	0.73	0.76	
Error of Judgment	0.81	0.85	0.73	0.86	
Improper Lookout	0.84	0.85	0.89	0.83	
Unsafe Speed	0.69	0.77	0.66	0.72	
Late Action	0.83	0.87	0.77	0.82	
Failure to Comply with Regulation	0.73	0.78	0.83	0.78	
Improper ship handling	0.76	0.76	0.75	0.78	
Misuse Radar and ARPA	0.67	0.68	0.7	0.77	
Failure to Comply with GS.	0.69	0.72	0.7	0.74	
Communication Problem	0.64	0.68	0.64	0.73	
Mental State	0.67	0.68	0.64	0.7	
Anxiety and Fear	0.63	0.6	0.53	0.65	
Health Unfitness	0.55	0.53	0.54	0.59	
Overloading	0.67	0.61	0.53	0.67	
Fatigue	0.78	0.79	0.7	0.79	
Management Problem	0.67	0.73	0.63	0.73	
Violation	0.35	0.36	0.32	0.44	
Drug and Alcohol	0.54	0.6	0.7	0.59	

Membership Grade of Human Elements Involved (Post Graduates)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	1	15	40	11	0.73
Error of Judgment	0	5	42	30	0.83
Improper Lookout	0	3	39	26	0.83
Unsafe Speed	0	14	43	10	0.74
Late Action	0	5	38	24	0.82
Failure to Comply with Regulation	0	5	42	20	0.81
Improper ship handling	0	10	46	12	0.76
Misuse Radar and ARPA	1	25	39	13	0.71
Failure to Comply with GS.	1	13	43	9	0.73
Communication Problem	0	16	45	6	0.71
Mental State	1	8	18	3	0.69
Anxiety and Fear	5	26	32	3	0.63
Health Unfitness	8	36	23	0	0.56
Overloading	4	27	28	5	0.63
Fatigue	0	8	42	17	0.78
Management Problem	1	16	42	7	0.71
Violation	33	24	6	2	0.41
Drug and Alcohol	5	17	13	2	0.58

Membership Grade of Human Elements Involved(University)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	5	33	51	24	0.71
Error of Judgment	2	10	44	57	0.85
Improper Lookout	3	5	52	53	0.84
Unsafe Speed	4	20	64	25	0.74
Late Action	0	10	57	47	0.83
Failure to Comply with Regulation	1	18	62	31	0.77
Improper ship handling	1	20	52	30	0.77
Misuse Radar and ARPA	4	25	66	18	0.72
Failure to Comply with GS.	3	22	67	18	0.73
Communication Problem	8	31	58	16	0.68
Mental State	3	77	36	7	0.60
Anxiety and Fear	14	39	48	10	0.62
Health Unfitness	17	54	27	3	0.54
Overloading	10	46	39	13	0.63
Fatigue	3	17	712	22	0.75
Management Problem	11	26	56	20	0.69
Violation	71	33	6	2	0.36
Drug and Alcohol	3	6	10	6	0.69

Membership Grade of Human Elements Involved (College)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	9	24	35	17	0.68
Error of Judgment	2	6	41	36	0.83
Improper Lookout	3	10	34	39	0.82
Unsafe Speed	6	21	39	15	0.69
Late Action	2	3	40	41	0.85
Failure to Comply with Regulation	2	13	51	17	0.75
Improper ship handling	7	12	42	20	0.73
Misuse Radar and ARPA	7	21	44	9	0.67
Failure to Comply with GS	16	23	39	13	0.63
Communication Problem	4	29	35	13	0.68
Mental State	7	17	20	12	0.67
Anxiety and Fear	10	29	37	6	0.62
Health Unfitness	13	38	17	4	0.54
Overloading	5	36	26	15	0.66
Fatigue	1	12	37	33	0.81
Management Problem	3	22	38	19	0.72
Violation	55	19	4	4	0.37
Drug and Alcohol	6	4	3	2	0.52

Membership Grade of Human Elements Involved(Vacational School and other)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	10	34	62	12	0.66
Error of Judgment	0	11	42	43	0.83
Improper Lookout	0	12	51	53	0.84
Unsafe Speed	10	38	50	23	0.68
Late Action	1	9	64	42	0.82
Failure to Comply with Regulation	2	34	51	30	0.73
Improper ship handling	2	14	72	31	0.78
Misuse Radar and ARPA	5	33	61	15	0.69
Failure to Comply with GS.	2	32	68	12	0.70
Communication Problem	11	46	50	7	0.62
Mental State	11	33	49	21	0.68
Anxiety and Fear	18	42	20	10	0.56
Health Unfitness	25	47	41	2	0.54
Overloading	6	36	50	24	0.70
Fatigue	4	10	67	37	0.79
Management Problem	9	34	60	16	0.67
Violation	92	16	5	3	0.33
Drug and Alcohol	3	2	4	1	0.58

Comparison of Membership Grade of Human Elements Involved(Based on Education Level)					
	Post Graduate	University	College	Vocational and other	
Incompetence	0.73	0.71	0.68	0.66	
Error of Judgment	0.83	0.85	0.83	0.83	
Improper Lookout	0.83	0.84	0.82	0.84	
Unsafe Speed	0.73	0.74	0.69	0.68	
Late Action	0.82	0.83	0.85	0.82	
Failure to Comply with Regulation	0.81	0.77	0.75	0.73	
Improper ship handling	0.76	0.77	0.73	0.78	
Misuse Radar and ARPA	0.71	0.72	0.67	0.69	
Failure to Comply with GS.	0.73	0.72	0.63	0.7	
Communication Problem	0.71	0.68	0.68	0.62	
Mental State	0.69	0.6	0.67	0.68	
Anxiety and Fear	0.63	0.62	0.62	0.56	
Health Unfitness	0.56	0.54	0.54	0.54	
Overloading	0.63	0.63	0.66	0.7	
Fatigue	0.78	0.75	0.81	0.79	
Management Problem	0.71	0.69	0.72	0.67	
Violation	0.41	0.36	0.37	0.33	
Drug and Alcohol	0.58	0.69	0.51	0.58	

Membership Grade of Human Elements Involved(No Sea Experience)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	1	8	14	4	0.69
Error of Judgment	0	1	14	13	0.86
Improper Lookout	0	3	13	11	0.82
Unsafe Speed	0	6	17	4	0.73
Late Action	0	4	13	10	0.81
Failure to Comply with Regulation	0	3	14	10	0.81
Improper ship handling	0	6	14	7	0.76
Misuse Radar and ARPA	1	8	15	3	0.69
Failure to Comply with GS.	1	3	15	7	0.77
Communication Problem	2	3	15	8	0.76
Mental State	0	1	3	1	0.75
Anxiety and Fear	3	12	8	4	0.62
Health Unfitness	3	11	12	1	0.60
Overloading	3	12	11	1	0.59
Fatigue	0	3	13	11	0.82
Management Problem	2	7	14	4	0.69
Violation	6	16	4	1	0.50
Drug and Alcohol	2	2	7	6	0.75

Membership Grade of Human Elements Involved(Less than 5 years)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	7	29	60	18	0.70
Error of Judgment	1	10	53	55	0.84
Improper Lookout	2	9	45	62	0.85
Unsafe Speed	4	26	61	29	0.74
Late Action	1	14	57	36	0.80
Failure to Comply with Regulation	2	26	60	29	0.75
Improper ship handling	3	21	75	27	0.75
Misuse Radar and ARPA	7	37	63	10	0.66
Failure to Comply with GS.	10	27	68	15	0.68
Communication Problem	10	46	51	7	0.62
Mental State	8	36	37	8	0.63
Anxiety and Fear	12	50	55	7	0.61
Health Unfitness	17	56	30	2	0.54
Overloading	5	47	42	23	0.68
Fatigue	2	12	66	39	0.80
Management Problem	9	35	52	14	0.66
Violation	89	25	2	2	0.32
Drug and Alcohol	1	7	6	2	0.64

Membership Grade of Human Elements Involved(5-10 years)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	10	32	51	25	0.69
Error of Judgment	0	12	51	51	0.84
Improper Lookout	0	7	52	56	0.86
Unsafe Speed	11	28	54	20	0.68
Late Action	0	2	62	48	0.85
Failure to Comply with Regulation	1	19	64	31	0.77
Improper ship handling	2	14	63	32	0.78
Misuse Radar and ARPA	4	23	73	14	0.71
Failure to Comply with GS.	3	25	64	19	0.72
Communication Problem	8	39	50	16	0.66
Mental State	11	24	42	18	0.68
Anxiety and Fear	10	38	49	10	0.64
Health Unfitness	15	56	32	3	0.55
Overloading	9	44	41	17	0.65
Fatigue	1	21	54	37	0.78
Management Problem	5	30	60	27	0.72
Violation	81	17	9	7	0.37
Drug and Alcohol	0	4	6	3	0.73

Membership Grade of Human Elements Involved(More than 10 years)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	7	32	59	14	0.68
Error of Judgment	3	8	57	43	0.82
Improper Lookout	4	9	58	40	0.80
Unsafe Speed	5	30	57	18	0.70
Late Action	2	7	61	42	0.82
Failure to Comply with Regulation	1	19	71	16	0.74
Improper ship handling	5	25	63	26	0.73
Misuse Radar and ARPA	6	27	58	10	0.68
Failure to Comply with GS.	8	30	60	12	0.67
Communication Problem	2	32	60	13	0.70
Mental State	4	18	35	15	0.71
Anxiety and Fear	11	33	54	8	0.64
Health Unfitness	26	35	31	3	0.53
Overloading	7	37	47	15	0.67
Fatigue	5	11	64	31	0.77
Management Problem	8	26	64	13	0.68
Violation	70	30	6	1	0.36
Drug and Alcohol	11	7	8	1	0.49

Comparison of Membership Grade of Human Elements Involved (Based on Sea Experience)					
	No S.E.	< 5 years	5-10 ys	>10 ys	
Incompetence	0.69	0.7	0.69	0.68	
Error of Judgment	0.86	0.84	0.84	0.82	
Improper Lookout	0.82	0.85	0.86	0.8	
Unsafe Speed	0.73	0.74	0.68	0.7	
Late Action	0.81	0.8	0.85	0.82	
Failure to Comply with Regulation	0.81	0.75	0.77	0.74	
Improper ship handling	0.76	0.75	0.78	0.73	
Misuse Radar and ARPA	0.69	0.66	0.71	0.68	
Failure to Comply with GS	0.77	0.68	0.72	0.67	
Communication Problem	0.76	0.62	0.66	0.7	
Mental State	0.75	0.63	0.68	0.71	
Anxiety and Fear	0.62	0.61	0.64	0.64	
Health Unfitness	0.6	0.54	0.55	0.53	
Overloading	0.59	0.68	0.65	0.67	
Fatigue	0.82	0.8	0.78	0.77	
Management Problem	0.89	0.66	0.72	0.68	
Violation	0.5	0.32	0.37	0.36	
Drug and Alcohol	0.75	0.64	0.73	0.49	

Membership Grade of Human Elements Involved (Master)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	1	17	33	13	0.73
Error of Judgment	1	4	26	33	0.86
Improper Lookout	2	2	30	31	0.85
Unsafe Speed	3	9	39	13	0.74
Late Action	0	2	37	26	0.84
Failure to Comply with Regulation	1	13	32	16	0.75
Improper ship handling	2	13	31	17	0.75
Misuse Radar and ARPA	4	16	36	8	0.69
Failure to Comply with GS.	6	14	30	13	0.70
Communication Problem	2	21	31	10	0.69
Mental State	3	9	19	3	0.66
Anxiety and Fear	7	24	27	5	0.62
Health Unfitness	10	31	16	1	0.53
Overloading	6	27	21	9	0.63
Fatigue	7	10	33	19	0.73
Management Problem	4	14	37	9	0.70
Violation	43	16	3	2	0.36
Drug and Alcohol	9	8	6	12	0.65

Membership Grade of Human Elements Involved (Chief Mate)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	2	12	15	7	0.69
Error of Judgment	1	3	9	23	0.88
Improper Lookout	1	1	11	23	0.89
Unsafe Speed	2	10	14	10	0.72
Late Action	1	2	16	18	0.84
Failure to Comply with Regulation	0	6	19	11	0.78
Improper ship handling	1	5	15	15	0.81
Misuse Radar and ARPA	0	7	23	6	0.74
Failure to Comply with GS.	0	6	20	9	0.77
Communication Problem	1	11	17	7	0.71
Mental State	1	6	13	4	0.71
Anxiety and Fear	2	14	16	4	0.65
Health Unfitness	8	15	8	1	0.52
Overloading	1	13	15	7	0.69
Fatigue	2	4	19	11	0.77
Management Problem	4	9	13	9	0.69
Violation	24	7	2	2	0.37
Drug and Alcohol	0	3	1	3	0.75

Membership Grade of Human Elements Involved (Navigation Mate)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	5	26	45	18	0.70
Error of Judgment	1	5	44	45	0.85
Improper Lookout	2	4	39	50	0.86
Unsafe Speed	9	31	36	17	0.66
Late Action	1	7	45	42	0.84
Failure to Comply with Regulation	3	11	62	17	0.75
Improper ship handling	0	8	59	26	0.80
Misuse Radar and ARPA	4	27	51	16	0.70
Failure to Comply with GS.	3	18	63	9	0.71
Communication Problem	4	32	52	5	0.66
Mental State	3	28	38	13	0.69
Anxiety and Fear	11	28	43	9	0.64
Health Unfitness	15	53	11	5	0.52
Overloading	7	40	29	16	0.65
Fatigue	4	9	46	26	0.78
Management Problem	10	20	40	22	0.70
Violation	64	20	5	2	0.35
Drug and Alcohol	0	0	3	2	0.85

Membership Grade of Human Elements Involved (Other personnel)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	17	45	90	22	0.67
Error of Judgment	1	19	93	61	0.81
Improper Lookout	1	20	86	54	0.80
Unsafe Speed	5	38	99	32	0.73
Late Action	0	15	92	63	0.82
Failure to Comply with Regulation	1	37	93	39	0.75
Improper ship handling	7	30	101	34	0.74
Misuse Radar and ARPA	9	46	99	13	0.67
Failure to Comply with GS.	13	45	95	21	0.68
Communication Problem	15	56	76	20	0.65
Mental State	13	39	46	22	0.66
Anxiety and Fear	16	54	79	10	0.63
Health Unfitness	28	65	65	2	0.56
Overloading	10	60	68	28	0.67
Fatigue	0	24	97	52	0.79
Management Problem	6	51	96	19	0.69
Violation	11	35	11	1	0.51
Drug and Alcohol	7	9	19	6	0.65

Comparison of Membership Grade of Human Elements Involved Based on Competence Level					
	Master	C.M.	N.M.	Other	
Incompetence	0.73	0.69	0.7	0.68	
Error of Judgment	0.86	0.88	0.85	0.81	
Improper Lookout	0.85	0.89	0.86	0.8	
Unsafe Speed	0.74	0.72	0.66	0.73	
Late Action	0.84	0.84	0.84	0.82	
Failure to Comply with Regulation	0.75	0.78	0.75	0.75	
Improper ship handling	0.75	0.81	0.8	0.74	
Misuse Radar and ARPA	0.69	0.74	0.7	0.67	
Failure to Comply with GS.	0.7	0.77	0.71	0.68	
Communication Problem	0.69	0.71	0.66	0.65	
Mental State	0.66	0.71	0.69	0.66	
Anxiety and Fear	0.62	0.65	0.64	0.63	
Health Unfitness	0.53	0.52	0.52	0.56	
Overloading	0.63	0.69	0.65	0.67	
Fatigue	0.73	0.77	0.78	0.79	
Management Problem	0.7	0.69	0.7	0.69	
Violation	0.36	0.37	0.35	0.51	
Drug and Alcohol	0.65	0.75	0.85	0.65	

Membership Grade of Human Elements Involved (No Collision/CQS Experience)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	21	72	114	38	0.67
Error of Judgment	4	27	118	95	0.81
Improper Lookout	5	25	110	104	0.82
Unsafe Speed	11	68	120	45	0.70
Late Action	0	21	126	97	0.83
Failure to Comply with Regulation	3	51	126	60	0.75
Improper ship handling	7	43	133	68	0.76
Misuse Radar and ARPA	7	78	130	25	0.68
Failure to Comply with GS.	14	63	126	40	0.70
Communication Problem	17	82	107	31	0.66
Mental State	12	58	61	29	0.67
Anxiety and Fear	19	100	98	22	0.63
Health Unfitness	37	105	72	5	0.55
Overloading	19	86	86	43	0.66
Fatigue	5	31	127	80	0.79
Management Problem	18	70	118	35	0.68
Violation	160	60	12	7	0.36
Drug and Alcohol	7	14	20	11	0.67

Membership Grade of Human Elements Involved(With Collision/CQS Experience)					
	Very unlikely	Unlikely	Likely	Very likely	Membership Grade
Incompetence	4	34	73	26	0.72
Error of Judgment	0	4	62	71	0.87
Improper Lookout	1	6	64	66	0.86
Unsafe Speed	9	24	75	29	0.73
Late Action	1	6	75	56	0.84
Failure to Comply with Regulation	4	19	88	25	0.75
Improper ship handling	2	13	85	38	0.79
Misuse Radar and ARPA	10	27	84	18	0.70
Failure to Comply with GS.	8	24	90	14	0.70
Communication Problem	5	41	79	11	0.68
Mental State	10	27	63	14	0.68
Anxiety and Fear	17	38	72	7	0.63
Health Unfitness	25	68	35	4	0.53
Overloading	7	55	57	15	0.65
Fatigue	3	18	76	28	0.76
Management Problem	7	34	74	27	0.71
Violation	92	31	9	3	0.36
Drug and Alcohol	7	3	9	9	0.68
Comparison of Membership Grade of Human Elements Involved(collision/CQS Experience)					
	No	Yes			
Incompetence	0.67	0.72			
Error of Judgment	0.81	0.87			
Improper Lookout	0.82	0.86			
Unsafe Speed	0.7	0.73			
Late Action	0.83	0.84			
Failure to Comply with Regulation	0.75	0.75			
Improper ship handling	0.76	0.79			
Misuse Radar and ARPA	0.68	0.7			
Failure to Comply with GS.	0.7	0.7			
Communication Problem	0.66	0.68			
Mental State	0.67	0.68			
Anxiety and Fear	0.63	0.63			
Health Unfitness	0.55	0.53			
Overloading	0.66	0.65			
Fatigue	0.79	0.76			
Management Problem	0.68	0.71			
Violation	0.36	0.36			
Drug and Alcohol	0.67	0.68			

Appendix D

Expert and Seafarer Views on Countermeasures against the Involvement of Human Elements in Collision at Sea

Experts and seafarer's view on assumed measure	
Assumed measures	Percentage of confirm
Enforce training and education	82
Update knowledge	66
Cooperation on technical issues	54
Legislation	42
Improve management	68
Improve ship design	31
Automated equipment	51
Safe manning	63
Quality system	59
enforce research work	69

Comparison of views on assumed measures based on nationality			
Assumed measures	Percentage of respondents with "yes"		
	Chinese	Developed N.	Other
Enforce training and education	84	70	79
Update knowledge	65	65	73
Cooperation on technical issues	53	43	59
Legislation	44	30	39
Improve management	67	70	71
Improve ship design	30	30	39
Automated equipment	57	22	35
Safe manning	61	61	73
Quality system	56	70	71
Enforce research work	68	74	74

Comparison of views on assumed measures based on occupation				
Assumed measures	Percentage of respondents with "yes"			
	Seafarers	SSC.	Ad. O.	Other
Enforce training and education	83	83	93	77
Update knowledge	67	75	73	68
Cooperation on technical issues	59	42	59	43
Legislation	51	25	33	32
Improve management	72	83	78	61
Improve ship design	38	8	23	33
Automated equipment	66	33	39	35
Safe manning	70	33	59	43
Quality system	62	58	62	44
Enforce research work	69	75	76	72

Comparison of views on assumed measures based on education level				
Assumed measures	Percentage of respondents with "yes"			
	Post graduate	University	College	Other
Enforce training and education	86	87	74	83
Update knowledge	77	72	57	62
Cooperation on technical issues	43	55	52	60
Legislation	30	44	44	47
Improve management	68	72	63	68
Improve ship design	26	35	27	32
Automated equipment	55	51	34	68
Safe manning	54	61	58	69
Quality system	58	59	57	62
Enforce research work	48	72	73	59

Comparison of views on assumed measures based on competence level				
Assumed measures	Percentage of respondents with "yes"			
	Master	Chief mate	Nav. mate	Other
Enforce training and education	74	79	90	75
Update knowledge	67	72	66	60
Cooperation on technical issues	47	59	58	49
Legislation	36	44	43	42
Improve management	59	41	80	67
Improve ship design	29	23	43	28
Automated equipment	42	58	60	48
Safe manning	53	59	56	52
Quality system	56	38	60	58
Enforce research work	73	43	74	59

Comparison of views on assumed measures based on sea experience				
Assumed measures	Percentage of respondents with "yes"			
	No	Less than 5 years	5-10 years	> 10 years
Enforce training and education	81	77	81	81
Update knowledge	78	60	65	67
Cooperation on technical issues	44	55	54	52
Legislation	38	39	44	41
Improve management	75	65	70	64
Improve ship design	17	34	30	27
Automated equipment	28	55	57	47
Safe manning	56	65	57	60
Quality system	50	58	54	61
Enforce research work	66	64	70	69

Comparison of views on assumed measures based on experience of collision/close-quarters situation		
Assumed measures	Percentage of respondents with "yes"	
	Yes	No
Enforce training and education	87	80
Update knowledge	70	67
Cooperation on technical issues	49	57
Legislation	37	50
Improve management	67	69
Improve ship design	22	36
Automated equipment	46	54
Safe manning	55	63
Quality system	57	61
Enforce research work	67	69