IMPACT OF AUTOMATIC IDENTIFICATION SYSTEM (AIS) ON SAFETY OF MARINE NAVIGATION

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Abstract

Automatic Identification System (AIS) was introduced with the overall aim to promote efficiency and safety of navigation, protection of environment, and safety of life at sea. Consequently, ship-borne AIS was implemented on a mandatory basis by IMO in 2000 and later amendments to chapter V of Safety of Life at Sea (SOLAS) Convention. Therefore SOLAS Convention vessels were required to carry AIS in a phased approach, from 1st July 2002 to end of December 2004. The intention is to provide more precise information and a clear traffic view in navigation operations, particularly in anti-collision operation. This mandatory implementation of AIS has raised a number of issues with respect to its success in fulfilment of the intended role.

In order to improve the efficiency of the AIS in navigation operation, this research mainly focused on the accuracy of AIS information, and practical use of the technology on board the ships. The intentions were to assess reliability of data, level of human failure associated with AIS, and the degree of actual use of the technology by navigators.

This research firstly provided impressions about AIS technology for anti-collision operation and other marine operation and, about a system's approach to the issue of human failure in marine risk management. Secondly, this research has assessed reliability of AIS data by examination of data collected through three AIS data studies. Thirdly, it has evaluated navigators' attitude and behaviour to AIS usage by analysing the data from navigators' feedback collected through the AIS questionnaire survey focused on their perceptions about different aspects of AIS related to its use.

This research revealed that some aspects of the AIS technology and some features of its users need further attention and improvement, so as to achieve its intended objectives in navigation.

This study finally contributed in proposing the AIS User Satisfaction Model as a suitable framework for evaluation of navigators' satisfaction and extent of the use of AIS. This model can probably be used as the basis for measuring navigators' attitude and behaviour about other similar maritime technologies.

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Dedication

To my late younger brother *Ahmad*, his wife *Samineh*, and their dear little daughter *Elaheh* who all passed away in a tragic car accident during the course of this research.

Abbreviations

A to N	Aids to Navigation
A	Attitude
ABSA	American Bureau of Shipping
AIS	Automatic Identification System
AISUS	AIS User Satisfaction
ANOVA	Analysis of Variance
ARPA	Automatic Radar Plotting Aid
B	Behaviour
C/L	Centre Line
CNIS	Channel Navigation Information Service
COG	Course Over Ground
COLREG	Collision Regulations
CPA	Closest Point of Approach
CSTDMA	Carrier-Sense Time Division Multiple Access
DGNSS	Differential Global Navigation Satellite System
DGPS	Differential Global Positioning System
DSC	Digital Selective Calling
DV	Dependent Variable
EC	European Commission
ECDIS	Electronic Chart Display and Information System
ECS	Electronic Chart System
ETA	Estimated Time of Arrival
EUS	End User Satisfaction Model
FATDMA	Fixed Access Time Division Multiple Access
GEMS	Generic Error Modelling System
GPS	Global Positioning System
GRT	Gross Registered Tonnage
GSM	Global System for Mobile Communications
I	Intention
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IBS	Integrated Bridge System
IEC	International Electrotechnical Commission
IMO	International Maritime Organisation

INMARSAT	International Maritime Satellite
IRPCS	International Regulation for Preventing Collisions at Sea
ITDMA	Incremental Time Division Multiple Access
ITU	International Telecommunication Union
IV	Independent Variable
LAN	Local Area Network
LCD	Liquid Crystal Display
MAIB	Marine Accident Investigation Branch
MCA	Maritime and Coastguard Agency
MKD	Minimum Keyboard and Display
MMSI	Maritime Mobile Service Identity
MSC	Maritime Safety Committee
NAV	Sub-Committee on Safety of Navigation
OOW	Officer of the Watch
PC	Personal Computer
PEOU	Perceived Ease of Use
PPU	Personal Pilot Unit
PSF	Performance Shaping Factor
PU	Perceived Usefulness
RATDMA	Random Access Time Division Multiple Access
RCC	Rescue Co-Ordination Centre
RF	Radio Frequency
ROR	Rules of the Road
ROT	Rate of Turn
SAR	Search and Rescue
SE	Self-Efficacy
SN	Subjective Norm
SOG	Speed Over Ground
SOLAS	Safety of Life at Sea
SOTDMA	Self Organising Time Division Multiple Access
SPSS	Statistical Package for the Social Sciences
SQ	System Quality
SS-E	System Self-Efficacy
STCW	Standard of Training, Certification and Watchkeeping
TAISUS	Total AIS User Satisfaction
TAM	Technology Acceptance Model
TCPA	Time of Closest Point of Approach

TDMA	Time Division Multiple Access
TPB	Theory of Planned Behaviour
TPEOU	Total Perceived Ease of Use
TPU	Total Perceived Usefulness
TRA	Theory of Reasoned Action
TSE	Total Self-Efficacy
TSQ	Total System Quality
UK	United Kingdom
UN	United Nations
UTC	Coordinated Universal Time
V/L	Vessel
VDL	VHF Digital Link
VHF	Very High Frequency
VIF	Variance Inflation Factor
VTS	Vessel Traffic Services

Chapter 1

Introduction

1.1 Background

Maritime transport is playing a vital role in worldwide trade and economics as approximately more than 90% of the world trade volume is carried through waterborne transport (Harati-Mokhtari, 2001; IMO Library Service, 2006; The Round Table of International Shipping Association, 2007). Maritime transport in comparison with air, rail, and road transport with regards to its carrying capacity can be a better and more effective alternative mode of transport due to ability of handling higher volume and weight of the trade requirements of the global society. Marine navigation is a key element of the maritime transport and shipping industry. Therefore, safety of marine navigation operation has always been of paramount importance and great concern to the international and national regulatory and supervisory authorities and all other stakeholders in respect of safety of ship, life, and marine environment.

Cost reduction considerations strongly affect the marine industry as a whole and put the improvement of safety at risk in terms of manning (minimum and less expensive crews recruitment), training (crews with less education and training and level of competency recruitment), and equipment (minimum standard and less expensive equipment being installed on board ships).

Many technological advances have been introduced to the shipping industry. These include facilities for provision of more useful information on board ships, new or more advanced electronic navigation aids on the bridge, semi and fully automated control systems, improved accident investigation facilities, and more precise vessel identification systems. These technological innovation and advances are affecting the operation ashore and navigation practices on board ship.

According to the European Commission (EC) (2001a), the contribution of human errors and other human related factors to maritime accidents is about 70%. Many research projects and concerted actions were commissioned by the European Commission to provide the marine industry with safe and efficient navigation operation. Research into the introduction of innovative designed technology, and working practices for safer ship operation is one of the five areas of EC research. Assessing safety risks related to operational shortcomings, human failure and need for harmonised training and education, better use of simulators and modern training tools are some of the results highlighted by EC research projects (European Commission, 2001a).

New technologies are introduced in all areas of the marine industry, especially to the ship's bridge, to support most of the ship's operations. The main purpose of introducing such technologies is to improve the efficiency and safety of marine navigation, and pollution prevention (Goulielmos, and Tzannatos, 1997). However, achievement of the goals from technology implementation are not always as expected, and may sometimes be associated with unpredicted impacts, such as the negative impact on the end-users. Such negative impacts on the user may be due to human factors issues and new demands as a result of changes to working practices on board.

The Automatic Identification System (AIS) is a new technology implemented by the International Maritime Organisation (IMO) for ship-to-ship application, mainly for anti-collision operation and hence to improve the efficiency and safety of navigation. But its implementation has raised a number of issues that could influence its intended effectiveness (Leonard-Williams, 1999; Brown et al, 2001; Cobley, 2003; Bailey, 2005a; and Norris, 2006). Lack of understanding of human factors associated with the application of AIS technology may affect proper communication between navigators and technology on the ship's bridge, and therefore, it may cause improper or lack of use of the technology. Such problems may lead to, or even further assist in, accidents and incidents, similar to radar-assisted collisions in its early stages of introduction, such as the collision between *Hyundai Dominion* and *Sky Hope*, and the collision between *Amenity* and *Tor Dania* (Marine Accident Investigation (MAIB), 2005a, and 2005b).

This research focuses on the impact of AIS application on board ships for navigation with an outlook to human factors aspects of AIS, which will be discussed in more detail in the next section.

The literature review in chapter 2 shows that there is a little published in-depth research into the impact of AIS on safety of navigation and this project attempts to remedy this deficiency.

This chapter contains a brief introduction to this research, and covers the objectives and scope of the research in section 1.2. Sections 1.3 and 1.4 cover the methodology and structure of this thesis, respectively.

1.2 Aims and Objectives

Since safety at sea, and especially safety of navigation, is directly related to human element, there is a need for the systematic application of ergonomics and human factors in the maritime industry, especially when new technology is being introduced. Because ergonomics mainly focus on human-system interface, lack of its application in marine system design will increase chances for human error and accidents. Karwowski, ed (2001) mentioned:

> *"Ergonomics evolve from studying the Interactions between humans and their surrounding work environment (with environment defined broadly to include machines, tools, the ambient environment, tasks, etc.)."*

NAC (2000 cited in Widdowson, 2002) defines the human factors as:

> *"A professional discipline concerned with improving the integration of human issues into the analysis, design, development, implementation, and the operational use of work systems."*

This research focuses on new AIS technology introduced into the shipping industry to enhance safety of navigation by improving navigators' efficiency in anti-collision and other navigation operation.

Standardised Automatic Identification System (AIS) development is critically important to the marine industry in providing a similar information environment for navigational use in different localities. The International Maritime Organization (IMO), in cooperation with other organisations, has published operational and technical standards for AIS equipment (Transportation Research Board, 2003). AIS has the potential to provide many benefits to parties engaged in the marine industry, especially to navigators and shore-based authorities. IMO has endorsed mandatory carriage requirements of AIS technology for Safety of Life at Sea (SOLAS) Convention vessels in a revision made to the Convention (Graveson, 2003).

The functions identified by IMO for use of AIS are:

a) To assist in navigation operation as a collision avoidance tool in ship-to-ship mode.
b) To assist vessel surveillance and traffic management in ship-to-shore mode.

As AIS has quickly received the endorsement for mandatory carriage by IMO, a number of issues were raised about the effectiveness of the technology for the intended purposes. These issues include accuracy of the AIS data transmitted, human factors implication, current system design, their capabilities and limitations, integration with existing navigational aids, etc. These problems associated with AIS application could affect its impact on intentions for promotion of efficiency and safety of marine navigation, and safety of maritime transport as a whole. Therefore, there is a requirement for research in these areas, in order to find remedial actions to reduce shortcomings and challenges in AIS implementation (Canadian Coast Guard, 1998; Glass, 2003; and IMO, 2001a).

In this research, with consideration of relevant human factors aspects associated with operating AIS technology, the accuracy of some of the AIS fields of information will be evaluated by conducting 3 AIS data studies, namely;

- VTS-based data study.
- Data-mining study.
- Proactive data study.

The research includes a thorough review of the literature and overview of the AIS. Further, harmony and standard of use of AIS by navigators, along with the impact of some of the demographic factors on navigators' attitude toward use of the AIS will be assessed through a questionnaire survey. A prospective model to study navigators' satisfaction with AIS status will be adopted analysing the reliability and validity of the questionnaire survey, and probably, be used as a basis for evaluation of the AIS user satisfaction, or for any other similar technologies.

1.2.1 Aim

The main aim of this research is to evaluate the following hypothesis:

"The Automatic Identification System (AIS) has a beneficial Impact on the Safety of Navigation".

Assessment of the impact of AIS on the safety of navigation will be carried out by examining the level of human failures, and the attitude of people performing navigation tasks on the ships bridge towards the use of AIS.

1.2.2 Objectives

This aim will be satisfied by achievement of the objectives listed below.

- To examine how the AIS technology has been accepted by navigators as a tool to improve the safety of marine navigation.
- To identify the ways in which the use of AIS can be improved and enhanced.
- To present a detailed overview of AIS technology and its application in marine navigation to further expand the reader's prospective practical understanding of the AIS technology, and what it does.
- To inspect the performance and accuracy of the information transmitted by AIS to identify the major issues associated with AIS application in navigation operation, especially for anti-collision activities.
- To assess navigators' performance in AIS usage for anti-collision by identifying and validating end user problems and required improvement actions.
- To adopt a suitable model for identifying a reliable and valid scale for the measurement of user satisfaction that can be used as a framework for examining end user performance and usage of AIS, and possibly other similar technologies in the future.

1.3 Justification for the Study

As already discussed, one of the main purposes of introducing AIS was to improve the efficiency and safety of marine navigation. The introduction of previous technologies such as Radar and ARPA onto the ship's bridge has shown that the risks related to operational shortcomings, human failures, and other human factor issues would affect the success in achieving the intended goals. The accelerated implementation of AIS for international security reasons has potentially led to a lack of in-depth pre-implementation research. This has raised a number of issues in its potential success as a useful aid to the navigator on the ship's bridge.

Proper understanding of the human factor issues should improve the human-technology interaction by reducing unpredicted consequences. This research may be beneficial in preventing AIS-assisted accidents perhaps similar to those in the early years of radar. This study will further be useful in enhancing safety of navigation by utilising the use of the technology in navigational tasks performed by navigators.

AIS has been implemented on ships for a small number of years and there has been little or no work on the navigators' attitude and behaviour to this new technology. The research will gather and evaluate information on navigators' usage of AIS. This will provide useful information for technology manufacturers for improved designs, trainers for course design and regulators for design of future regulations.

1.4 Methodology

This section will discuss the methodology that is going to be used for investigations required in this thesis. Data required assessing the level of human failure associated with AIS performance would be collected by observation through three AIS data studies. Data collection includes:

- Recording of data transmitted by AIS at a Liverpool Vessel Traffic Services (VTS) station
- Use of data recorded from a number of AIS receivers located worldwide, and
- Proactive data recorded at the university site.

The methodology for these data collection will be explained, in more detail, in chapter 4. These data will be analysed and discussed with the aid of 'Microsoft Excel 2000' computer software for individual AIS fields of information (i.e. type of the ship, navigational status, etc.).

To further validate the result of the analysis of the first set of data, a questionnaire survey will be conducted to collect another set of data required. The study sample for this set of data will be the navigators that are active in ship navigation at the time of data collection. Questionnaire data will be analysed with the aid of 'SPSS version 14' computer software, and the statistical technique that will be used for validity analysis of the questionnaire construct in chapter 7 will be multiple regression. Further details of methodology for the questionnaire survey will be given in chapters 5 and 7.

1.5 Structure of this Research

The methodologies described and developed in this thesis are to examine the recent development in marine navigation technologies and how they affect performance and safety of marine navigation, especially application of an Automatic Identification System (AIS) for ship-to-ship use.

The objectives set for this research were to explore the impact of AIS technology on safety of navigation centred at examinations of associated human failure in application and use, and behaviour of navigators in relation to satisfaction and usage of the AIS technology.

Chapter 2 of this thesis is a comprehensive review of the literature, which examines the previous studies and research related to the subject areas of this project.

Chapter 3 outlines the current use of Automatic Identification System (AIS) technology onboard ship and ashore and its objectives. It also gives a practical understanding of the principle, design, development, and implementation of shipboard AIS. It also discusses AIS information display types as well as the symbols used to present the information on board. The potential use of AIS for other purposes such as search and rescue, vessel surveillance and traffic management, and aids to navigation is also considered in this chapter.

Chapter 4 describes human factors, different approaches to human error, and risk management in marine navigation as the basis for a system's approach to evaluation of error with AIS application for navigation. Further, this chapter examines accuracy of the AIS information in manually inputted data fields in order to discover the level of inaccuracies and failures, and remedial action to reduce the chances of such errors. As a result of this examination, a questionnaire is devised which relates to a user satisfaction model is considered in later chapters. This examination will be carried out by AIS data research studies, including VTS-based study, data-mining study, proactive study, and former related studies. Accuracy, and precision of information presented to the mariners by AIS on the bridge is crucial for collision avoidance and safe navigation. The way that AIS data is represented on the bridge can significantly affect interpretation by the navigators. Chapter 4 will also make suggestions to reduce ambiguities and improve the definition of information required on the bridge for anti-collision operation.

Chapter 5 assesses navigators' perceptions about some aspects of the AIS technology, which is highlighted during literature review and AIS studies, and impact of demographic factors on their responses. The assessment includes:

- Perceived usefulness of AIS.
- Perceived ease of use of AIS.
- Perception of the AIS information display.
- Training.
- Perception about AIS and use of VHF.
- Perception about some disadvantages of AIS.

This chapter will carry out the assessment by analysing navigators' feedback collected through a questionnaire designed for this purpose. The data analysis will show the degree of AIS usage in anti-collision and other navigation operation. This chapter also evaluate the significance of factors such as training, type of training, certificate of competency, and experience of navigators, and type of AIS display on perception of the navigators about AIS characteristics, capabilities and limitations.

Chapter 6 discusses some of the well-known and commonly used theories and models of human behaviour and attitudes in new technology acceptance. It also discusses technology implementation programmes and the application of technology acceptance models in both the voluntarily and mandatory environments in order to adopt a suitable model to be used as a basis for assessing navigators' satisfaction with AIS as a mandatory navigational aid. This chapter then discusses the adaptation of the AIS User Satisfaction Model based on the End User Satisfaction Model (EUS) introduced by Adamson and Shine (2003). This chapter further discusses its appropriateness for assessing the degree of use of AIS on the ship by navigators.

Chapter 7 examines reliability and validity of measurement constructs used in the AIS questionnaire survey, using the AIS User Satisfaction Model adopted in chapter 6, to show the survey consistency, stability, and measurement ability. The analysis was carried out by statistical technique of multiple regression, using computer software of SPSS version 14. This chapter also discusses modifications required to the model in order to increase its aptness for measuring AIS user satisfaction or satisfaction of the user with similar new technology in future.

In chapter 8 the main findings will be summarised, conclusions drawn, and recommendations will be made.

Appendix A shows the publications in the proceedings of conferences or journals arising from this research. Appendices B and C provide the extra information about this thesis such as the questionnaire sample, data, coding, and etc., which have been referred to in the body of thesis.

1.6 Limitations of the Research

This research has concentrated on the main AIS fields that are inputted manually and has not specifically considered information relayed automatically from other shipboard navigational equipments, such as speed, position, heading, rate of turn, etc. This was due to practical reasons such as no availability of facilities for exclusive research purpose, and to avoid interruption of normal VTS operation, where the study was carried out in port VTS station.

Chapter 2

Literature Review

2.1 Introduction

Safety of marine navigation has always been of great concern to the marine industry, and new technologies have always been introduced to improve and enhance safety. There is limited literature about the impact of AIS on the safety of navigation, which may be due to the short time interval between introduction and mandatory implementation of the technology. Perhaps, there has not been enough time available for real time experiments between AIS introduction and its mandatory carriage requirement to properly evaluate the system influence and contribution on enhancement of safety of navigation. Further, the limited number of experiments and case studies in this regard has been carried out in limited time scales.

The aim of this chapter is to conceptualise the purpose and area of this research. This will be carried out through a thorough review of some of the available literatures concerning new technology specially AIS Technology, human factors aspects of new technology, and their relation to safety of navigation. Firstly the literatures on new technology are covered in section 2.2. Literatures on Automatic Identification System (AIS) are discussed in section 2.3. Safety of marine navigation and human factors aspect of new technology are covered in sections 2.4 and 2.5, respectively. Section 2.6 covers the discussion and conclusion for this chapter.

2.2 Impact of New Technology

The marine industry like many other industries such as air industry is in a constant state of change. Many aspects of the technologies have experienced a great deal of advancement. Machinery automation, propulsion systems, cargo handling equipment, navigation support equipment, communication related technologies, and information management systems have all undergone revolutionary changes. Similarly, new sources of navigational information and data have been invented and introduced to the bridges of these ships. More or less, these advanced and automated new technologies have been advantageous to the marine industry by improving navigational performance and enhancing safety.

New technology may bring many extra responsibilities to the user and may need the working practices and related regulations to be changed. Therefore, different skill levels may be required by the actual users and operators of the new technology to perform their duties in an efficient manner. Naturally, with all the new technologies some issues will arise after implementation and practical use in the actual work environment. Modern technology has changed the way in which a ship is operated. The aim of these technological changes is to increase overall quality in shipping in terms of efficiency, safety and prevention of pollution, and human factors are nearly implicated. Despite reduction of marine accidents, issues such as over-reliance, inadequate training, and deficiencies in design, implementation, and procedures for operation of the equipment have been causally linked to some of the accidents at sea, such as in the case of the grounding of the passenger ship Royal Majesty on Rose and Crown Shoal near Nantucket, Massachusetts (Accident Investigation Reports, 2003). There have been many such examples of problems caused by the introduction of new technologies to vessels since the introduction of radar over 60 years ago. Lack of attention to the human-system interface, in terms of the design, layout, and integration of systems, and training in their use, is the root cause of many accidents today. Increased use of electronic technology caused the mariner to be less 'hands on' and driven more towards automation which in general results in less cross checking, and less teamwork (Middleton, 2003). Bonsall (2006) highlighted the march of technology in the marine industry and the necessity for involvement of maritime education and training organisations and institutions in any debate on any change. He further argued that it is not practicable to prevent technological change, and therefore, it should be covered in training programmes. Formal training before the implementation stage can make the use of new technology more effective.

Some of the new equipment, which has been made for some special purposes, may find its way for use in some other areas, but may not properly match in its new area of application. When new technology is introduced in the marine industry, apart from good points highlighted by makers and suppliers, there needs to be a much closer consideration of potential shortcomings and weaknesses, which require researching. Possibly, with the use of today's modern research tools, such as simulators, we can discover capabilities, benefits, limitations and effectiveness of the new technology well before the implementation stages to prevent new technology assisted accidents (Holder, 2002; Hall, 1998; Denham et al, 1993; Accident Investigation Reports, 2003; Marine Board, Commission on Engineering and Technical Systems, 1999).

Today technical advancements in new technologies have revolutionised the way in which the marine industry is being operated. The ships being built today are larger, faster, have higher carrying capacity, and have more specialised missions. Ports are being built with smaller margins of safety due to economical considerations. More efficient machineries and new navigational equipment have been installed on board ships. Examples of these technological advances being introduced to the shipping industry and waterborne transport are, new electronic navigational aids on the bridge, automatic control systems, improved accident investigation, and more precise vessel identification facilities.

New technology has been described as (European Commission, 2000):

> *"A technology that has already been implemented on board ships/harbour and/or is expected to be implemented to a large extent in the near future," and five main categories of new technology that have been defined are:*
>
> *a. Ship design related new technologies*
>
> *b. Cargo related new technologies*
>
> *c. Navigation support related technologies*
>
> *d. Communication and management support related new technologies*
>
> *e. Machinery related new technologies*

The introduction of new technology in all areas of the marine industry, especially to the ship's bridge to support most of the ship's operations, is inevitable. Sometimes the introduced technology may not assist the mariners due to its impact on the user. They may require changes to working practices to overcome the potential for overload by too much information from many individual types of equipment. Such problems may be deepening in adverse weather conditions and unexpected navigation situations, especially in areas of dense traffic, where there is limited time for action.

At present the emerging technological changes are to improve overall quality in shipping, which is expressed in terms of improvements in (Goulielmos, and Tzannatos, 1997):

- *Efficiency.*
- *Safety.*

- *Pollution prevention.*

Some of the new technologies have been implemented by the international and national regulations through responsible and monitoring authorities to improve safety and working conditions. Some others are also being used on a voluntary basis by ship-owners for cost effectiveness. It was pointed out by the European Commission (2000a) that the implementation of new technology in the marine industry could be due to the following motivations:

1. *Safety considerations: contributing to disaster and pollution prevention.*
2. *Regulatory requirements: a minimum level of technological equipment is required by regulatory institutions.*
3. *Cost-effectiveness (cost-push): the intense global competition stimulates the use of new technology as a contribution to the reduction of operational costs.*
4. *Customer demands: some technological concepts are developed to (better) fulfil customer needs such as faster or more environmentally friendly transport.*
5. *Technological innovation (technology-pull): new design fresh from the drawing table may create their own demand.*
6. *Improvement of working conditions and quality of life on board ships: in order to attract appropriate personnel, ship owners may want to invest in technology applications, which provide for instance better ergonomics or workload reductions.*

Technology is often introduced to the ship's bridge to reduce human error and improve safety and performance in navigational operation and environment. In safety-critical systems, such as the navigation systems, human and technology are jointly executing different tasks and monitoring operations. Therefore, human-technology interaction seems to be a very important research area, which could minimise mismatch between the human and the technology, and therefore reduce chances of error. Human performance, to a great extent, is affected by his/her interaction with technology. Poor design of controls, displays, procedures, etc., could complicate the operation of new technology and equipment. Additional tasks demanded by new technology can sometimes increase the navigator's workload, which may result in information overload and may contribute to disasters. Today, the tasks of the navigating officers on the bridge of the ship cover a very wide area consisting of many planning and navigation control, main and auxiliary engines monitoring and control, communications, administration, and more other tasks. Assimilation and incorporating a large body of knowledge from a number of new technologies might exceed information capacity of the operator, which could affect their decision making on the bridge (Grabowski, and Sanborn, 2003); Civil Aviation Authority, 2002).

Another reason for developing new technologies to be used onboard ships could be to improve and optimise the efficiency of the human element to cope with industrial challenges. This could change the role of the human involved in the operations due to an alteration in the amount and type of duties performed. The new technology sometimes creates new pathways to error, shift consequences of error into the future and delays opportunities for error detection and recovery. Problems may persist and even deepen if communications between human and machines, and assessment of the situations are poor, which may contribute to accidents and incidents. The human element forms the interface between different parts of the maritime system. Any incompatibility between parts of the system may cause failure due to increased disorientation and cognitive load on the human element. Sometimes, development of technology will improve the quality of different hardware in the system but less attention is paid to human as the interface between different parts of the hardware in the system (Goulielmos, and Tzannatos, 1997; Mazzarino, and Maggi, 2000; Lotzhoft, and Dekker, 2002; Co et al, 1998).

Technological innovation and advancement are affecting the operational practices on board ships and ashore in many ways. The European Commission (2000a) stated that the introduction of new technologies would bring about changes in the organisation and people in such organisation. It will increase the technical complexity of the system under consideration while reducing the amount of the operator's routine tasks. This causes the skill level of the operator to be changed and technically be retrained to cope with increased technical complexity of the job (Squire, 2003).

The trend of development in design and operation of ships will continue due to the introduction of new technologies and other changes in the marine industry (Harre, 2002). Rapid technological advancement and innovation causes major changes in the state of the marine industry. The new generation of ships needs to run more efficiently with fewer personnel (Harding, 2000).

The introduction of new technologies affects safe navigation and manoeuvring of the ship. Independent onboard systems with different interfaces offering too much information to the operators may increase chances for confusion and information overload for the mariners. There may be a demand for new training on the basic operation of such technologies. In navigational operation, over-reliance of the officer of the watch (OOW) on new technologies together with inadequate training, improperly designed technology and implementation programme, and poor ergonomics, might have a negative response on the effectiveness of new technologies for safe navigational operations (Squire, 2003).

The application of new technologies has changed the state of marine navigation in many ways. Kopacz et al (2004) mentioned that marine navigation has been changed and the navigation process has gone towards the safe and efficient operation of ships at sea. These changes will have new consequences in the marine industry. Stalberg (2006) argued that the effect of extensive adoption of new anti-collision technology on the high frequency of collision has not been very significant. The use of more advanced technologies, such as integrated bridge systems equipped with a number of tools create a new category of incidents. He believed that bridge teams might take greater risks in avoiding potential collisions, such as temptation to accept narrow margins with no room for error, because of having a more complete picture of the situation.

The acceptance and conventional use of new technology in a professional manner is an important issue that should be properly investigated in implementation stages of technology. Human factors issues may affect implementation success, which could be different between voluntary and mandatory implementation. A number of theoretical models have been introduced to study human attitude and behaviour with technology. In order, to select a suitable framework for measuring technology usage behaviour in navigation, some of the well-known models that have dealt with technology usage behaviour will be discussed, later in this research. The Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975), Theory of Planned Behaviour (TPB) (Ajzen, 1991), Technology Acceptance Model (TAM) (Davis, 1986), and Extended Technology Acceptance Model (TAM2) (Venkatesh and Davis, 2000) are some of the commonly applied theories and models for prediction of user attitude and behaviour, which will be discussed in chapter 6.

2.3 Automatic Identification System (AIS)

Requirements for ships to install Automatic Identification System (AIS) are an example of the mandatory application of new technology in the marine industry. Automatic Identification System (AIS) is one of the newest technologies introduced to the marine industry to be used onboard the ship and ashore. A full description of the AIS is given in chapter 3. The original aim for application of this technology was improving vessel identification, traffic management, and security in port and coastal waterways. However, without any commitment on ports and coastal states, the idea was developed and AIS was implemented as an anti-collision aid for SOLAS convention vessels.

AIS is mainly intended for ship-to-ship application for collision and disaster avoidance and its main ability is in its strength for information exchange between ships at sea (Kurin, 2002). AIS may be applied in different sectors of marine industry on a mandatory or voluntarily basis. The degrees of application and its usefulness may vary according to the nature and type of activities in different fields of application. It can be applied (Fisher, 2003; Kenyon, 2003):

- To ships for ship-to-ship anti collision operation at sea all around the world.
- To shore station for traffic monitoring and management.
- To ports for their VTS.

Kenyon (2003) believed that AIS could be applied for security reasons by providing useful information about ships and their cargoes. However, Fisher (2003) highlighted that its use for security is limited due to problems of spoofing and switching off by target vessels. According to Moore (2001) the main reasons for introduction of AIS are:

> *(a) Mariners interests to obtain identity of the other vessels automatically in a more effective and reliable manner.*
>
> *(b) Interests of coastal states that are responsible for prevention of marine pollution, traffic management, and security to identify and monitor vessels activities to replace the physical identification.*
>
> *(c) Commercial interests, including port authorities, pilots, and ship operators through provision of fast information to mariners.*

2.3.1 AIS Studies and Research

As the AIS technology in the maritime industry is still in its development stage proper research is required to evaluate its functions and use. AIS technology, like any other new equipment, may have some good and some bad points but the actual effectiveness of this new technology should be examined by practical experiments and research.

An example of such research is the AIS pilot project conducted jointly by the Canadian Coast Guard and the marine industry between March 1996 and December 1996 on the St. Lawrence River before its mandatory carriage requirement (Canadian Coast Guard, 1998). It is important to highlight the fact that there was no internationally agreed radio band for use and only a single radio channel was used for this study. Further, because only a small number of vessels with AIS transponders installed onboard participated in this pilot study, the available shipping traffic was limited and evaluation of a full-scale traffic scenario was not taken into account. Another study, designed to evaluate AIS application in a joint planning partnership project (California Department of Fish and Game, 2001), was carried out by a number of representatives from the maritime industry. This included ferryboat operators, tug/escort companies, barge operators, container and dry cargo vessels, pilot, and government agencies. Some of the limitations of this study were the very short time gap in which this test was carried out (about 2 months), the AIS was in its introductory stages, and much of its potentials yet to be discovered.

In an AIS evaluation test (Western Marine Community, 2002), bridge teams of three modern cruise ships have mentioned that displaying AIS targets on electronic chart or radar can improve the safety of navigation by assisting in better identification of SOLAS Convention ships, and providing an additional source of information for collision prevention. However, special attention should be paid to large amounts of information that may cause confusion to the navigators. AIS reliability and usefulness in detecting targets in radar blind sectors has been emphasised, but it was also found occasionally that AIS detection ranges are very limited. It is also recommended that non-SOLAS ships carry a class 'B' transponder (the descriptions of the class 'B' AIS is given in section 3.2.7.2 of chapter 3. The European Union (1999), in a practical study on the use of AIS, concluded that AIS reduces manual workload and risks of misinterpretations. It improves situation awareness in shipping traffic, and decreases inaccuracies in navigation and traffic surveillance.

2.3.2 AIS as a Navigational Aid

The position of AIS on the bridge is very important, especially when it interacts with other navigational equipment such as radar and ECDIS. AIS provides a lot of information, but navigators use only some of the AIS information for anti-collision operation. Other authorities will use the rest of the information ashore for other purposes such as shipping surveillance, traffic management, etc. Substantial risk of possible information overload due to introduction of AIS on board is one of the main concerns (Leonard-Williams, 1999; Edwards and Pietrazewski, 2000; Squire, 2003; Holder, 2002; Cobley, 2003; Creech, 2003) that can affect its real effectiveness as a navigational aid. The way in which AIS data is presented to navigators, along with information from other navigational aids, can affect their degree of situation awareness on the ship's bridge.

2.3.3 AIS Pros and Cons

The introduction of AIS technology, same as any other new technology, in the marine industry is associated with different arguments. Different points of view have highlighted positive and negative outcomes that may be derived from the use of AIS in navigation and other related marine operations. Sometimes many things have to be done in order to achieve the highest positive results from a new technology. Therefore, reviewing positive and negative opinion on AIS technology might be helpful in this respect.

Early users of AIS, especially in the development and implementation stages, may see themselves exposed to higher risk than later users. In an AIS study conducted by the Canadian Coast Guard (1998) it was expected that:

> *In the long term, with an ideal system (where everyone is equipped), we believe that the AIS is a tool that can make a great contribution to the effectiveness of marine navigation because of the very precise positioning of each vessel, the coverage area and the rebroadcast possibilities. However, an IMO standard will have to be developed to make certain it is used.*

As it has been mentioned above, this even long-term success of AIS is not straightforward and it depends upon certain conditions to be fulfilled. The requirement for all vessels to carry AIS and amendment to the regulation for its actual use onboard may be examples of such conditions.

The study conducted jointly by a number of representatives from the maritime industry (California Department of Fish and Game, 2001) showed some positive impacts of AIS. It confirmed improvement of efficiency and safety of navigation, providing valuable information to the whole marine industry, improving environmental protection, and advancement to port and shipping management. However, it also indicated that the available personal pilot unit (PPU) technology is not safe to be used for regular ship navigation operation, as it does not provide enough features to improve such operation.

2.3.4 AIS a Complementary to Radar Technology

AIS technology is being regarded as a good complement to radar and ARPA but not a replacement of it. If AIS technology is used properly, as a complementary navigational aid to radar and ARPA, for anti-collision purposes, it can simplify the identification of ships and assist in decision making if it becomes more reliable and all vessels carry AIS equipment (Harre, 2000; and Western Marine Community, 2002). According to the Fisheries and Oceans Canada (1998) in radar coverage areas, AIS accuracy is not less than radar. However, the equipment available at the time was unable to provide the true bearing of the targets, which is essential navigation information. Pettersson (2002) also emphasised the importance of the radar, as the main collision avoidance tool on the bridge. He believed that the AIS technology, as a navigational aid, has the capability of rectifying some of the limitations of the radar in the future as a complement to radar. For example, with path prediction ability of the AIS in meeting situations, ships could be able to see exactly the way in which other ships are manoeuvring.

An alteration of course and/or speed by vessels that could be readily apparent to others is an important factor in collision avoidance. Fukuto (2002) argued that time of detection of an alteration of speed and course is an important factor that affects the action taken to avoid collision and it will affect the safety of navigation. This delay in detection of an alteration after an abrupt alteration has improved from 100 seconds for radar to 20 seconds for AIS. This makes the AIS technology more effective than radar in this respect.

Further, Kurin (2002) pointed out that Coastal states can also make use of the benefits of the AIS technology as a complement to radar coast station by enabling them to get more precise ship information and other required parameters from AIS equipped vessels through their AIS network ashore. He also believed that, unlike radar, AIS technology provides real time heading information. Therefore, it is more useful in avoiding collision at sea by better detection of targets in traditional radar shadow areas and improving radio

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communications efficiency. Pot (2002) mentioned the following five major advantages for AIS, which improves radar detection abilities:

- Helps radar to detect targets around a bend.
- Gives detailed information of a radar detected echo including ship's name useful for calling them on VHF.
- Provide better target path prediction with the ability of measuring Rate of Turn (ROT).
- Provide larger detection range than radar.
- Reduces confusion about target's intentions.

He also pointed out some risks associated with AIS and radar integration. GPS information of AIS due to different reasons may not be correct, position of AIS target and position of radar echo may not coincide with each other on the radar screen, and corrected Time of Closest Point of Approach (TCPA) taking into account ROT may be complicated.

Table 2.1 shows a comparison of AIS and radar positive and negative features, which has been produced by Harre (2000).

Table 2. 1 Comparative advantages and disadvantages of Radar and AIS (adapted from Harre, 2000)

According to Harre (2002) AIS automatically identifies targets and it improves vessel tracking by providing more accurate positioning and dynamic information of ships. Unlike radar, it needs cooperation of the vessels to have their AIS, and other equipment such as GPS receiver, functional. In addition unlike radar, there is a possibility of not detecting unlawful operations and non-SOLAS vessels. He further believed that another disadvantage of AIS in comparison with radar is the lack of any facility to check the integrity of the map presentation due to not showing coastlines.

2.3.5 AIS Display Issue

The way in which AIS information is displayed is an important issue affecting the success of AIS technology in marine navigation operation. The technical and operational standards for AIS published by IMO have only included Minimum Keyboard and Display type and do not include other types of onboard displays (Patraiko, 2002). Squire (2003) also highlighted that the MKD system set out by the organisations is not a user-friendly system for displaying AIS information. Therefore, it cannot be very effective for the safety of navigation unless the display problem is resolved. More effort is needed to further develop a user-friendly interface for the new AIS technology in order to reduce operator workload (Edwards and Pietrazewski, 2000).

The AIS displays importance, for improvement of the safety of navigational operation and marine traffic management is also highlighted by the Transport Research Board (2003). The suitability of MKD for display of AIS information is under question due to its restrictions on data presentation (Cobley, 2003; Fisher, 2003). The shortcoming of the graphical display system of AIS and symbology used in the system may create problems for navigators. Further, navigators need to cope with visual differences in the presentation of data and information from different equipment on the bridge for safe navigation of their ships that increases chances of human error due to information overload (Creech, 2003).

Current MKD of AIS technology as the minimum requirement by IMO appears to be inappropriate because of the difficulty in interpreting its data (Beatty, 2003). Data from the MKD system is in a text format, which needs to be plotted on the chart and interpreted by AIS users. MKD, as the most elementary AIS display, transmits the graphical images that are considered not to have enough information density and only allow the operator to read the information with limited input and control of the display device. This is because the display is limited to three lines of alphanumeric information.

This type of display would require the user to carry out manual plotting to translate targets to a geographic reference, which negates the real time nature of the information (Bronaugh, 2005).

Stand-alone graphical display, integration of AIS display with radar/ARPA or Electronic Chart Display and Information System (ECDIS)/ Electronic Chart System (ECS) are other alternatives for displaying AIS information. The display of AIS information in a stand-alone graphical display will overcome most of the shortcomings of MKD type, but does not show coastlines (Harre, 2000). AIS display integrated with other navigational aids is useful in reducing the number of independent stand-alone equipment on the bridge. Therefore, the OOW would need less time to check different data from different information sources (Fisheries and Oceans Canada, 1998; Harre, 2002). It was mentioned, in a pre-implementation programme by the Western Marine Community (2002), that displaying AIS targets on electronic chart or radar could improve safety of navigation. Advantages of integration of AIS with ECDIS was also emphasised by Motz et al (2003).

2.3.6 AIS and VHF Communication

The impact of AIS on VHF use is of particular concern to the marine industry. The impact can be negative if it causes unsuccessful and confusing VHF communication (Holder, 2002). Harre (2002) believed that AIS reduces voice communication, and exchanges safety-related information, which will give more time to navigators for their situation assessment and decision-making. Pot (2000) argued that, by the introduction of AIS, the amount of time spent on verbal communication could be halved. Hadnett (2003) concluded that AIS would clear lots of ambiguities in VHF communication, which in the past have contributed to some collisions and near misses. Extra knowledge gained from AIS could optimise voice communication on VHF (Heaps and Nock, 2003). Further, proper utilisation of AIS technology will optimise radio communication by reducing information exchange between vessels and coast stations but it cannot totally replace VHF communications (Fisheries and Oceans Canada, 1998). According to Leonard-Williams (1999), the application of AIS in VTS will improve ship safety and will relieve the OOW from making many VHF calls to the shore station.

Although Kurin's (2002) belief that the AIS system is more useful in avoiding collision by radio communications efficiency. Hadnett (2003) and Bailey (2005a) stated that there is a risk of regular use of VHF agreements for collision avoidance, which may be an excuse not to comply with the International Regulations for Preventing Collisions at Sea

(IRPCS). Further, Bailey (2005a) also pointed out that access to a vessel name encourages the use of VHF to establish contact with other vessels. This may cause increased VHF traffic, and specially, increased negotiation of collision avoidance as indirect consequences of AIS technology. In addition, this increased use of VHF for collision avoidance negotiation may further delay decision making, cause confusion due to ambiguous or imprecise use of language.

2.3.7 AIS In Vessel Traffic Services (VTS)

Vessel Traffic Service (VTS) can also take advantage of AIS to optimise monitoring, control, and management of marine traffic. AIS has potential for improvement of VTS operation in ports (Harre, 2000; and Fisher, 2003). It is argued (Leonard-Williams, 1999) that ship-shore application of AIS in vessel traffic services (VTS) will improve ship safety and will relieve the OOW from the task of reporting to a VTS station. AIS assists in a better identification of vessels, and improved traffic safety for shore based vessel traffic services (Holder, 2002). Oltmann and Bober (1999) also mentioned AIS as a valuable piece of equipment because with the use of AIS technology there is no need for ships polling, and it results in VTS stations having a very good traffic image of all AIS equipped ships in their coverage area. He emphasised the benefits of application of AIS to VTS, especially, in areas with low or without radar coverage such as inland waterways, canals, and estuaries.

AIS expands VTS radar station coverage outside current coverage areas, which increases the controlling ability of the coastal state authorities. Further, AIS has got the ability to handle considerably more shipping traffic with the same amount of staff engaged in present VTS stations (Pot, 2000). He also argued that it has a significant impact on the time required for voice communication by VTS operators (the amount of time spent on verbal communication could be halved). Edwards and Pietrazewski (2000) also concluded that mariners and VTS operators would have a better navigational situation around them with AIS. Even though some researchers highlighted many important shortcomings of the AIS system, Heaps and Nock (2003) believe that AIS has many benefits in VTS operations. For example, additional information obtained from this equipment improves quality of advice and guidance given to different port users. They also thought that it possibly reduces costs by better organisation and management of pilots, berth occupancy, and other similar services. Extra knowledge and navigational information from AIS could enhance safety and increase data reliability. AIS cost effectiveness was also pointed out by Kurin (2002) who believed that AIS enables VTS stations to obtain required ship information from AIS equipped vessels automatically, which in a larger area of coastal waters, reduces cost of VTS operation in comparison with radar VTS.

2.3.8 AIS and Non-SOLAS Vessels

Non-SOLAS vessels, such as small ships of under 300 GRT, pleasure crafts, etc., are exempted by IMO. Carriage of AIS equipment for such vessels is voluntary. Some of the main reasons for exempting such vessels from carrying AIS are technical impracticality (power requirement, antenna installation, space, etc.), and the possibility of overload of the VHF radio bands used by AIS for transmission and reception of information.

Advantages of the use of AIS by SOLAS-exempted vessels have been identified by a number of researchers. Brown et al (2001) mentioned a number of identified advantages such as the development of safety of navigation; improvement in being detected by other AIS equipped vessels, which decreases the risk of collision, and enhances other marine operations. They also emphasised the usefulness of AIS for small craft to make themselves visible to larger vessels during bad weather conditions with poor visibility, especially, when radar ability to detect such vessels is reduced due to rain or sea clutter, fog, and the nature of their construction. Creech (2003) also pointed out that the operational situation display of AIS is always associated with the danger of missing some targets due to the fact that not all vessels are required to be equipped with AIS. The present cost of AIS technology for non-SOLAS vessels is not reasonable and on this basis, the marine industry will not be able to make use of full potential of safety improvements as a result of AIS introduction. On the other hand, fitting AIS on large numbers of small vessels could cause system overload, which in some areas could make it unusable (Pike, 2003).

According to Norris (2006), Class B AIS designed for vessel, not covered by mandatory requirements under SOLAS Regulations, with reduced specification will decrease the cost of the technology from that of class A, perhaps to £500 for basic equipment types. Many government states have already shown interest in mandating Class B AIS for smaller vessels due to security reasons. As a result, Software Radio Technology, UK has invested £1.5M to design a Class B AIS for a price of under $500 (Digital Ship, 2005).

An international standard published by the International Electrotechnical Commission (IEC) (2006) pointed out that Class B AIS is working on Carrier-Sense Time Division Multiple Access (CSTDMA) principle, is compatible with International

Telecommunication Union Recommendation (ITU-R Recommendation M.1371-1), and the main purpose of Class B AIS is for fitted vessels to be visible and take part in the AIS network. The following statement is directly quoted from IEC (2006) standard:

> *The new technology, hereinafter referred to as "Carrier-Sense TDMA (CSTDMA)", requires that the Class B"CS"AIS listens to the AIS network to determine if the network is free of activity and, only if the network is free, can it transmit its information. This Class B AIS is also required to listen for reservations from base stations and comply with these reservations. This polite operation ensures that this Class B AIS minimises the probability of interference with Class A, Base Station or A to N (Aids to Navigation) AIS operations.*

2.3.9 AIS and Training

The application of AIS to the bridge requires a proper integration with other navigational aids in order to improve navigation and collision avoidance alertness. As is the case with many other navigation technologies, appropriate knowledge and skill on capabilities and limitations, and sources of data of the AIS is very important for the navigators. This demands a proper training programme. Apparently, the level of knowledge and understanding of AIS is generally low (Brown et al, 2001), which could increase chances of confusion, navigator's workload, and lack of understanding of real benefits that AIS can bring to operators. Edwards and Pietrazewski (2000) argued that proper training of the AIS operators could reduce the amount of stress in carrying out their navigational tasks. For the AIS to be a useful navigational aid, an impression about the total AIS and introductory training on its normal operation along with understanding the basics and use of the technology prior to actual on board use of it is necessary and vital (Koehler, 2003).

According to Woods (2003), for AIS to be a useful navigational tool for navigation and anti-collision operations, training requirement for this new technology should be identified as a proper training course. A training course for AIS should become compulsory, as are many other STCW mandatory courses. He further emphasised that, because of the capability of a simulator in showing all elements of navigation from very simple to full scale scenarios, the use of a training simulator for AIS training could be helpful. Winbow (2003) also underlined the importance of a mandatory training course for navigators in order to improve effectiveness of the AIS on board ship. He further believed that the training for AIS should include the basic operation of the equipment, setting up, data input and manipulation, changing screens, and extracting necessary information. The use of data and their correlation with information from other navigational equipment should also be included in any training agenda. Further, he mentioned that, by adopting proper trainings, the OOW should have enough skills to select suitable source(s) of information for navigational decision-makings. According to Bronaugh (2005), understanding the sources of the AIS data is extremely important for AIS operators, because knowledge of where information is coming from will enable them to detect errors early. The AIS operator must also be acquainted with different symbols and graphical presentation, and interpretation of AIS information. The objectives of an AIS training course for the mariners are (Bronaugh, 2005) to:

- Understand the principles of AIS data and their presentation.
- Operate the AIS function of the equipment.
- Be aware of potential errors.

Norris (2006) believed that a large number of the AIS problems would have been prevented with proper training in the use of AIS, including necessity of regular checking of the data transmitted by own ship. He further mentioned about the hidden complexity of AIS, especially for enhancing situation awareness, which is also underlined in the IMO Model Course for AIS. The aim of the recommended IMO Model Course is to assist nautical colleges in setting up suitable training courses with emphasis on the shortcomings of MKD and the benefits of AIS display integrated with radar. It is unfortunate that the AIS Model Course is only becoming available after 5 years from the starting date of AIS implementation (Norris, 2006). Bailey (2005b) believed that during the fast implementation of AIS, the requirement for training was overlooked, because more attention has been given to the technical issues than to operator training. Further, transmission of erroneous critical navigational information by ships AIS may suggest that the navigators were not sufficiently competent in operational use of AIS technology.

2.3.10 Other Viewpoints About AIS Technology

There are other different viewpoints about the AIS technology. For example, Leonard-Williams (1999) believed that AIS improves collision regulation compliance by the navigators. Nevertheless, Squire (2003) had doubt about AIS application as a useful navigational aid for anti-collision purposes. He further pointed out that it is not a proper system to be applied for the safety of navigation. It is also of less use in the short term. In this section some other viewpoints about AIS are discussed. AIS may be the most advanced tool for safety of navigation since introduction of radar and its real benefits are in the important information it sends and receives (English, 2003).

Holder (2002) argued that, on board ships, AIS would assist the OOW to identify other ships much better than radar. The impact of AIS on reducing the number of collisions could be positive if it improves mutual detection of ships and application of anti-collision rules. It has potential to enhance mariners' ability in performing their duties efficiently and safely. Apart from improvement of marine safety it can be a valuable tool to other sections of the marine community by providing useful information. Nevertheless, as a tool for pilots, it is not enhancing the navigation and operation of ships in pilotage activities (California Department of Fisheries, 2001). Harre (2000) believed that AIS capability to acquire data automatically and information (heading, sailing directions ahead, or astern, and navigating status of the other traffic participants that is not possible by use of radar alone) improves mariners' abilities in performing their navigation tasks. This is very important and useful in preventing collisions. Harre (2002) also pointed out some of the advantages of AIS technology as it automatically identifies targets. It will improve vessel tracking by providing more accurate positioning and dynamic information of ships.

Harding (2002) considered that AIS where installed will improve identification of ships and remove ambiguities. Vessels can come to agreements to avoid collision in compliance with rules. Therefore it enhances the confidence of the mariners in ships' manoeuvring. (Holder, 2002) believed that the impact can be negative if it causes violation of International Regulation for Preventing Collisions at Sea (IRPCS). Nevertheless, Leonard-Williams (1999) highlighted improvement of ship safety in ship-shore application of AIS, and improved compliance of navigators with the International Regulations for Preventing Collisions at Sea (IRPCS) due to the possibility of being monitored from shore stations. Oltmann and Bober (1999) argued that AIS would be very valuable equipment for collision avoidance with lower cost compared with radar. AIS technology is a system with great potential. Stability and precision of vessels' tracking, advantages over radar, autonomous mode of large data exchange at high update rates with improvement in efficiency of ship reporting system made it is an excellent new technology. It can enhance the safety of navigation, but limitation of its dependence on other ships' cooperation and omission of small crafts causes the system not to be a perfect and ideal system (Davidson, 2002).

According to Hadnett (2003), AIS will enhance the situational awareness of the bridge watch keepers by its detailed information. Therefore, it will play an effective role in safety of navigation and avoiding collision, especially in areas with high traffic density associated with higher risks to navigation. He also argued that with AIS, navigators could make earlier assessment of the risk of collision than with radar. Therefore, they will have more time to take early action to avoid collision. It does not have some of the limitations of the radar, which in the past has resulted in numbers of collisions and near misses. AIS technology enhances safety in different visibility conditions and improves mariners' efficiency (Edwards and Pietrazewski, 2000). AIS also provides new improvement to safety at sea, and if all vessels are fitted with AIS the risk of collision should reduce (Pike, 2003). Bronaugh's (2004) opinion was that the AIS automatic transmission and reception of safety information gives a clear traffic situation. AIS, as a new advanced technology, will minimise distraction in ship's bridge team operation. Therefore, it enhances safety of navigation. As the cost of marine accidents is very high, from different aspects, use of AIS as a complement to ECDIS is necessary to boost safety at sea in confined and restricted waters.

On the other hand, effectiveness of new technologies on the safety of navigation in early stages of introduction has some limitations. Oltmann and Bober (1999) emphasised the abilities and application of radar for detecting all crafts at sea in comparison with the ability of AIS, which only detects targets if they carry AIS and is operational. Leonard-Williams (1999) pointed out that different AIS issues in ship-to-ship mode of application such as training in operational use of AIS and understanding of information presented by AIS for anti-collision purposes need further investigation. He also added that there are some other aspects of AIS such as not all vessels carrying transponders onboard, not providing target's relative motion information of AIS, incorrect data input to the AIS equipment, possibility of being misused by criminals, and information overload affecting its success. Squire (2003) was also not sure about AIS application as a useful navigational aid for anti-collision purposes in the short term. He argued that AIS might be a valuable tool in the long term if its negative issues especially in respect to human factors are resolved.

In research by the California Department of Fisheries (2001) it was stated that there is still a long way to go to make the AIS technology a reliable system with full ability to the mariners. Harding (2002) also argued that situation for confusion will exist, as most of the ships are not required to carry an AIS system. Leonard-Williams (1999) also highlighted the necessity of further study to identify AIS operational problems and human factors aspects of AIS, especially in ship-to-ship application. He thought that with further investigation and research it might be possible to answer questions such as AIS's capability to offer a solution to anti-collision operations, its ability to assist in collision avoidance while it does not directly gives relative information, its threats of misunderstanding of erroneous and invalid data input, and information overload. He believed that some of AIS problems could have been identified and resolved if it was studied carefully in advance. Interfacing and integration of AIS with existing systems such as gyrocompass, rate of turn (ROT) indicators, radars, etc, on board older ships are difficult and sometime not possible due to technical reasons. GPS vulnerability, and own ship's data input (as the main problem of AIS) are some other issues (Beatty 2003). Motz et al (2003) also mentioned lack of practical experimentation on the usefulness of AIS with a special emphasise on the use of simulation to test the integration of AIS with other onboard navigational aids.

Another negative point of AIS is that it can be a very useful tool for pirates and terrorists, as it will make marine surveillance easier for them (Creech, 2003). Cobley (2003) highlighted the problem of dealing with lots of different types of navigational information by mariners, and the way they are presented on the bridge. He believed that there is a substantial risk of information overload, and further, present radars due to their limitations cannot handle the amount of data generated by AIS.

The real effectiveness of AIS in aiding the safety of marine navigation could be established with further suitable research. For example, how best the AIS information (e.g., symbols and icons) should be displayed to be useful and unambiguous to the mariners is an important issue, which requires further research (Cobley, 2003). Fisher (2003) also mentioned that AIS might bring new dangers into navigation. Some other issues that need further study are application for collision avoidance, and security. More practical researching on how AIS will interact with the existing anti-collision regulations is necessary. It is mentioned that AIS, as with many other pieces of navigational equipment, is intended to facilitate mariners to conduct their tasks in compliance with compulsory rules and regulations. It might cause distraction and could negatively affect mariners in maintenance of an appropriate visual lookout (Stitt, 2003). Proper practical evaluation tests of the system can reassure the agreed advantages and improvement of navigation safety (Transport Research Board, 2003). Harre (2002) also mentioned the need for careful consideration of AIS practical experiences to find out its operational benefits and limitations. Leonard-Williams (1999) suggested that preferable use of simulators, rather than the real ship's bridge, would help to improve safety and achieve economical benefits in the early stages of evaluation.

2.4 Safety of Marine Navigation

Safety of maritime transport and particularly safety of navigation has always been of supreme importance to the marine industry. The impacts of maritime accidents on the safety of life and environment are considerable and always have been major issues. European Commission (2001b) has stated that:

> *Safety implies freedom from danger. The ultimate level of safety desired by human beings is to be in a situation without any risk of personal accident, injury, or material damage. In reality, this is impossible because a widespread set of dangers cannot be avoided completely. So safety generally refers to the level of danger that is socially acceptable in a real-life situation.*

The overall safety at sea consists of different components, but the most important part of safety at sea is the safety of navigation, which has been defined as (Kopacz et al, 2001):

> *Safety of navigation can be considered as 'such conditions of conducting the ships at sea which ensure that ships are not endangered by collisions, stranding or storm damage'. Such safety is achieved by the proper navigation processes, as well as by ensuring the proper environmental and operational conditions for the realisation of these processes.*

The main elements contributing to safety of navigation are as follows (see figure 2.1):

Ships and navigational technology, they mainly consist of ships navigational properties, its dynamical stability, and navigational equipment.

Navigational information and environment, the environment consists of ambient environment (sea and weather condition, day and night) and density of ships traffic. Availability of safety *related information services*, vessel identification and traffic services, aids to navigation, and etc. are also very important.

Regulations and procedures, they include laws, regulations and requirements by national and international maritime organisations regarding navigational technologies and their operational aspects, and navigation process and emergency procedures, which will affect safety of navigation.

Human element, it includes the ships crew that will affect safety of navigation through their social, physiological, and psychological characteristics. These characteristics include a level of navigational competence, proficiencies, knowledge and experience, fitness for assigned tasks, language communication, teamwork, etc. One of the main tasks of the human element is coordination and management of the other elements of the navigation safety system.

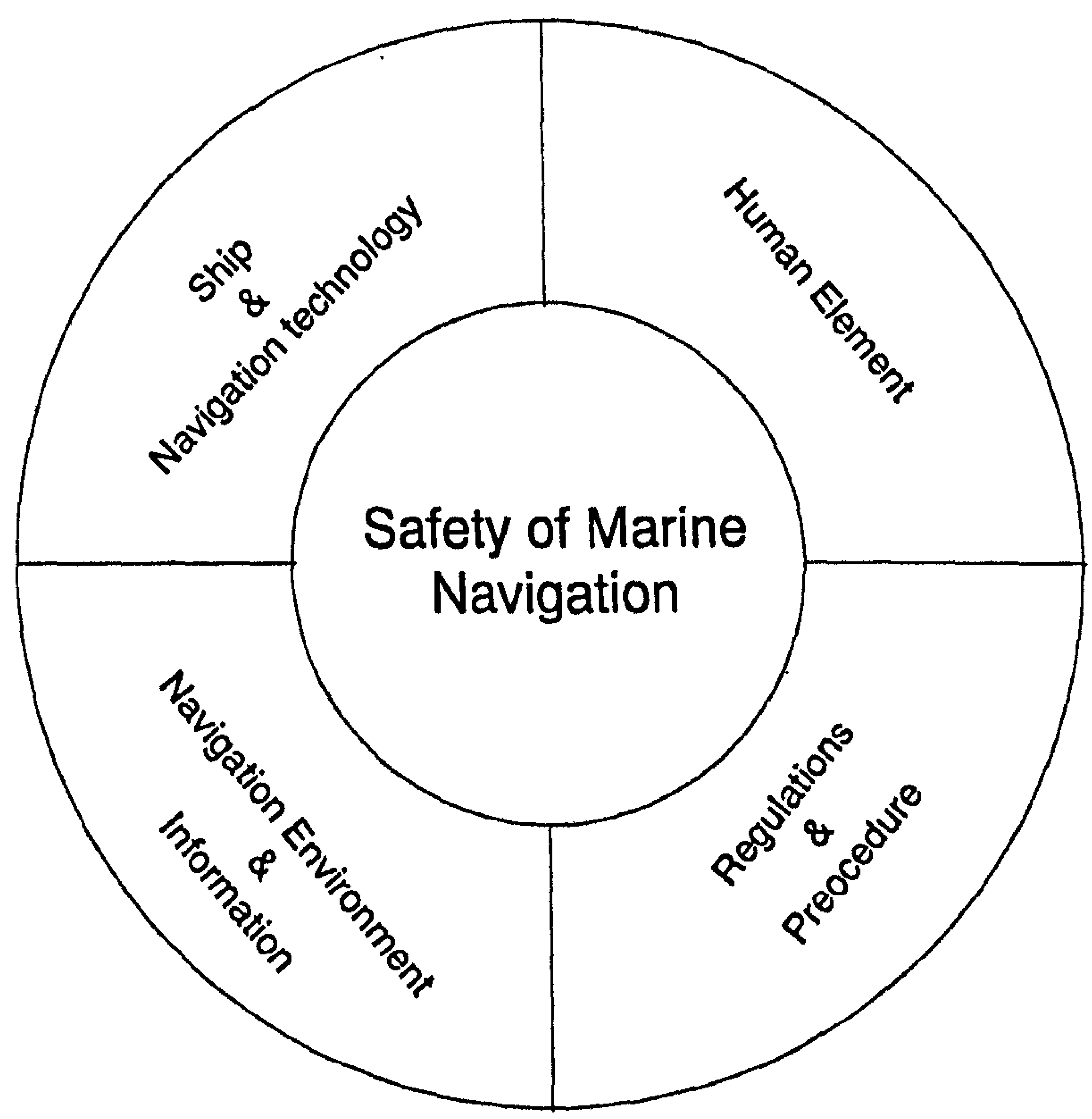

Figure 2. 1 Main elements of the safety of marine navigation

Interaction between different elements of the safety of navigation is very important. Therefore, any changes in each element or sub-elements should take place with considerations of the other sections. For example, introducing a new technology to improve safety should take into account the effects on the human elements (i.e., proper training is needed to operate or monitor the new equipment well before its mandatory use on board). Failure to consider human factors issues associated with new technology may sometimes not promote safety but actually put it more at risk.

IMO, as one of the United Nation (UN) agencies, in close co-operation with other international organisations such as International Association of Lighthouse and Aids to Navigation Authorities (IALA), International Telecommunication Union (ITU), International Maritime Satellite Organisation (INMARSAT), etc, is responsible for the safety of navigation. They provide rules and regulations through international conventions, circulars, notices, etc. IMO has also taken many steps towards safer navigation by implementation of new regulations and technologies. Safety of Life at Sea (SOLAS)-1974 Convention, International Regulations for Preventing Collisions at Sea (IRPCS)-1972, and Standards of Training, Certification and Watchkeeping for Seafarers (STCW)-1978 are examples of these conventions. It is understandable that, with rapid technological changes taking place in the maritime industry, safety regulations and procedures set by the organisation should also be updated accordingly to improve standards of safety at sea. Investigation after major accidents and incidents at sea is another source for updating regulations to promote safety at sea. The revised Chapter V of the SOLAS Convention dealing with safety of navigation is taking into account the new technological changes.

National authorities of the maritime states such as maritime administrations & ports organisations and classification societies play an important role in implementation of safety of navigation by enforcing the observance of good practice of the safety of navigation's regulation and requirements (Kopacz et al, 2001). Alderton (2004) believed that the major problem of maritime safety is the enforcement of legislation as not all states are willing or have the skilled personnel to implement the official safety requirements. The extension of enforcement of legal safety requirements to port states by 1978 SOLAS Convention and its later amendments is to overcome this implementation problem.

2.5 Human Factors Aspects of New Technology

Accidents and incidents in maritime operations are to a great extent dependant on human and organisational factors. Therefore, better integration of human factors into maritime operations can improve the overall safety of navigation. The interaction of humans with technology and technical systems, or the human-system interface, is very important in safety performance not only in the marine industry but also in all other industries. In the marine navigation system, human-system interface has a strong role due to the different and nearly exceptional nature of the working environment and conditions with adverse working conditions. Adverse working conditions can reduce human performance and affect efficiency of navigation and therefore reduce safety. Today's tasks of navigating officers on the bridge consist of many activities in different conditions of weather, visibility, and traffic, which are physiologically and psychologically very much different from tasks ashore.

The study of the impact of new intelligent technologies in complex, safety-critical systems on the performance of the system and operator is very important. The technology affects the system performance and the human is responsible for performing different duties, and supervising safety to improve performance of operation in the system. The amount of reliance of the operator on technology in safety-critical systems is a significant measure towards improving safety and performance, and therefore, it must be studied carefully. Impact of the use of technology in different stress and time dependant conditions is also very important to be understood (Grabowski and Sanborn, 2003). They also argued that level of familiarisation, confidence, and satisfaction of the operator would affect the amount of impact of technology on the system performance. In a qualitative analysis of some accidents by Johnson (2004) it is argued that many have developed when unexpected changes have occurred in operational requirements and needed fast programming in complex, safety critical systems. He believed that better and more effective training is needed for new technology users to be familiar with new programmable systems, to understand the limitation of such systems, and to improve their performance in teamwork operation. New technologies on board ships in the marine industry, the same as in any other industry, will bring about some changes and new requirement such as the demand for new operational quality and competence levels for mariners.

The introduction and development of new technologies on board ships has affected maritime education and training, which demands a new quality standard. In order to cope with new technologies on board appropriate utilisation of new training technologies such as simulators, computers, workshops and laboratories should be made. Important human factors issues, which must be improved to cope with rapid technological changes, involve factors related to incentive and motivation, management and command, mental workload, skill and competency level, and other factors related to physical and mental abilities of the human element (Mazzarino and Maggi, 2000). According to the American Bureau of Shipping (2003), systematic application of human factors engineering is very important in improving safety and efficiency. Many documents, circulars, and guidelines issued by the IMO and other organisations emphasised different aspects of ergonomics (interaction of human with technology in working environment). However, there is still a lack of efficient application of ergonomics in the maritime industry.

The introduction of advanced technologies often places new requirements on both the human element in the organisation and the organisation itself. New advanced technologies may relieve the operators from some of their usual daily tasks but they might increase the technical complication of the profession. This demands new levels of skill to operate new systems safely. Therefore, technical training requirement will change (Co et al, 1998). Further, automated technologies will affect the confidence and performance of the operators. Introduction of new advanced technologies, change in manning scale, and structural changes in the marine industry has changed the operation of ships and this trend will continue in the future as well. Therefore, the management of the human element in the marine industry is very important in ensuring an acceptable level of marine safety (Pomeroy, 2002). Both the human and technical factors are contributing to marine safety, and in safety assessment or accident investigation they should be examined separately as well as jointly. Pomeroy (2002) also pointed out that training and education ought to be updated and applied in order to take the development of new systems into account. He identified the case of the grounding of the Royal Majesty passenger ship and cited the lack of proper training of the crew in operation and management of new technologies on the bridge as one of the main aspects of the accident.

The majority of marine accidents involve some sort of human contribution and 75 – 96% of marine casualties have been due to human error, which makes the avoidance of human error an extremely important subject (Rothblum, 2000). Alderton (2004) believed that shipping casualties are seldom caused by one simple error and they often occur due to coincidence of several doubtful practices and actions together in one situation. He further thought that the causes of marine mishaps based on:

- Failure in communications.
- Imbalance between rapid speed of technological advances and awareness of potential hazardous consequences.
- Imbalance between rapid speed of technological advances and the ability of operators to efficiently use their new technologies.

According to Thompson (2003), human factors are affecting marine safety, and many existing accidents at sea directly result from human failure. Enhanced crew training, using the latest training technologies such as simulator and computer will result in a better understanding of human factors that affect safety and management at sea. Study of human factors such as communication effectiveness, human performance and intellectual capabilities and restrictions, human attitude and behaviours, workload and stresses can be very effective in improving safety. According to Rothblum (2000) some of the human errors at sea are not due to the direct fault of people and the errors are due to shortcoming and limitation of technologies and working environment. He further argued that inadequate involvement of human factors in design processes might cause poor interaction between operator and technology. Alderton (2005) argued that ship safety is mostly related to ports and most of the safety related problems arise in the port environment or in the port approaches. He further mentioned that only 19% of the safety problems take place in open water.

The fast technological modernisation and development, with economical forces, resulted in big changes in marine industry and the ways in which ships are being operated. These changes will demand better understanding of human factors and requirements of the users of new technologies on board ships. Marine simulators can be used for these purposes. As the use of simulators for training purposes has been accepted in STCW 95, simulators can be used to improve the mariners' abilities in ships' operation. Simulators can be used to study the efficiency of different actions taken by the mariners without any consequences of taking an incorrect action or decision in a complicated situation that is not possible in real working conditions. It can also be used to practice all other navigational activities on the bridge such as bridge procedures, team work, and passage planning by navigators in different stages of their sea services (Mantel, 2000).

Safety has largely been improved due to new technological and engineering changes in recent years. However, sometimes there has been an unintentional safety reduction caused by unexpected impacts of new technologies on the human or other organisation factors. It has been claimed (Baker and McCafferty 2005; Steber, 2005) that human error is the cause of the majority of accidents at sea. Human factors such as fatigue, negligence, inadequate training, poor communication and teamwork, equipment design problems, etc. are sometimes responsible for such errors. Therefore, more attention should be paid to the human element in marine systems. Different parts of the system are consistent and changes in one part of the system may influence the other components, and therefore, may affect the overall safety of the system (National Research Council, 1997). Proper research and improvement in human and organisational aspects are essential for preventing human errors and improvement of the safety of marine systems. Proper research should be carried out on the different human factors aspects of new technology such as interface design to properly evaluate performance, decide on requirements, and set principles and standards.

Proper human factor research and application of principles of human factors to new technologies on board can improve design and new systems operations, and therefore, will improve safety (Transportation Research Board, 2003).

Pomeroy (2000) highlighted that new technologies can result in more complex human interfaces. Sometimes the complexity of the interface may introduce problems for operator performance that will increase the possibilities of accidents in the marine industry. He believed that the standards, regulations, and specifications have not been promoted in accordance with the increase in technological complexity of the system. He also mentioned that involvement of human element in operation of advanced and complex systems on board ships is different with old traditional systems. With new complex technologies, integration of the operator and system will increase. Therefore, new standards and measures in the marine industry are needed in order to integrate the human element into system design, and development of marine systems. He concluded that, as the marine systems are hybrid human-technical structures, human factors should be considered more actively for better improvement of marine safety.

Today, many different classes and types of ships are built for different missions to perform a wide range of tasks. Therefore, control and navigation of these wide varieties of specialised ships will include many functions, such as planning, and operation in an ever-changing surrounding environment with different mission and threats. The officers in charge of the navigational watch on the bridge have to undertake many duties and activities such as: navigation, collision avoidance, communication, monitoring different systems and operations, and management. They should also do the planning for additional tasks such as cargo operation, ship maintenance, etc. Application of new technologies and equipment on board, due to requirement by regulations, or willingly, might impose additional workload on the OOW and demand further requirements and needs. Alderton (2004) pointed out that the growing number of specialised ships and trades along with the increased amount of complicated technologies requires some improvements in training of seafarers. He further added that navigation safety and capability could be improved by standard education and training of the seafarers in accordance with STCW (Standards of Training, Certification, and Watchkeeping) Convention.

Some of the most important aspects of the use of AIS are to understand proper process and operation of the equipment itself, its integration with other equipment, and management of the information provided for navigation and the collision avoidance function. Simulators could be used, as modern training and research tools, to evaluate new technologies prior to technology implementation so that corrective action can be taken. Simulation provides cheap, safe, and fast means for research and training. Simulators can present situations and circumstances that are rare and infrequently happen on the actual job.

The shipping industry with great diversity of navigational challenges and severe changes in weather condition, visibility, and wind has a critical nature. Therefore, any new technology should only be introduced with a high degree of concern and care.

2.6 Discussion and Conclusion

The result of the literature review on new technology in the marine industry showed that many aspects of the technologies have experienced advances and new sources of navigational information have been introduced to the ships' bridge. Despite a number of advantages of the advanced and automated technology in improvement of performance and safety of navigation, there have been some unforeseen impacts of such technologies, which may have negative impacts on human elements. Examples of the negative impacts could be over-reliance, reduction in competency level, deficiencies due to improper implementation, inadequate regulation and procedures, etc. Improper consideration of human factors in technology implementation could result in errors that may lead to catastrophic events. The nature of the marine environment with diverse conditions may intensify the problems at sea. Research on interaction between human and technology is of paramount importance in avoiding chances of error due to human-technology mismatch.

Although the AIS is a very new navigational aid on board ships, it has attracted much attention and its use has been under observation by a number of researchers. There have been few in-depth AIS studies before and after its implementation. However, the introduction of AIS technology in marine navigation has been associated with a number of debates and disputes on the use of AIS as a navigational aid for anti-collision purposes. Proper standards on the use of AIS, accuracy of the AIS information, its impact on the other navigational aids such as radar, its display issue, its impacts on VHF communication, its impacts on VTS, AIS concern related to non-SOLAS vessels, and some human factor aspects of the AIS such as navigators training on the basic operations, capabilities, and limitation of AIS were some of the most important issues observed during literature review. The need for further research was also highlighted in the literature reviewed.

The importance of the safety of marine navigation due to considerable impacts of marine accidents on the safety of life, property, and environment was emphasised in a number of studies. It was concluded that 4 main elements of safety of navigation are the ship and its navigational technologies, navigational information and environment, regulations and procedures, and human element. Introduction of new technology should be with consideration of all the elements contributing to safety of navigation. with special emphasis on the human element as the most flexible and managing part. It was pointed out in the literature that the majority of marine accidents are caused by some sort of human contribution and errors. Some of the causes of the marine accidents are the imbalance between pace of technological changes and awareness of their consequences and imbalance between the rapid speed of technological changes and the training of the operators. Proper consideration of human factors in introducing new technology on board could improve safety in marine navigation operation. Changes in ship operation due to technological development require proper understanding of the requirements of the frontline operators. This could be achieved through human factor consideration during different stages of technology implementation.

Proper operation, data integrity and maintenance, utilisation in navigational operations, and information management of the AIS should be properly investigated as they could affect technological success. In the case of radar technology, it took about 20 years from the date of its introduction in the British Merchant Navy for the navigators to use radar technology competently. Many radar-assisted collisions occurred during this time (Alderton, 2004) and training was only instigated after. AIS research could resolve the associated AIS problems such as issue related to its quick mandatory implementation, and further could reveal its practical advantages and disadvantages on promotion of safety of navigation. Therefore, this research will first study aspects of the accuracy of AIS information. Secondly, it assesses the navigators' AIS satisfaction with the help of a questionnaire survey in order to discover the extent of use of AIS on board ships. Finally, it reviews some of the common theoretical models of human attitude and behaviour in order to identify a suitable model for measuring user satisfaction with AIS and other similar technologies.

2.7 Summary

This chapter has carried out a re-examination of the available literature on introduction of new technologies in the marine industry, especially the introduction of AIS for navigation on the ships bridges. Different reasons for the application of new technologies and incentive for AIS application were also discussed. Some of the possible impacts of new technologies, and AIS in particular, on navigational operation were investigated. Some of the AIS issues highlighted in the literature were reviewed in order to set up the scene and basis for this research. Different views about the importance of the safety of navigation, main constituting elements of the safety, and impact of new technology on the safety were discussed.

Human factors' aspects of implementing new technology, the role of human element in marine navigation, and human contribution to marine accidents were reviewed. It was concluded that, due to different navigational challenges and the diversity of the marine environment in the shipping industry, new technology should only be introduced with particular concern and care. Further, AIS research is needed to investigate about different issues affecting AIS usefulness as a navigational aid.

Further literature on AIS will be reviewed and discussed in chapter 3, which is an overview of AIS technology. Some other literature on human factors and human error will also be discussed in chapter 4.

Chapter 3

Automatic Identification System (AIS)

3.1 Introduction

Wireless digital communication is the basis for many high technology systems of today. With the latest VHF (Very High Frequency) digital modulation, communication of data on the radio frequency bands is faster and more reliable. Satellite navigation technology allows accurate and reliable automatic positioning for all kind of vessels. The differential Global Positioning System (DGPS) with increased accuracy in positioning and rapid exchange of other data has provided feasible means for automatic transponders. Improvement of satellite navigation and digital data communication systems are the basis for integration of navigation and communication systems. With transmitting and receiving of digital data containing navigational information to and from other ships by means of VHF radio transmission used in AIS (Automatic Identification System) the precise and accurate identification of ships is available. Application of the principle of automatic reporting of information, including collision avoidance and situational awareness, can improve safety of navigation and marine environment (European Organisation for the Safety of Air Navigation (EUROCONTROL), 2002).

Development of AIS technology initially was for use in Vessel Traffic Systems (VTS) but a transponder system with automatic operation using VHF radio band for ship-to-ship and ship-to-shore use was suggested by some of the Scandinavian states to IMO. Consequently a system called ship-borne Automatic Identification System (AIS) was adopted by IMO. The performance standard of ship-borne AIS was recommended by an IMO sub-committee on safety of navigation (NAV) in 1997 and upon approval of the IMO Maritime Safety Committee (MSC) in 1998 was introduced under resolution MSC.74 (69). On a request by IMO in 1997, the International Telecommunication Union (ITU) allocated two radio channels as: AIS1 (161.975MHz) and AIS2 (162.025MHz) to be used worldwide on the high seas, for the automatic ship identification and surveillance system. Under the initiative of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) a draft of the technical characteristics of AIS was prepared and submitted to the ITU Radio-communication Study Group. Then the technical characteristics for a ship-borne AIS using Time Division Multiple Access (TDMA) in the maritime mobile band were formally approved by ITU in November 1998 (ITU-RM.1371-1). Following the adoption of the IMO performance standards and the

ITU technical characteristics, the standard for operational and performance requirement, and testing requirements to be used by administrations for approval of the type of AIS equipment to be fitted on SOLAS convention ships, was adopted in 2001 (SAAB Transponder Tech AB, 2004; and IALA, 2002a).

This chapter covers an overview of the AIS technology in order to provide the reader with a comprehensive explanation and understanding of the technology. Firstly, mobile AIS stations will be covered in section 3.2. Secondly, this chapter covers fixed AIS stations in section 3.3. AIS accuracy and security issues will be covered in section 3.4. Finally, section 3.5 contains the conclusion of this chapter.

3.2 Mobile AIS Stations

According to the recommendation ITU-R M.1371-1, AIS stations are subdivided into "mobile" and "fixed" stations, which are based on the capability and intended purpose of the AIS stations. It is the capabilities of the station to control the AIS VDL rather than the physical degree of mobility that determine whether it is mobile or fixed (IALA, 2002b).

Mobile stations are not able to control the VDL and are to be used by mobile AIS members, such as ships, SAR aircrafts, and floating aids to navigation (A to N). Mobile AIS stations include (IALA, 2002b):

- Ship borne Class A, B, and A derivatives stations.
- SAR airborne stations.
- A to N stations.

3.2.1 Ship borne Mobile AIS

Shipborn mobile AIS must fully comply with the VDL principles. They are required to recognise different types of messages, but the way in which they process the messages, their interfaces to external display systems, and sensor system may be different between different types of AIS stations (IALA, 2002b).

3.2.2 IMO Carriage Requirement

In 2000, IMO (International Maritime Organisation), to ensure safe navigation, adopted a new requirement for ships to carry Automatic Identification Systems through amendment to chapter V of SOLAS (Safety Of Life At Sea) Convention. Mandatory carriage of AIS

EXCLUDED UNDER INSTRUCTION FROM UNIVERSITY by SOLAS vessels was in a phase approach, from 1st July 2002 to July 2008, but later there were some modifications at IMO Conference of Contracting Governments to the International Convention for the Safety of Life at Sea, 1974, 9-13 December 2002. According to the latest modifications to regulation 19 of chapter V (Safety of Navigation) of the Convention, AIS should be fitted aboard ships as shown in table 3.1 (IALA, 2002a):

Table 3. 1 AIS carriage requirement (source: IALA, 2002a)

As the IMO carriage requirement only applies to SOLAS Convention ships, there are no international regulations that can oblige non-SOLAS ships such as ships navigating in inland waterways, small fishing vessels, and pleasure craft to carry the AIS equipment on board such vessels. It is left to discretion and judgement of national state administrations and operators to provide their own implementation plan for use or not to use AIS, by non-SOLAS Convention vessels, to improve the safety of marine navigation and consequently safety of life at sea. It is evident that small crafts do not need all data, which is transmitted by AIS equipment for SOLAS ships, but what is important for them is their identification by large ships and traffic control stations. Further, the current price of the Class 'A' AIS for small vessels does not appear to be sensible. Therefore, another class of AIS with less data, which will be cheaper, may be used for non-SOLAS ships (see section 3.2.7.2).

3.2.3 General Description of AIS

The AIS technology initially called ship-to-ship, ship-to-shore transponder, later known as "universal ship-borne Automatic Identification System (AIS)" is introduced with the overall aim to promote the efficiency of navigation and enhance safety of navigation, protection of marine environment, and safety of life at sea. It is intended to provide a clear traffic view to ships and shore stations with fitted and operational receiver.

It is a system operating on VHF maritime mobile radio band and broadcasting required information in a continuous and autonomous mode. It exchanges data regarding navigational and voyage related information of ships and other related messages with other ships and shore stations. It can handle multiple reports at very high update rates depending upon navigational conditions and speed of ships.

AIS transponder uses Self-Organising Time Division Multiple Access (SOTDMA) VHF Digital Link (VDL) for its reliable operation. VDL is self-synchronising and unlike other modes does not rely on a ground station to provide the channel synchronising signal for Time Division Multiple Access (TDMA) and therefore, permits ship-to-ship communication in absence of a ground station. The Global System for Mobile communications (GSM) is an example of TDMA system.

3.2.4 Principle of Operation

Two VHF frequencies in the maritime mobile band have been allocated for AIS use, VHF channel 87B (161.975 MHz) for AIS1, and channel 88B (162.025MHz) for AIS2. These channels will be used for worldwide automatic identification and surveillance of ships. All the data transmitted will be framed in one-minute frames by an AIS terminal. One minute of each AIS channel has been divided into 2,250 slots. Each time slot will have duration of $\left(\frac{60\,\text{sec.}}{2250\,\text{slots}}\right) = 26.7$ m.sec.. Therefore, there will be a total of $2{,}250 \times 2$ = 4,500 slots of 26.7 milliseconds together available in AIS1 and AIS2 channels. This process of dividing up a channel into time slots is called Time Division Multiple Access (TDMA), (see figure 3.1).

Every ship will use these radio frequencies to transmit and receive predefined ship related information and messages with collected data through sensors from other ship's equipment such as gyrocompass, GPS, speed log, etc. This transmission and reception of information is in a Self-Organising Time Division Multiple Access mode at rapid update rates to and from all vessels and other stations within the coverage range, which is 20 to 40 nautical miles. The coverage range depends mainly on the height of antenna above sea level, which is related to size of the ship, and other environmental conditions for VHF radio frequency.

The information transmitted from AIS will be in time slots of 26.7 milliseconds duration with 256 bits of data at a rate of 9600 bits per second. In figure 3.1, when ship 1 transmits its message on one time slot the next time slot will be simultaneously assigned for its next message. As these time slots have been assigned by ship 1, ships 2, 3, and other ships will send their messages in another time slot but in the same way as ship 1. If some ships are out of VHF range from each other, or if there are limited available slots, there is a possiblity of the same time slot being used by two or more ships which are out of VHF range of each other (see figure 3.2 as an example), but there may be other users in between that are in their radio range, and therefore, experience slot contention . To reduce chances of data packet collision, SOTDMA employs a procedure whereby user can change its current and reserved time slots if it notices other users competeing for its reservation. Further there is an additional AIS protocol that only allows the closest ship to be heard. Because of these abilities of AIS which resolves the access problem without user concern and involvment it is called Self-Organising Time Division Multiple Access (SOTDMA). By formation of a cellular system with every ship at its own centre, the problem of system overload has been prevented and this has made the AIS system a very secure and reliable identification system (Pettersson, 2002). Other modes of operation of AIS are:

- RATDMA (Random Access Time Division Multiple Access), used for random slot allocation and higher update rates initiation.
- FATDMA (Fixed Access Time Division Multiple Access), used by shore stations for high level of throughput, different update rates and non-frequent transmissions.
- CSTDMA (Carrier-Sense Time Division Multiple Access), used by Class 'B' AIS that cannot pre-assign time slots, and transmits only when a slot is free.

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- ITDMA (Incremental Time Division Multiple Access), used for slot allocation in the next time fram for achieving faster update rates.

Figure 3. 1 Self-organising time division multiple access principle used in AIS (adopted from: Bole et al, 2005; IMO, 2002a)

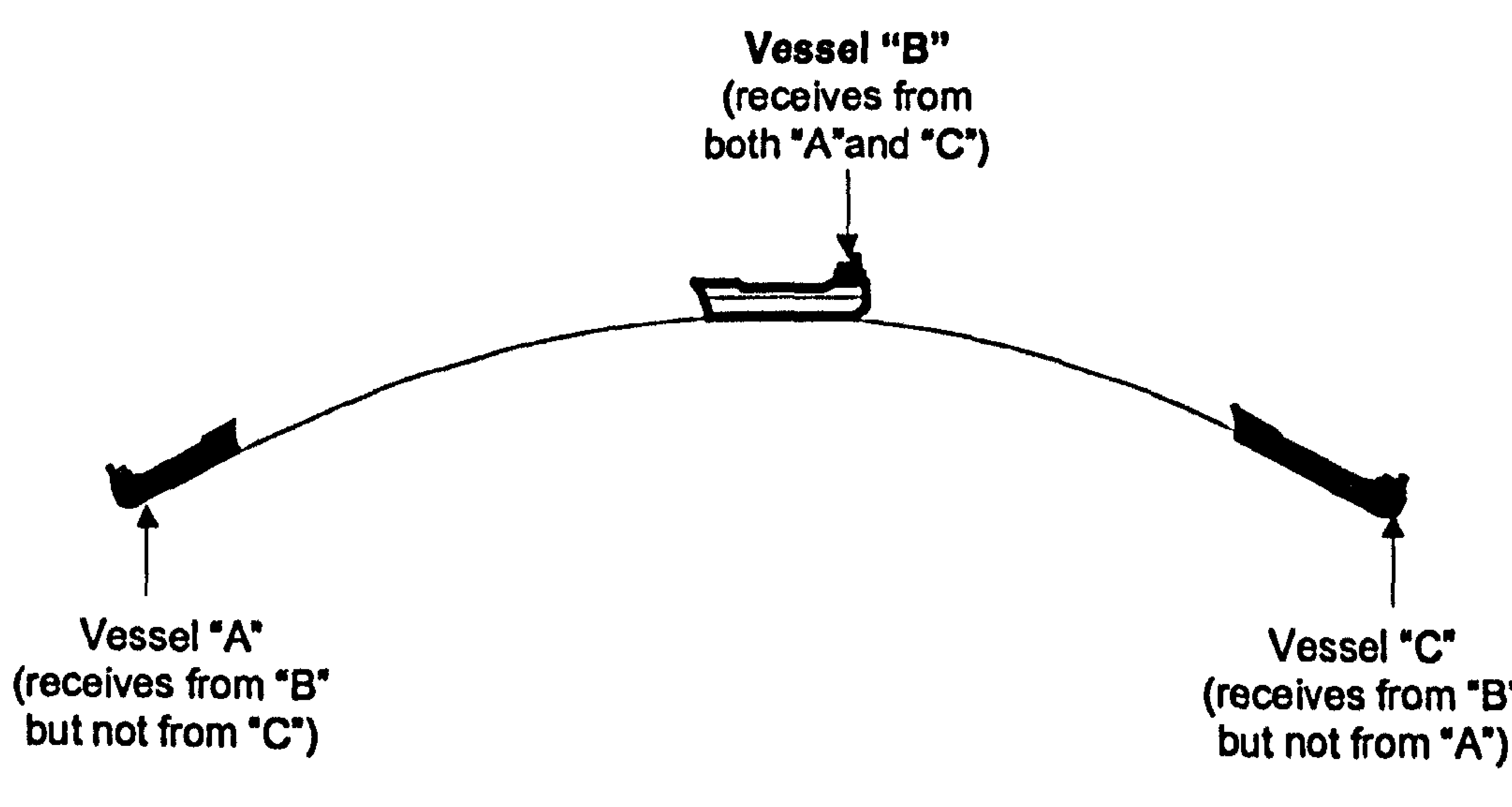

Figure 3. 2 Potential information collision at vessel "B" in SOTDMA

3.2.5 Types of AIS Messages

The AIS messages contain different types of information and are classified as static data, dynamic data, and voyage related data. Transmission of messages with the more important data such as voyage related data are prioritised over the other messages.

Static data is entered into the AIS on installation and needs to be changed if the ship type changes by a major conversion or if her name or ownership changes, voyage related data is entered manually during each voyage, and Dynamic data will automatically be updated through the AIS connected ship sensors (Callsen-Bracker, n.d.; Nauticast, n.d.). The following information is included in the AIS messages (IALA, 2002a):

3.2.5.1 Static Information

IMO and Maritime Mobile Service Identity (MMSI) numbers

Call sign and name

Type of vessel (cargo, passenger, tanker, etc.)

Length and beam

Location of position fixing antenna such as GPS/DGPS (aft of bow, port or starboard of C/L)

3.2.5.2 Dynamic Information

Ship's position with accuracy indication (for better or worse than 10m) and integrity status

Time in UTC (Coordinated Universal Time)

Course over ground

Speed over ground

Heading

Navigational status (e.g., not under command, constrained by draught, etc.)

Rate of turn (where available)

Angle of heel (optional)

Angle of pitch and roll (optional)

3.2.5.3 Voyage Related Information

Ship's draught

Type of cargo

Destination and estimated time of arrival (at master discretion)

Route plan-waypoints (optional)

Number of persons on board (on request)

3.2.5.4 Short Safety Messaging

Short text messages with important navigational safety related information are shown in an extra window.

3.2.6 AIS Components

Figure 3.3 shows the principle components of ship borne mobile AIS station. These components are (IMO, 2002; and IALA, 2002b):

- **D/GPS (Differential / Global Positioning System) receiver input**: GPS or DGPS is providing for back up of ship's information such as position, course over ground (COG), and speed over ground (SOG).
- **DSC (Digital Selective Calling) VHF receiver**: This receiver is fixed on channel 70 (156.525 MHz) for channel managements and DSC polling.
- **VHF transceiver**: This part is equipped with one transmitter and two receivers for TDMA operation.
- **Controller**: this controller will manage functions of different parts of the AIS. It is the controller unit that will process all the input and output signals.
- **Internal GPS (Global Positioning System) receiver**: internal GPS is providing Coordinated Universal Time (UTC) for synchronising transmissions for preventing transmission overlaps. It is also providing ship's position information, course and speed over the ground.
- **Power supply**: the equipment should be connected to an emergency power source in addition to the main supply.
- **Gyro compass**: providing Heading and rate of turn. In some ships the ROT indicator may not be available (it is optional), which in that case turn direction will be derived from Gyro compass that provide heading information.
- **Speed input**: is connected to ships speed log.
- **Alarm output**: must be connected to an audible alarm device or ships alarm system.
- **Display system**: present the AIS information consisting of data and graphics on internal and external equipment.

Internal display System: is a built in MKD (Minimum Keyboard and Display) system which is the minimum requirement by the IMO.

External display systems: can be a remote stand-alone graphical display unit or integrated with other navigational equipment if capable of processing and displaying

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AIS information such as: Radar/ARPA, and ECDIS via the AIS presentation interface (input/output).

Pilot plug: plug connected to the ship's AIS system to be used by the pilot for interfacing with his personal equipment while engaged on pilotage duty for input and output of data.

Figure 3. 3 AIS Block diagram showing different components (source: IALA, 2002b)

3.2.7 Types of Ship borne AIS

There are three types of AIS mobile equipment for vessels. All of them should transmit and receive required information via VDL (VHF digital Link) to and from other stations within the radio range, as described above.

3.2.7.1 Class 'A' AIS

Class 'A' is any AIS, which is in full accordance with IMO carriage requirements. It should comply with ITU, IEC, and IMO performance standards. All SOLAS Convention ships should use this class of equipment.

3.2.7.2 Class 'B' AIS

Class 'B' AIS, with fewer features and reduced cost, provides information not necessarily in full accordance with IMO carriage requirements as required by Class 'A' AIS. It should function on VDL principles. The standard for Class 'B' equipment was proposed by Technical Committee 80 Of the International Electrotechnical Committee (Royal Institute of Navigation, 2005). The Class 'B' AIS is nearly identical to the Class 'A' but it is different in the following features (Dziewicki, 2006):

- Has a lower rate of information update than a Class 'A'.
- Does not transmit IMO number or call sign, ETA or destination, navigational status, rate of turn information, and draught.
- Requirement for text safety messages and binary messages is only to receive, and not to transmit.

The result of a study by Working Group 8a of the Technical Committee 80 of the International Electrotechnical Commission (Royal Institute of Navigation, 2005) has proposed a design using Carrier-Sense Time Division Multiple Access (CSTDMA). There is no difference in reception of information from other ships and safety messages between Class "A" and proposed Class "B" AIS. The difference is in the transmission procedures where Class "B" cannot pre-assign time slots and transmits only when a slot is free. Since the transmitted message for Class "B" AIS is limited to a single slot therefore it can transmit a position report of the vessel same as Class "A", but safety messages and other ship's information such as name, call sign, etc. cannot be transmitted. To reduce costs, standard for Class "B" AIS specifies a transmitter power of 1 Watt for a range of about 3 miles, requirement for built in GPS and no need of external GPS, no requirement for any other sensors from navigational equipment as required for the Class "A". The update rate of transmission of 30 seconds, and means to switch it off by shore based competent authorities through added special message will overcome possible overloading of the AIS channels.

3.2.7.3 Class 'A-Derivatives'

Any other varieties of AIS equipment not yet defined which will be used for professional applications by ships not falling in SOLAS categories (i.e., ships navigating on inland waterways) are called Class A-Derivatives. This type functions the same as Class "A" AIS (IALA, 2002a; IALA, 2002b).

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3.2.8 Rate of Information Update

For the AIS to provide almost real-time information maximum of 2000 reports per minutes has been selected in autonomous mode, with update rates given in tables 3.2 and 3.3, (IALA, 2002a; IMO, 2002). When ships are altering their course and speed update rate for some data will vary to get more accurate rate of turn prediction. This increased update rate depends up on the required position accuracy.

Table 3. 2 Update rates for Class "A" ship-borne AIS (source: IALA, 2002a)

Table 3. 3 Rate of update for Class "B" ship borne AIS (source: IALA, 2002a)

3.2.9 Types of on Board AIS Display

The ways of displaying AIS information are very important because the system displays are means of converting AIS data into useful information and representing them to the users. As the operating environment and condition in which AIS information should be introduced to mariners are diverse, the design of the AIS display as an interface between technology and humans has got a significant impact on the usefulness and effectiveness of the system for safety of navigation. The display systems should be designed in such a way to deliver direct and clear information to prevent increase in bridge team workload. As the display system in AIS technology is the most important interface between technology and human element, the efficiency of information exchange between AIS stations, up to a great extent, depend upon the display system. The present available types of AIS displays are as follow (IALA, 2002a; Transportation Research Board, 2003):

3.2.9.1 MKD (Minimum Keyboard and Display)

MKD is the basic display means of the AIS system that is required by the IMO regulation for SOLAS vessels with minimum of three lines of 16 characters alphanumeric information to obtain target vessels data on a LCD (Liquid Crystal Display) screen and a simple keyboard for data input and control of the equipment by the navigating officers on the bridge. The data shown on MKD include position, bearing, range, and name of particular target ship. Vertical scrolling of data will show other AIS detected targets and horizontal scrolling will provide additional data of the selected ship. MKD is the lowest possible cost system, which can be installed on the bridge. The problem with this display system on the bridge is that it may not provide adequate information for the OOW and causes distraction due to requirement for getting further detailed information from other navigational equipment such as radar/ARPA and ECDIS, or plotting the targets positions on the chart. This could be disadvantageous to the safety of navigation and therefore, minimum requirement for AIS display may need to be changed. Figure 3.4 is an example of MKG equipment.

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Figure 3. 4 MKD AIS (source: SIMRAD Yachting, 2006)

3.2.9.2 Stand-Alone Graphical Display

Stand-alone graphical display can be a sophisticated personal computer (PC) graphical display similar to radar. However, in a stand-alone graphical display only AIS targets will be displayed and their information will be shown. It is a full colour and high-resolution screen. A full keyboard can be included for data input. With AIS information of the targets given on the screen, such as range and bearing, they can be recognized on the radar screen.

Another type of stand-alone graphical display is a less sophisticated simple display screen with low-resolution monochrome, which shows the graphical marine traffic environment and AIS targets using simple icons. The AIS information, such as position, bearing, range, course, speed, and etc., is displayed for each target vessel.

Certain target types with particular symbols for displaying in a stand-alone AIS graphical display have been recommended by IMO sub-committee on safety of navigation (NAV) at its 47^{th} session on July 2001. The following types of target have been recommended (IALA, 2002a):

Sleeping target indicates only the location of AIS equipped vessel. Additional information of such vessels will not be shown until the operator acquires it. That can be useful for preventing information overload on the bridge.

Activated target is a particular vessel (sleeping target) activated by the operator to get some dynamic information such as COG, SOG, and heading about that vessel.

Selected target is a vessel (sleeping or activated) selected by the operator to get its detailed information including special navigation status, closest point of approach (CPA), and time to closest point of approach (TCPA).

Dangerous target is a target that getting closer than predefined limits for CPA and TCPA, and therefore, is being regarded as a dangerous vessel. Display of this type of target will be associated with an alarm.

Lost target is a target previously displayed on the AIS but currently its signal is not received. The lost target symbols will be displayed with an alarm.

Table 3.4 shows IMO recommendation on AIS symbols for different targets (IALA, 2002a).

The amount and speed of information supplied to the OOW by stand-alone type of display is more than MKD.

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Table 3. 4 Recommended AIS targets symbols by IMO (source: IALA, 2002a)

3.2.9.3 Integrated Display

AIS has the capability to be integrated with some other navigational aids available on the bridge, and AIS graphical information can be shown on graphical display of the particular navigational equipment. This integration can increase benefits of AIS use. Most common navigational facilities for integration are radar/ARPA and electronic chart display and information system (ECDIS). The integration of AIS information with radar/ARPA and ECDIS will probably increase the degree of sophistication. Some of today's radar/ARPA and ECDIS that are being installed on ships bridges have the capability to present AIS information on their graphical displays but display of AIS information on old radar/ARPA and ECDIS may not be possible. Currently, there is not a regulatory requirement for ECDIS to be carried on board ships. Therefore, requirements for integration of AIS information with ECDIS may not be very effective in resolving problems associated with the AIS display of information. The adoption of the revised performance standards for radar equipment, by IMO Maritime Safety Committee (MSC), in 2004, set out new requirements for marine radars (Bole et al, 2005). The integration and display of AIS information should be provided in radar equipment. mandated by SOLAS Convention, on or after 1st July 2008 (see table 3.5).

Table 3. 5 New radar's performance requirements for various SOLAS Convention vessels (source: IMO, 2004)

According to information given on display of radar/ARPA integrated with AIS, the OOW will be able to differentiate which targets are equipped with AIS and which ones are not. Of the important issues in AIS integration with radar/ARPA to consider are the possibility of screen overload with danger of information overload for the OOW, and correlation and fusion of radar/ARPA and AIS data (SWAN Consortium, 2001). Figure 3.5 shows an AIS display integrated with ECDIS, and figure 3.6 is an example of its screenshot. An example of a screenshot of AIS display integrated with radar is shown in figure 3.7.

Figure 3. 5 Display of AIS integrated with ECDIS (source: SIMRAD Yachting, 2006)

Figure 3. 6 A screenshot of AIS integrated with ECDIS (source: SIMRAD Yachting, 2006)

Figure 3. 7 A screenshot of AIS integrated with Radar/ARPA (source: Buffalo Computer Graphics (BCG) Inc., 2007)

3.2.10 SAR Airborne AIS Station

The search and rescue (SAR) aircraft station is an AIS system certified for installation on aircraft used in SAR operations. Using SAR aircraft AIS station, ships, aircrafts, and operation co-ordinator will be able to know each other identity and position, and communicate with each other via text or binary messages. The transmission rate of update for SAR aircraft position is ten seconds. A SAR aircraft AIS station could be used to relay ship information over a wide geographical area to a rescue co-ordination centre (RCC) with the help of a separate communication link (IALA, 2002b).

3.2.11 Aids to Navigation AIS Station

Both the floating and fixed aids to navigation may be equipped with AIS capable of transmitting AIS messages in more than one format. Application of AIS to Aids to

Navigation is to promote and enhance safety and efficiency of navigation by one or more of the following (IALA, 2002b):

- Providing means for positive identifying an aids to navigation on AIS display in all weather conditions.
- Complementing existing signals from aids to navigation.
- Broadcasting position of floating aids to navigation more accurately (by DGNSS).
- Monitoring, indicating and tracking of possible off station and drifting of aids to navigation.
- Establishing reference points for radar.
- A possible replacement of, or complement to, racons.
- Providing data on weather, tide and sea state.
- Identification of vessels involved in collisions with aids to navigation.
- Gathering real-time information for condition monitoring.
- Remotely controlling changes in parameters of A to N.

Implementing AIS on aids to navigation may be in the following ways (IALA, 2002b):

- By an actual AIS mobile unit of real A to N.
- By a synthetic AIS A to N.
- By a virtual AIS.

3.3 Fixed AIS Stations

Apart from AIS application to vessels for ship-to-ship communication of information, installation of AIS ashore was also considered for exchange of information between shore station and ship to further enhance the safety of marine navigation. Fixed stations have much superior control on the VDL than mobile AIS stations, and are to be used by the shore based competent authorities when setting up their AIS service, such as a base station. A fixed station could be mounted on a mobile device such as a light vessel. A fixed AIS shore station is a physical AIS unit, which exists on its own. Components of a fixed AIS shore station include (IALA, 2002b):

- AIS base stations or AIS repeaters (simplex or duplex).
- VHF/RF equipment.

- Power supply.
- Resource for data transfer to and from the base station (controller).
- Shelter against environmental damage (physical protection facilities).

3.3.1 The AIS Base Station

The base stations are the most essential part of the fixed AIS station ashore. They are interfacing AIS equipped vessels with any complex ashore within their radio coverage area through the defined VDL protocol. Transmission of information from ships to shore services and relay of messages from shore to ships will be done through base stations.

3.3.2 The AIS Repeater Station

The AIS repeater station is used to increase the AIS base station coverage, or to resolve the radio broadcast problem in coverage area by relaying all the received AIS traffic. It should be used with caution, as the load of VHF Data Link will be doubled for AIS mobile stations.

3.3.3 The AIS Network

The AIS networks ashore will connect shipside and shore side AIS systems. These networks will enable the authorities of coastal states to exchange real time information and data between shore stations, between shore and ships, and between ships, which are out of VHF range of each other. Indeed, management of AIS communication between all different parties will be done by network system, which includes collecting, storing, processing, and broadcasting of data. The AIS network can handle safety related information, weather information, aids to navigation, and any other necessary information. It will send the messages to the visible participants and queue the messages for the vessels, which are out of reach until they are within coverage range of the network. The levels of users' communication capability and access to the system information can be limited to their needs and requirements by filtering function but the system administrator has the unrestricted access to the system. Layout, size and number of component of the network system depend on different requirements such as the area to be covered and AIS traffic. The basic AIS network elements, which are required in all different circumstances, consist of the following (IALA, 2002a; IALA, 2002b; Baltic Marine Environment Protection Commission, 2002):

- Base station.

- Controller or interconnection network.
- AIS network application.

It is import to mention that functionality of AIS network ashore does not affect the ship-to-shore communication function in any way.

AIS network is an integrated system consists of a set of infrastructure with interconnected base stations and shore facilities that can be used for routing of information in following cases:

- From base station to shore facility (for routing of vessel and AIS position reports within certain VTS coverage area to correct shore facility).
- From shore facility to a mobile AIS (for routing of traffic management and information messages to the base station which the vessel that the message has been addressed is within its coverage area).
- From one mobile AIS to another mobile AIS (for routing of messages between mobile AIS units which are outside of coverage area of each other but within the network coverage area).

The AIS network systems can be on a national or regional level using Local Area Network (LAN) connection, or on international level using devoted line or connection to the Internet.

3.4 AIS Accuracy and Security Issues

AIS can improve identification of targets when visual identification is difficult, especially at night or in reduced visibility by automatic and transparent data exchange between ships. This could improve situational awareness for navigators by providing clear identification of all other AIS-equipped vessels. For the AIS to best serve its users and to improve operational efficiency and marine safety, it is necessary to have a good understanding of its operational issues and level of accuracy. The following are some of the AIS operational and accuracy issues (MCA, 2002; Ramsvik, n.d):

- Some of the AIS information being entered manually (by navigators or equipment installers) may be associated with error.

- The accuracy of position, COG, and SOG is fully dependent upon GPS/DGPS. Any failure in GPS is giving no position and thus incorrect or no position transmission by AIS.
- There is less than 100% of world coverage of GPS and in these areas AIS would not work.
- It is possible that AIS data be used by unauthorised people, or set up "ghost AIS" to send false data.
- AIS may be used as a screening tool for pirates, terrorists, and all others with a simple AIS receiver.

3.5 Discussion and Conclusion

AIS technology was initially intended for use in VTS ashore but it was implemented for ships use by IMO, prior to its adoption by VTS stations. The overall aim was to promote the efficiency and safety of navigation, protection of marine environment, and safety of life at sea. The main organisations that were engaged in setting the AIS technical characteristics and standards, and regulations for AIS carriage are IMO, IALA, ITU, and IEC. The AIS stations are subdivided into mobile and fixed stations according to their capability in controlling the AIS VDL and purpose of use.

Two VHF channels (87B and 88B) are allocated for AIS use. The principle of operation of AIS is based on Time Division Multiple Access (TDMA), which divides one minute of each channel into 2,250 time slots of 26.7 milliseconds duration each. In order to reduce chances of data packet collision between stations using Class 'A' AIS, access to time slots is carried out automatically by AIS, without involvement of users that is called Self Organising Time Division Multiple Access (SOTDMA). However, AIS could also operate in other modes, such as RATDMA, ITDMA, FATDMA, and CSTDMA. Class 'B' AIS is proposed to operate in CSTDMA mode, which differs with Class 'A' AIS only in the transmission procedures and rate of update.

AIS information could be displayed via internal or external means of display, but the internal MKD is the minimum requirement by IMO regulations. Apparently, the amount of information displayed by MKD is less than that of other types of AIS display, and requires more time for interpretation. The rate of information update depends upon the type of information, ship's status and speed. AIS, apart from navigation, can be used for search and rescue operation, aids to navigation, and traffic surveillance and management.

Despite the AIS apparent abilities in improving target identification, data exchange at night or in restricted visibility, and situational awareness, some issues are believed to possibly limit such abilities. These issues include the possibility of error due to manual data input, inaccurate position, COG, and SOG due to GPS failure or its less than 100% worldwide coverage, and security issues due to the possibility of data being used by unauthorised people such as pirates and terrorists and sending false data by ghost AIS.

3.6 Summary

Following the literature review in chapter 2, this chapter has provided a general idea of the AIS technology to the readers. The first section of the chapter is descriptions of the mobile AIS stations, which include carriage requirement, general description, and principle of operation, types, different messages, displays and some other characteristics of the AIS. The second section described fixed AIS stations, which includes the AIS base station, repeater station, and AIS network. The third section discussed some of the accuracy and security issues of AIS that might affect its reliability of use in marine navigation operation.

The next chapter discusses the human factors issues associated with AIS. and it further examines the AIS information accuracy, and level of human failures in AIS application for ship's use.

Chapter 4

Human Error and Automatic Identification System (AIS)

4.1 Introduction

Humans and machines are both essential parts of many complex systems in the maritime industry. Because the operation of human and machine in a system depends up on each other, any changes in one of them will affect the other. Despite improvement in efficiency, reliability, and safety brought about by automated technology, the systems are getting more complex with a higher degree of integration. These complicated facilities have imposed new costs to the systems, and created new types of failures and errors. The instructions under which the automated technology operates rely on the human part of the system. However, human ability to process so much information is limited and he/she is naturally prone to make an error. One problem of automation is their limited capabilities and their weakness in cases of uncertainty due to limited recognition of the true world. Another problem is the complexity, which creates difficulty for the human to predict automation behaviour in different conditions (Billings, 1996; Steber, 2005). The 'safe and efficient performances' of joint systems, is heavily dependent upon how functions are allocated between the human and the machine (Hollnagel, 2005). A key problem is that new technological equipment is sometimes 'bolted on' to an existing system without prior investigation of its potential impact on the functioning of the joint human-machine collaboration. This chapter examines the introduction of the Automatic Identification System (AIS) to the ship's bridge and its potential impact on the safety of marine navigation.

In a majority of cases, the problem of new technology is not paying sufficient attention to human needs and capabilities by the designers of technological systems, which make the use of technology difficult. The increased pace of technological changes has added to the intensity of these problems. Negligence of human factors in technological design will add to the occurrence rate of human error due to his/her isolation from, and possible dissatisfaction with, the new technology. The consequences of human error in safety-critical systems such as maritime navigation and aviation can be a serious threat. Focusing mainly on technology without proper engagement of human science in system design will not take into account the human capabilities and limitations. Inclusion of physical, psychological, and organisational factors affecting human performance can lead to a better human-technology interaction and integration. The way in which system designer presents information to the human operator through system displays is a very important issue, which should match the human characteristics in order to optimise the human-technology interaction (Vincente, K. J., 2002).

Technology-driven advances have sometimes resulted in the design and introduction of complex systems with less user-centred interfaces that can increase the chances of human error due to information overload or misunderstanding. New technology, with higher degrees of automation and reliability, reduces the opportunity for on the job training and therefore requires well-planned training programmes. It is argued (Dekker, 2002a) that automation presents new chances for error and pathways to system failure due to the changing work and role of the human in the system and sets up new limitations to the human operators due to lack of practice and decrease in vigilance, and changes teamwork operational practices. Furthermore, automation introduces qualitative changes in operational workload.

New technology and automation are introduced on board ships for many different reasons, such as economics, to enhance safety, to fulfil commitments under new regulation, etc. Automated new technology has been applied in all maritime work domains including navigation, propulsion, cargo handling, maintenance, ship management, and communication. Installation and use of Integrated Bridge System (IBS), Electronic Chart Display and Information System (ECDIS), Voyage Data Recorder (VDR), Differential Global Positioning System (DGPS), and Automatic Identification System (AIS) are some examples of recent new technologies on ships' bridges to improve the safety of marine navigation. New technology added to ships can sometimes have adverse effects on human elements due to their complexity or the changes they impose on working practices. Some of these undesirable effects on the human element could result from lack of knowledge and skills required by the operators. New technology can sometimes negatively affect safety of navigation due to their unforeseen impacts on the mariners. Where possible, systems should be developed to ensure compatibility with human expectations (Sanders and McCormick, 1993). It is the human who should always control and coordinate the different parts of a system; therefore integration of humans with the technology is a very important issue. Lutzhoft (2005) believed that human-technology integration has not received enough attention and yet, in some cases, work improvement strategies for the bridge have suggested an increase in automation and new technology. Trying to solve the problem of human-technology integration by introducing more technology may reduce the role of the human operator even further with a resultant reduction in his/her situational awareness.

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This chapter evaluates accuracy of the AIS information by focusing on the AIS contemporary human factors issues on the ship's bridge. The AIS information will be examined by 3 AIS studies carried out during this research, Also in this chapter, the "Swiss Cheese" accident model will be used to define different layers acting as safeguards against errors in AIS application. Firstly, it covers accident and human element in section 4.2. Secondly, it covers marine navigation risk management in section 4.3. Human factors in marine navigation will be discussed in section 4.4. AIS and human error is discussed in section 4.5. Sections 4.6, and 4.7 cover analysis and conclusion, respectively.

4.2 Accident and Human Element

One of the advantages of accident investigation is identification of the causes of human error in maritime accidents and near misses. The results of such investigations are very useful for the enhancement of safety of marine navigation in adopting preventative steps and strategies for similar future cases. They are also very useful for training mariners to improve their skills and emergency preparedness. Baker and McCafferty (2005) compared a number of the accident databases and argued that deficiencies in management practices, lack of situation awareness, and risk taking/risk tolerance contributed in accident causation. It was stated that 80 to 85% of all recorded maritime accidents are directly due to human error or are associated with human error (Baker and McCafferty 2005; Steber, 2005). Figure 4.1 (Baker and Seah, 2004) indicates that the contribution of human error to maritime accidents has increased over a ten-year period from 1991 to 2001. Most of the accidents are the result of senseless and avoidable human errors.

Figure 4. 1- Ten-year trend in maritime accidents categorised as attributable to human error (adapted from Baker and Seah, 2004)

Baker and McCafferty (2005) found that common areas, which need further attention, are compliance with the anti-collision regulations, bridge resource management, and bridge automation. The concern about human factors is growing as human error is significantly implicated in so many marine accidents. Pomeroy and Tomlinson (2000) stated that many of the incidents attributed to machinery faults and failures are actually the result of errors (i.e. latent failures) that have been designed and constructed into highly complex systems. This is more evident in system integration and interfacing.

4.3 Marine Navigation Risk Management

Safety is an important element of marine navigation as a complex system and many people at different levels, including navigators, are involved in its control and management by different means. Laws, rules and regulations, procedures, and other instructions are official means of controlling systems operations. Senior officers, shipping managers, designers, classification societies, and national and international regulators are also contributing to the safety of marine navigation. The main focus is to enhance safety of mariners' performance through motivation, education and training, system design, and procedures and rules. Figure 4.2 shows the various elements at different levels contributing to safety of system and risk management in marine navigation adapted from Rasmussen's (1997, 2000) framework for risk management in socio-technical complex systems. This structural hierarchy describes the individuals and organisations involved in marine navigation systems. The behaviours associated with the navigation process are at the lowest level. The second level includes the activities of individual mariners directly engaged in the navigation operation. The third level describes the activities of senior officers that supervise the junior officers. Next level up includes the activities of the shipping companies. The fifth level describes the activities of the designers responsible for designing the equipment, and their interface and operation procedures. Maritime associations and organisations (i.e. classification societies) are in the sixth level, which are responsible for setting industrial and professional rules and regulations. The seventh level includes Activities of national regulators. They are monitoring navigation, enforcing maritime regulation, and setting up local rules and regulations. The international organizations responsible for setting laws are at the highest level of the hierarchy. The way in which decisions of top levels influence activities of lower levels, and the feedback from the lower levels to top levels, will be very important determinants of safety in marine navigation. In addition, some external dynamic forces will put pressure on the system and change the structure of the system over the time by introducing new requirements for mariners that will change work practices on board ship. Consequently,

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these may affect responsibilities, and workload of the mariners on board ships. Penetrations through different defence levels of the system, due to departure from accepted procedures and regulations as a result of financial and psychological pressures of external dynamic forces could increase chances of error (Rasmussen, 1997, 1999, 2000; Vincente, 2002).

Figure 4. 2- The socio-technical system involved in safety and risk management in marine navigation system (adapted from generic model of Rasmussen, 1997, 2000)

4.4 Human Factors in Marine Navigation

The increasing use of new technology improves navigational capability, but the marine accident's risk factor also increases due to the related technical complexity of such modern technology. Erroneous actions of humans have been a contributing factor in many collisions and accidents in complex navigational systems. Better understanding of human factors of navigators operating modern technology could reduce marine accidents and enhance the safety of navigation. Generating a system to reveal and express the factor related to knowledge and attitude of navigators and interactions between navigators and the surrounding environment could help in understanding human factors, and therefore, narrow the gap between the navigators' cognition and actual navigational risk (Itoh et al, 2004).

The human element, being the most flexible and adaptable part, is the most important element of the marine navigation system, but also as the most vulnerable part, the system influences and pressures could unfavourably affect its performance. The role of navigators in the complex operational environment, which involves different aspects of their performance and behaviour, could be optimised with a proper human factors study concerned with an understanding of their practical capabilities and limitations in a real world (Civil Aviation Authority, 2002).

4.4.1 Human Factors Model

A conceptual model of human factor, named the SHEL model, was first introduced by Edwards in 1972 and later modified by Hawkins in 1984 to assist the understanding of human factors in civil aviation (Civil Aviation Authority, 2002). It is now formally introduced as a human factor framework by IMO (Itoh et al, 2004). The model represented different components of human factors in block shapes that aim to show the interactions between various system components and the frontline operator. Itoh et al (2004) have produced a variation of the SHEL model called the m-SHEL model. It is originally adopted, by Kawano (2002 cited in Itoh et al, 2004) for the navigation operation to analyse the human factors that contribute to marine accidents and incidents. Figure 4.3 is the representation of m-SHEL model adapted from Kawano (2002). The model includes four blocks representing: Liveware (L), Software (S), Hardware (H), and Environment (E). Liveware is the human, the most flexible but the most critical part in the system. Software includes policies, rules and regulation, codes of practices, procedures, manuals, symbology, etc. Hardware comprises physical non-human elements of the system, such as equipment, machines, and tools. Environment includes physical factors and the situation in which the Liveware, Hardware, and Software of the system must function, such as the economical, political, and social environment as well as the physical environment. The letter "m" was added to the model to represent the

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management of the whole system's control. The edges of the blocks are not simple and straight to show that the particular attention is to paid to the interfaces to properly match the liveware to the other system components in order to avoid stress and system failure. In marine navigation, the important interactions exist in interfaces between navigators and elements adjacent to them. These elements include physical and non-physical parts and factors such as navigational equipment and devices, regulations, ambient environmental conditions, and other Lifeware involved in the marine operation.

Figure 4. 3- The m-SHEL Model (adapted from Civil Aviation Authority, 2002; and Kawano, 2002)

All the components of the m-SHEL model must be adapted and matched to the Liveware, which is at the centre of the model. The interfaces between human and other system parts in the human factor model consist of following 5 main interfaces (Civil Aviation Authority, 2002; and Itoh et al, 2004):

Liveware-Liveware (L-L)

This interface encompasses relationships between people within the bridge, their basic and technical capabilities and limitations. Proper matching of this interface could improve the navigation teamwork.

Liveware-Hardware (L-H)

This considers human-machine integration, and it is related to human and physical aspects of the system. This interface includes different aspects of the equipment design such as displays, controls, location, and other physical characteristics to match different characteristics of the user. Quality, performance, equipment reliability, and role sharing between human and machine are also considered in this interface.

Liveware-Software (L-S)

This interface is related to human and non-physical aspects of the system such as rules and regulations, procedures, manuals, computer programmes and symbols to resolve misinterpretation and application.

Liveware-Environment (L-E)

This interface encompasses interaction between human and economical, political, social, and ambient environment in which the system components interact.

Liveware-management (L-m)

This interface considers the relationship between staff and management in controlling the whole system. Proper staff/management relationship could decreases the human workload and enhance the technical capabilities.

4.4.2 Need for Human Factors Research

In spite of its longer history, the maritime industry has generated far less human factors research than the aviation industry. Human factors research in aviation has resulted in a reduced accident rate and the enhancement of safety to a point where, now, commercial flights are safer than other modes of transport (Shappell and Wiegmann, 2000). One reason for this difference might be that the main focus of aviation is on the transport of passengers in contrast to the marine industry, which has focused more heavily on cargo transport.

Today, the maritime industry has been exposed to a number of significant advances. However, there have been a number of limitations, imposed due to economic pressures and organisational restrictions, which have changed the role of the human element in navigation systems. The scale of damage suffered, taken together with the implication of human error as a major cause for the accidents, has led to the highlighting of safety within the marine community and internationally. Therefore, human factors studies aiming to reduce human error are now an important area of concern.

Research on human factors and the lessons learned from investigations of accidents and near misses will be useful in reducing accidents and minimising their consequences. Information gained from studying human errors can also be applied to design processes and management systems, which can reduce chances of future disasters (Parliamentary Office of Science and Technology, 2001).

The root causes of some of the human error in performance may be poor equipment or procedures design or inadequate training or operating instructions. Therefore, knowledge achieved from human factors research, centrally aiming at human performance capabilities and limitations, is useful in optimising human performance in order to minimise, both human and financial losses. Human factors technology in marine navigation will improve efficiency and safety of the system, and performance efficiency of the crew (Civil Aviation Authority, 2002).

4.4.3 Human Error

The European Commission (2000b) pointed out that following five main functions could be identified in marine transportation:

1. ***Navigation*** (includes passage planning, track keeping, and collision avoidance).
2. ***Propulsion*** (the responsibility for the integrity of the ships propulsion system and associated auxiliaries).
3. ***Cargo handling*** (Loading, discharging, and keeping the cargo and passengers in good condition).
4. ***Platform maintenance*** (keeping the ship, its equipment, and the crew in operational condition).
5. ***Ship management*** (task allocations, control and supervision and communication).

The work environment and nature of the sea and their impact on mariners and ships are likely to increase the possibility of error on board ship. Factors such as changes in working practice, information overload, information and equipment over-reliance, inadequate training, and fatigue have influenced some accidents at sea, for example, the collision between Norwegian Dream and Ever Decent (Bell, 2000 cited in Pomeroy and Tomlinson, 2000), and the grounding of passenger ship Royal Majesty (National Transportation Safety Board, 1997).

The immediate responses required in any working situation often depend upon proper initial calculations being made using accurately retrieved mental knowledge and information. This significant human ability to deal with complex informational tasks is one of the important advantages of humans over machines. Therefore, for the human to select and retrieve correct knowledge for his/her response, situational awareness, and situational assessment are very important. Lack of situational awareness may lead to an incorrect assessment of the system state and hence to an inappropriate decision. Training and practical experience are both important in this regard since the allocation of sophisticated tasks to junior, inexperienced or inadequately trained people may be linked with error.

4.4.3.1 Definition of Human Error

Mismatch in interfaces between different components of the m-SHEL model could induce an error and control of such human error depends upon understanding the nature of error. Errors can be of different origins, such as negligence, incorrect assessment and decision, and/or as a result of poor equipment design. These errors could have different consequences in different circumstances and situations.

There are various definitions of the human error, which have been assigned in different contexts to serve distinct purposes. Some of the definitions for the human error by different researchers are given below.

Karwowski (2001) defines the human error as the deviation of human performance from some intended, desired, or ideal standards.

Reason (1990) defined human error as a generic term that includes all those instances in which a planned sequence of mental or physical activities fails to achieve its intended result, when these failures cannot be attributed to the involvement of some chance agency.

Swain and Guttman (1983) defined an error as an action with a performance not within the limits of tolerable performance defined by the system (deviation from expected performance).

According to Hollangel (1993) an erroneous action is the one, which fails to produce, the expected result and/or which produces an unwanted consequence.

Senders and Moray (1991) defined error "as a human action that fails to meet an implicit or explicit standard, or in terms of the results of behaviour, an error would be a single malfunction leading to a complete failure of the task with no recovery possible".

Whittingham (2004) provides the following recent definition of human error, which incorporates aspects of some of the previous definitions (i.e., Karwowski, 2001; Reason, 1990; Swain and Guttman, 1983; Hollangel, 1993; Senders and Moray, 1991):

> *"An unintended failure of a purposeful action, either singly or as part of a planned sequence of action, to achieve an intended outcome within set limits of tolerability pertaining to either the action or the outcome".*

The probability of human error is strongly related to the individuals performing the task, task complexity, the time required to complete the task, and the individual's competency level (Pillay and Wang, 2003).

Reason (1990) argued that human error could only be applied to intentional actions because only two kinds of failure lead to error.

a) When the actions fail to go as intended (execution failures or slips and lapses).
b) b) When intended actions fail to achieve their desired consequences (planning failures or mistakes).

Figure 4.4 shows intentional actions leading to error adapted from Reason's (1990) algorithm for distinguishing the varieties of intentional behaviour (non-intentional behaviour, unintentional behaviour, and intentional but mistaken behaviour).

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Figure 4. 4- Intentional behaviours leading to errors (adapted from Reason, 1990)

4.4.3.2 Human Error and Accidents

Human contributions to accidents can be investigated by looking back on the sequence of actions and measures that appear to have caused them. However, this may not be of much help for accident prevention. According to Dekker (2002b), there are different approaches to investigating human error and to determining the human role in accidents. He distinguishes between the Old View of human error, which views human error as a cause of failure and New View of human error, which views human error as a symptom, rather than a cause, of failure. In the New View of human error the investigation looks for problems deep in the system of which human errors are only warning signs. Safety creation and system improvement is mainly dependent upon understanding and controlling connections between features of people, tools, tasks, and operating environments. The emphasis in the New View is on latent factors such as long-standing organisational deficiencies, design and implementation problems, and procedural shortcomings (Dekker, 2002b).

Table 4.1 shows the issues of concern in Old View and New View of human error according to Dekker (2002b).

Table 4. 1- Outlooks of "Old View" and "New View" on human error (adapted from Dekker, 2002b)

Reason (1990) also considers that there are two approaches to the problem of human fallibility: the Person Approach and the System Approach. *The person approach* focuses on the unsafe acts-errors (arising from unusual mental processes) and procedural violation-of people. Main countermeasures for such errors are reducing unwanted variability in human behaviour. *The system approach* concentrates on the recurrent error traps in the workplace or organisational processes (arising from penetration in system defences). Main countermeasures for such errors are changing the conditions under which human works.

The main difference between the two approaches is that in case of an accident, the issue for person approach will be "who" but in system approach will be "how" and "why". The system approach to human error will look into unsafe acts out of their system context.

4.4.4 Latent and Active Failures

Two kinds of human failures (errors) are important in accident development in complex technological systems: active and latent errors. *Active errors* are produced immediately before or at the time of accidents or incidents. They are usually failures within the actions carried out by frontline operators, for example, ship's officers.

Latent errors are resident failures already existent in systems and may remain inactive, hidden, and undetected for a long time, becoming apparent in time of their effect (when in combination with other factors being triggered and break the system's defences). Latent errors are generally associated with actions and decisions of those who are remote and indirectly connected with the control of the system, such as high-level decision makers, designers, rules and procedures makers, and maintenance workers (Wang and Trbojevic, 2007; Reason, 1990; Noyes, 2001; Wittingham, 2004). Latent errors are potential causes of accidents in technological systems that need a trigger to become active. Significant latent errors can be seen in the *Herald of Free Enterprise* disaster in 1987 in which 189 out of 459 people lost their lives due to system error, management error, and design error (Reason, 1990).

4.4.5 Classification of Human Error

To understand and examine underlying causes of accidents or further define the problems in human contributed accidents, it is important to investigate what really constitutes human errors. Understanding the factors causing accidents is also very important for preventing similar accidents in future. Classifying human error by taking into account the local contextual factors is very important for finding relationships between influencing error tendency and task features.

Sanders and McCormick (1993) mentioned that an effective classification of errors could provide useful data and information on human errors, the way in which they are caused, and how they might be prevented.

Maritime operations today have become safer, but under increased pressure. These pressures come from increased traffic, particularly in certain navigation areas, and from fierce commercial competition, which sometimes causes balance of economy against safety. Therefore, a framework for analysis and classification of human error in maritime operations would be a significant safety enhancement. However, there is no available maritime- specific human error framework (European Commission, 2002). In this section some of the familiar methods of analysis and classification of human error, which have been developed for domains other than maritime domains, are described.

There are many different classifications of human error in the literature. Different human factors researchers use them to specify and measure original casual factors. The examples of such classifications are: Rasmussen's skill-rule-knowledge based classification of human performance, Reason's unsafe acts model, Hollnagel's phenotypes and genotypes classification, Endsley's situation awareness classification, Wickens & Flach's information processing model, and Shappell & Wiegmann's classification.

Reason (1990) believed that classification of human error might be according to the following features.

Behavioural level - errors may be classified according to features of erroneous behaviour that include formal characteristics of the error or its results and outcome. The behavioural level classification may not properly describe the categories of cognitive failures.

Contextual level - errors may be classified with reference to contextual triggering features for anticipation and prevention where many slips form at this level. The main point of attention in this classification is to the interaction between local triggers and underlying error tendencies, which is a complex phenomenon. This classification describes the critical relationship between character of the task or situation and type of error.

Conceptual level - errors are classified based on the cognitive mechanism leading to an error. This classification is based mainly upon theoretical inferences. The conceptual level of classification has potential for finding underlying causes of errors.

Senders and Moray (1991) (cited in Redmill, F. and Rajan, J. (ed), 1997) mentioned that classification of human error could be of the following three broad categories:

Phenomenological - errors are described according to conditions that lead to observable events. Distinctive error types include omission, substitution, and repetition. This classification describes *what* led to an incident or accident. It is normally used in assessments of human reliability.

Cognitive mechanism - errors are categorised in relation to stages of human information processing. Usual errors are perceptual error, memory lapse, and attentional error. This classification explains *how* an incident or accident happened. It is useful in investigations after an incident or accident.

Revealed biases or deep-rooted tendencies - errors of this category are defined according to the root factors leading to events. The aim of this classification is to answer *why* incident or accident happened.

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A widely used error model in most of the research on human error is the generic error modelling system (GEMS) presented by Reason (1990). This classification is based on the skill, rule, and knowledge performance model of Rasmussen in 1974. It looks at the origin of the basic type of human error at different cognitive stages (Whittingham, 2004: Trepess, 2003). Figure 4.5 shows Reason's (1990) error classification. Whittingham also believed that detailed examination of the types of error applicable to the task is possible through GEMS classification.

Figure 4. 5- Classification of human error according to unsafe acts and performance levels (adapted from Reason, 1990)

4.4.6 Error Types

Some of the basic types of human error widely referred to in human research are described below.

4.4.6.1 Slip

Slip is an error due to failure in cognitive execution of an action sequence with correct intention. It is unintended deviation, omission of action from what is planned, and it involves inappropriate level of attention to the monitoring of actions or perceptions. Slips are associated with skill-base performances and they normally occur in low-level actions in routine and familiar tasks and situations. Slips are easily observable by others (Whittingham, 2004; Karwowski, 2001; Reason, 1990).

4.4.6.2 Lapse

A lapse is an error due to cognitive storage of task information where the intention is correct. It largely involves memory failure and is known as mental slip or omission to execute an action. Lapses are also associated with skill-based behaviour and may be only evident to the person who experiences them. They include forgetting or the inability to recall some known items in memory. Lapses are not recognizable by others as they are private events (Karwowski, 2001; Reason, 1990; Whittingham, 2004).

4.4.6.3 Mistake

Safe, productive, and efficient human behaviour in hazardous systems is governed by plans of action, which are guided and controlled by rules, regulation and procedures, generally known as rules. Some of these controlling rules are prescribed externally and some of them are acquired through training and experience. A mistake is an error due to failure in cognitive planning of an action sequence. It can be due to judgement failure or deficiency in formulating intentions or selection of the means to achieve an objective. It is selection of inappropriate or incorrect plan for an action to achieve a desired outcome. Mistakes are often hard to detect and recover, and can be unnoticed for a long period. Mistakes are more complex than slips. Mistakes are further subdivided into two types, rule-based and knowledge-based (Reason, 1990; Whittingham, 2004; Karwowski, 2001).

- Rule-based Mistake

Rule-based mistakes occur in stage of selection of a plan to achieve a desired outcome. It is either due to misapplication of good rules or due to the application of bad or inadequate rules. It is associated with the wrong application of familiar rules and procedures. Reason (1990) referred to rule-based mistake as "*the failure of expertise*".

- Knowledge-based Mistake

Knowledge-based mistake occurs in stage of generation of a new experiential plan in unique situations for which no predefined control plan exists. It is due to incomplete knowledge about the situation or incompleteness of a mental model. Reason (1990) referred to knowledge based mistake as "*the lack of expertise*".

4.4.6.4 Violation

There is a distinction between violation and other types of error. Violation is when inappropriate actions are being carried out intentionally and contrary to safe working practices, where other errors are unintentional failures of planned actions to achieve desired goals.

4.4.6.5 Error of Omission

Error of omission is failing to act as required. It is a failure to carry out the appropriate action, for example, forgetting to shut off a valve (Sanders and McCormick, 1993).

4.4.6.6 Error of Commission

Error of commission is a failure to perform the appropriate action correctly, for example, further opening of a valve instead of shutting it off. This type of error also includes actions that have been carried out correctly but out of sequence (sometimes known as sequence or substitution error) and actions that have been carried out not within the particular time (sometimes known as timing error) (Sanders and McCormick, 1993).

4.4.7 Human Performance Shaping Factors (PSF)

Despite its ubiquity, Hollnagel (2005) suggested that we should use the term 'human error' sparingly since it tends to focus on the outcome without acknowledging that the "human performance (as well as the performance of technological systems) is always variable". He highlighted that it might be more appropriate to find better ways to detect and control undesirable variability in human performance, which may sometimes lead to "unexpected and unwanted consequences".

Wang and Trbojevic (2007) referred to Performance Shaping Factors (PSFs), which are associated with any system, as factors that can influence human performance positively or negatively, thus decreasing or increasing the likelihood of human errors respectively. Performance-shaping factors are classified as *internal PSFs*, which are internal factors related to the operators, their characteristics and differences such as skill, experience, task familiarity, etc. or *external PSFs*, which are factors external to the operators such as equipment design and installation, task complexity, work environment, organisational factors, operating procedures, etc. Generally external PSFs make a greater contribution to human error configuration than internal PSFs. The optimal design of systems, involving human-machine interactions, would involve the reduction of task complexity or difficulty thus leading to improved human performance and reliability. A proper balance between

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the capability of the human operator and the difficulty of the task would decrease the likelihood of human error (Noyes, 2001; Whittingham, 2004).

Generally the influence of external PSFs in contributing to human errors are more than internal PSFs and therefore, proper design of systems to optimise human machine interactions is vital in reducing opportunities for making errors (Noyes, 2001). According to Whittingham (2004) task complexity or difficulty is one of the most obvious factors affecting human performance and hence his/her reliability. He also believed that task complexity needs to be looked at from two aspects: the difficulty of the task and capability of the person carrying the complex task. A proper balance between the capability of the human operator and the difficulty of the task will decrease the likelihood of human error. Table 4.2 is a typical scheme for grouping PSFs introduced by Whittingham (2004).

Table 4. 2- Typical Performance Shaping Factors (Source: Whittingham, 2004)

4.5 AIS and Human Error

The International Maritime Organisation (IMO) (2001b) objectives for implementation of AIS are to enhance safety and efficiency of navigation, safety of life at sea, and maritime environmental protection through better identification of vessels, assisted target tracking, and improved situational awareness and assessment through simplified and additional information. AIS can also improve the quality of vessel traffic surveillance (VTS) and waterway. The motivation for adoption of AIS was its autonomous ability to identify other AIS fitted vessels and to provide extra precise information about target ships that can be used in collision avoidance. It has the ability, due to its operation on VHF radio frequency, to detect other equipped targets in situations where the radar detection is limited such as around bends, behind hills, and in conditions of restricted visibility by fog, rain, etc. It exchanges data regarding navigational and voyage related information of ships and other related messages with other ships and shore stations. It can handle multiple reports at different update rates, which vary according to speed and status of the ships. The information can be received by anyone equipped with a relatively low cost receiver. The AIS information consists of different types of data classified as static, dynamic, voyage related information, and short safety messages. Static data are entered into the AIS on installation and need to be changed only if the ship type changes by a major conversion or if her name or call sign changes. Most of the dynamic data will automatically be updated through the AIS-connected ship sensors, and Voyage related data is entered manually during each voyage. As was stated in chapter 3, the following information is included in the AIS messages (IALA, 2002):

- **Static information**
  - IMO and Maritime Mobile Service Identity (MMSI) number
  - Call sign and name
  - Type of vessel (passenger, tanker, etc.)
  - Length and beam
  - Location of position fixing antenna such as GPS/DGPS (aft of bow, port or starboard of C/L)

- **Dynamic information**
  - Ship's position with accuracy indication (for better or worse than 10m) and integrity status
  - Time in UTC (coordinated universal time)
  - Course over ground (COG)
  - Speed over ground (SOG)

- Heading
- Navigational status (e.g., not under command, constrained by draught, etc.)
- Rate of turn (where available)
- Angle of heel (optional)
- Pitch and roll (optional)

- **Voyage related information**
    - Ship's draught
    - Type of cargo
    - Destination and estimated time of arrival (at master discretion)
    - Route Plan-waypoints (optional)
    - Number of persons on board (on request)

- **Short safety messaging**
    - Short text messages with important navigational safety related information are shown in an extra window.

For AIS to be successful in achieving these goals, proper research needs to be carried out on different aspects of AIS design, installation, capabilities and limitations, regulation, integration, operators' training, integrity of data transmitted, etc.

Fast mandatory implementation of AIS equipment for SOLAS ships, without adequate earlier research on its use, may be having a negative impact on its success and hence endanger safety of marine navigation. The collision between *Hyundai Dominion* and *Sky Hope* (Marine Accident Investigation Branch (MAIB), 2005a) is an example of an AIS-assisted collision in which the Hyundai Dominion's OOW used the AIS text facility to communicate to the Sky Hope. This action critically reduced the time available for taking relevant action to avoid collision. Further, *Sky Hope* OOW did not notice the AIS message sent by *Hyundai Dominion* due to the absence of an audible alarm system for received messages in the AIS equipment.

Poor performance and transmission of erroneous information by AIS are vital issues on the use of AIS equipment for anti-collision operations at sea. These issues have also been raised in the 16th session of IALA AIS Committee (Sandford, 2005). The next sections investigate the issue of human error on the accuracy of the AIS data transmitted and its impact on the ships bridge.

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4.5.1 AIS Data Studies

This section consists of 3 separate studies of AIS data, each able to assess different AIS fields. However, even then not all AIS fields have been evaluated. The section then discusses the results by individual AIS field.

4.5.1.1 VTS-based AIS Study

This study was conducted over about one month, during September- October 2005 at the Liverpool Vessel Traffic Service (VTS) station. The study was conducted on vessels leaving and approaching Liverpool Bay, and also vessels at anchor or alongside in port (Figures 4.6 & 4.7).

Figure 4. 6- Liverpool Bay AIS chart (source: AISLive.com - Live Ship Info)

Figure 4. 7- Mersey and Dee Approaches AIS chart (source: AISLive.com - Live Ship Info)

The data collection was carried out for about 6 hours a day (3 hours morning and 3 hours afternoon), at high tides when ships movements were at a high level on the Mersey. A set of ships information was recorded from AIS and they were compared with the same items of information from the database available in the port VTS station. The data collected from AIS consisted of MMSI number, vessel type, ship's name and call sign, length, and beam. Additionally, the AIS ships navigational status was checked against its radar plot. During this period, a total number of 94 different AIS equipped vessels (V/L) were investigated. In some cases, the ship was contacted through VHF, however this was not routinely done because of the possibility of interfering with safe navigation in a pilotage area. Many discrepancies found were in the fields of vessel's status with 30% inconsistencies found, vessel beam with 18%, vessel length with 47%, and vessel type with 74% (see figure 4.8). In many cases the inconsistencies may be considered minor, as will be shown in the discussion later.

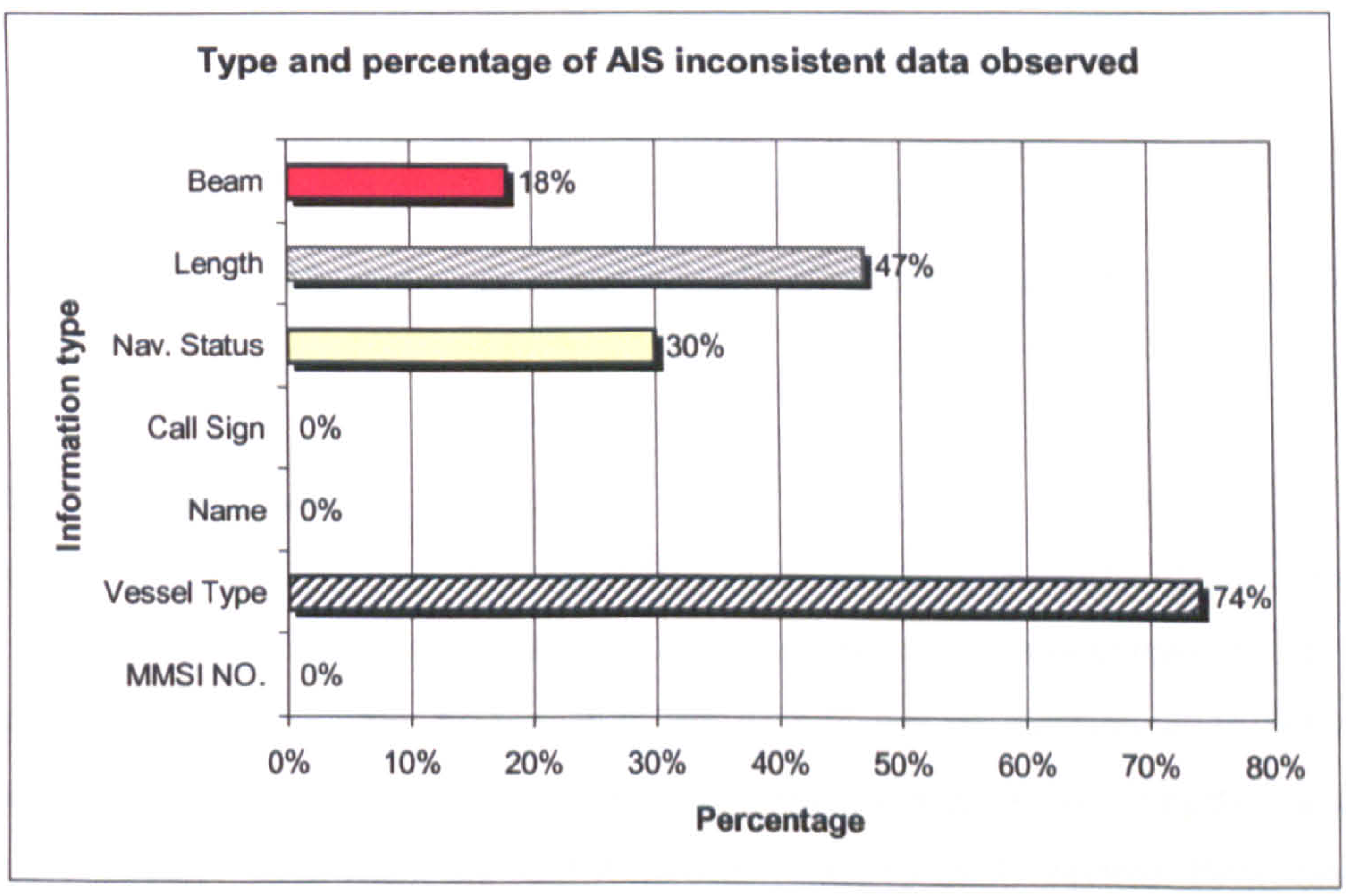

Figure 4. 8- Percentage of ships observed with inconsistent AIS information in the VTS-based AIS study

4.5.1.2 Data-mining AIS Study

This is a study conducted earlier (first reported in Harati-Mokhtari et al. 2005) for data recorded by AISLive Company of Lloyds Register-Fairplay Ltd. The data consisted of 400,059 AIS reports from 1st March to 17th March 2005, collected from a number of AIS receivers located in a worldwide geographical area. The initial data was collected by AISLive for a limited number of detectable errors of MMSI number, IMO number, position, course over ground (COG), and speed over ground (SOG). The initial data examination showed that 30,946 reports were associated with at least one error of above-mentioned types. The error rate of about 8% detected means that 1 in every 14 AIS transmissions in the sample is associated with at least one piece of erroneous data of the above-mentioned types. In addition, the above 30,946 AIS transmissions were analysed at Liverpool John Moores University for additional detectable problems such as errors in name, call sign, ship type, ship dimensions, etc.

4.5.1.3 Proactive AIS Study

Data was also collected through the services of AISweb of Dolphin Maritime Software Ltd, UK. The main focus of this study was to look specifically for duplicate MMSI numbers and behaviours of some AIS stations with incorrect MMSI number in a wide geographical area mainly in European waterways from 23rd November 2005 to 2nd May 2006. Four incorrect MMSI numbers of 0, 1, 1193046, and 999999999 were kept under surveillance. The data for these AIS stations were recorded at ad-hoc times and dates; there was not continuous monitoring of the network.

4.5.2 Findings

The findings of the AIS studies are summarised below, organised by individual AIS fields.

4.5.2.1 MMSI Number

The maritime Mobile Service Identity (MMSI) number is a unique number given to every vessel for AIS identification. It is a data field that should be manually entered at the time of installation of AIS on the bridge. It is the sole means of discrimination between different AIS transmitting stations. A particular problem that could have negative impact on the safe use of AIS is when the MMSI number is not correctly entered. Broadcasting of the same MMSI number by more than one station creates discrepancies such as target swap in information received by other AIS stations. This problem was particularly noted with many vessels transmitting the incorrect default MMSI of 1193046 (The Nautical Institute, 2005a). This may be the default MMSI for a specific model of an AIS transponder and due to not entering the MMSI number in accordance with installation procedure or a specific equipment fault, which means that it defaults back to this number. Whatever the cause, more than one ship concurrently has been using this MMSI number.

In our Proactive AIS study observations were made on an ad-hoc basis from 23rd November 2005 to 2nd May 2006. There were up to 25 vessels transmitting the incorrect MMSI number of 1193046 using the AISweb database. On all these occasions, the MMSI number was associated with a different ship with different particulars. The only common particulars between these observed stations were MMSI and IMO numbers. In some cases even the IMO numbers are also changed into a different figure. Table 4.3 below illustrates three particular examples.

Date of Observation	23/11/2005 at 15:01	24/01/2006 at 12:13	25/01/2006 at 11:35
Vessel Name	**** ******	*********	******** *******
MMSI	**1193046**	**1193046**	**1193046**
IMO No.	**303174162**	**303174162**	**303174162**
Call Sign	A****	D*****	****
Latitude	51° 54.249 N	42° 17.983 N	42° 18.612 N
Longitude	1° 40.903 E	8° 36.220 E	8° 34.562 E
Fixing Device	GPS	GPS	GPS
Type	Cargo ships	Pilot Vessel	Tugs
Dimensions	Length: 275m Width: 40m	Length: 220m Width: 43m	Length: 35m Width: 10m
Destination	FELIXSTOWE	SHEERNESS	SAVONA
ETA	23 November - 02:00 UTC	23 January - 20:30 UTC	23 January - 08:00 UTC

*** The author has blanked names & call signs out.**

Table 4. 3- The same MMSI number with 3 different ships' particulars transmitted on AIS

Three more MMSI numbers appearing on multiple stations were also detected in the Proactive AIS study, as shown in table 4.4.

MMSI number	Number of different ships
0	5
1	3
1193046	25
999999999	3

Table 4. 4- MMSI numbers detected on multiple AIS stations

This phenomenon is a serious issue. The navigating officers on the bridge should check their AIS transmission data regularly to make sure that their AIS equipment is free of such faults and transmitting correct information.

In another probable observation of this problem, The Nautical Institute (2005b) reported that there was MMSI number of a vessel at anchor and a passing ferry which swapped over and remained thus so for a certain period of time until the passing vessel was some distance away from anchored vessel. In another Nautical Institute (2005c) report an AIS target swap showed as a sudden and unexpected change of data from a container vessel into a vessel engaged in fishing. The destination changed from Genoa into Casablanca with a 28.5m draught. She showed this false information for about 15 minutes, until the data reverted to indicate the correct status. In another instance, a harbour service vessel operating in a UK port changed its transmission to a vessel of 220m lengths, heading for Casablanca and this continued for 4 days until the vessel was informed about the error. While we do not know the exact reasons for errors of this type, they are more likely due to faults in programming, installation, or equipment design. Further research and monitoring of the equipment (possibly from shore) is required to check for errors of this type.

In the "Data-mining AIS study", 2% of the erroneous static information identified was in the field containing MMSI numbers. The errors identified were only those incorrect MMSI entries with figures incorporating less than 9 digits. It is possible that, even with the correct field length, some of the digits showing are wrong when compared with an accurate MMSI database. The errors of this type could be due to omissions or mistakes by technicians responsible for installing the equipment on board ships. In a small number of cases it could be test equipment.

4.5.2.2 Vessel Type

This information is nominally part of the static data and this infers that it is inputted to the AIS by the equipment installers. Vessel type must be selected from a default list predefined in the factory by the particular AIS equipment manufacturers. In the "VTS-based AIS study", out of 94 ships under investigation, 6% of vessels had no vessel type available and 3% were defined as "vessel". Altogether, the researchers and VTS operators were unhappy with 74% of the observed ship types and in the "Data-mining AIS study" the equivalent figure was 56%. The problems of this category include vague or misleading vessel types. Commonly, the general ship type "Cargo" or "Vessel", rather than an informative ship type is entered into the AIS equipment, but other peculiarities exist. Table 4.5 shows examples from our "VTS-based AIS study" where similar vessels were broadcasting different ship types under AIS. In some cases the problem is unnecessary vagueness, as for example the use of "Cargo" for a vessel, when "tanker" could have been correctly used. In other cases, the most important and appropriate descriptor may be difficult to assess, unless more guidance is provided to navigators and installers. For example, a high-speed Ro-Ro passenger ferry can legitimately be defined as a "High Speed Craft" or "Passenger" or "Cargo" under AIS. All three types were observed separately on three sister vessels servicing the same port.

Vessel type (according to Lloyds Register database)	AIS ship type observed on different vessels during "VTS-based AIS study"
Tanker	"Cargo", "Tanker"
Dredger	"Dredger", "Vessel"
High-speed ro-ro passenger	"Cargo", "HSC", "Passenger"
Supply vessel	"Tug", "Vessel"

Table 4. 5- Examples of similar ships showing different AIS "ship type" descriptors from the "VTS-based AIS study"

Part of the problem is that there is currently not enough categories defined to cover all ships types and it is not feasible to have every potential ship-type. However, some very common and distinctive categories of vessels, such as container, car carrier and bulk carrier, are not separately identified in the AIS specification and would be identified as "cargo". Such differentiation would be helpful for visual identification at sea, as well as for VTS operators. Similarly "Tanker" applies to the different categories of chemical tanker, petroleum tankers and gas carriers. However, incorporating more ship types would require time-consuming regulation and system changes that are not feasible in short-term.

Within the current system, it would increase confidence in the system if navigators see more accurate descriptions with fewer variations between similar vessels. This can only be enforced in the first instance, by better guidance to installers and navigators.

A more minor problem is that the AIS text descriptors of ship type number codes available for selection vary slightly from one manufacturer to another. The actual list of options for ship type available is limited and is transmitted as a 2-digit number in the AIS message. Standardisation, across all AIS manufacturers, of the text descriptors would be a good feature of the equipment, in order that as navigators move to different ships they get familiar and accustomed to the information displayed. For example, on one model, the ship type number 32 is "Vessel-Tow>200m, Breadth>25m" while on another model the same number is displayed as "Towing (large tow)".

Additionally, this so-called static field showing "vessel type" is altered for some vessel types according to their navigational status on voyage. There is also potential ambiguity between a vessel type and vessel status as in the ship type "Vessel-sailing" used in some models. These aspects are discussed in detail later in this chapter.

4.5.2.3 Ship's Name and Call sign

Although in the limited "VTS-based AIS study" there were not any incorrect name or call signs identified, in the wider "Data-mining AIS study", problems noticed were that fields were left blank. No name or call sign were given in 6% of the filtered static information sample. This represents 0.5% of the total unfiltered AIS messages recorded. Another problem noticed during this study is that abbreviations were used in the field of ship name. In many cases, but not all, this was because an insufficient number of characters were available which limits this field to 20 characters in the AIS equipment. The errors in these two categories are either, due to omission by installing technicians or due to the regulatory design, which does not allow ship's names in full if they are longer than 20 characters. These limitations mean that there can be confusion about the ship's name, when a prime purpose of AIS was to clarify this problem. It is still a common practise to use a ship's name in voice communications even though the alternatives of using MMSI number (via Digital Selective Calling) or call sign are also available. Alternative suggestions would be for the IMO to pass a regulation limiting ships names to 20 characters or to increase the minimum number of characters available for ships names in AIS equipment, or to train navigators to avoid using the ship name for communications.

4.5.2.4 Vessel Navigational Status

Ship status is dynamic information that has to be manually entered by the officer of the watch (OOW) and changed or updated as necessary by the navigation officer during a passage. In current AIS receivers, the equipment does not incorporate automatic crosschecking of information received and transmitted. In the "VTS-based AIS study", 30% of ships were detected as displaying incorrect status information and there were probably more examples undetected by the research. Four percent of them were displaying an incorrect status for power driven vessels underway using their engines by showing their status as underway sailing, an option that should be used only by sailing vessels under sail. Other examples detected by the research include a ship underway at 10 knots shown as moored and ships alongside or at anchor shown as underway or sailing.

Navigational status is very important information in situational awareness and anti-collision, particularly as it can decide when a ship would be the "stand-on" or "give way" vessel. Rather confusingly, the AIS data programming shows that navigational status for some vessel categories is given in the field of ship type as well the navigational status field. For example, the navigational status of tugs or dredgers is basically shown in the field of ship type and not just in field of navigational status as shown in table 4.6.

Anti-collision information defined by lights and shapes under the International Regulations for Preventing Collisions at Sea			Equivalent settings on an AIS receiver programmed according to the IALA Guidelines for AIS		
Category of vessel	**Navigational status**	**Extra information**	**Vessel type**	**Navigational status**	**Extra information**
Power driven vessel	Underway	L< 50m or L ≥50m	Passenger/cargo/tanker/HSC/other types of ship	Underway using engine	In length field
Pilot vessel - Not engaged in pilotage duty	Underway	L< 50m or L ≥50m	Other vessel or still Pilot vessel?	Underway using engine	In length field
	At anchor	L< 50m or L ≥50m	Other vessel or still Pilot vessel?	At anchor	In length field
Pilot vessel - Engaged in pilotage duty	Underway	L< 50m or L ≥50m	Pilot vessel	Underway using engine	In length field
	At anchor	L< 50m or L ≥50m	Pilot vessel	At anchor	In length field
Tug - Not engaged in towing	Underway or making way	L< 50m or L ≥50m	Tug	Underway using engine	In length & speed fields
Tug - Engaged in towing	Underway or making way	L< 50m or L ≥50m & L of tow ≤200m	Towing	Underway using engine	In length & speed fields
Tug - Engaged in towing	Underway or making way	L< 50m or L ≥50m & L of tow > 200m	Towing & L of the tow exceeds 200m or breadth exceeds 25m	Underway using engine	In length & speed fields
Tug – Engaged in towing and restricted in her ability to manoeuvre	Underway or making way	L< 50m or L ≥50m & L of tow ≤200m	Towing	Restricted in her ability to manoeuvre	In length & speed fields
Tug – Engaged in towing and restricted in her ability to manoeuvre	Underway or making way	L< 50m or L ≥50m & L of tow > 200m	Towing & L of the tow exceeds 200m or breadth exceeds 25m	Restricted in her ability to manoeuvre	In length & speed fields
Fishing vessel - Not engaged in fishing	Underway or making way	L<50m or L ≥50m	Fishing	Underway using engine	In length & speed fields
	At anchor	L<50m or L ≥50m	Fishing	At anchor	In length field
Fishing vessel – Engaged in trawling	Underway or making way or at anchor	L<50m or L ≥50m	Fishing	Engaged in fishing	In length & speed fields
Fishing vessel - Other than trawler engaged in fishing	Underway or making way or at anchor	L<50m or L ≥50m	Fishing	Engaged in fishing	In length & speed fields
Fishing vessel - Other than trawler engaged in fishing with outlying gear >150m	Underway or making way or at anchor	L<50m or L ≥50m	Fishing	Engaged in fishing	In length & speed fields. Use of safety message field to communicate obstruction?
Dredger - Not engaged in dredging or underwater operation	Underway or making way	L<50m or L ≥50m	Cargo ship or other type	Underway using engine	In length & speed fields
	At anchor	L<50m or L ≥50m	Cargo ship or other type	At anchor	In length field
Dredger - Engaged in dredging or underwater operation with obstruction	Underway or making way or at anchor	L<50m or L ≥50m	Engaged in dredging or underwater operations	Restricted in her ability to manoeuvre	In length & speed fields. Use of safety message field to communicate obstruction?
Sailing vessel - under sail only	Underway		Sailing	Underway by sail	
Sailing vessel - Propelled by machinery (with or without sail)	Underway		Sailing	Underway using engine	

Table 4. 6- Comparison of selected ship types and navigational statuses defined in IRPCS with AIS options according to IALA (2002) guidelines

In table 4.6 some examples of ship types, their different status according to IRPCS and the corresponding data are shown, which would be shown by the AIS. The examples have been selected to show how the philosophy of AIS data is different between different vessel types, In some categories the system has kept ship type according to stated philosophy of the static AIS data so, for example, a fishing vessel remains a fishing vessel throughout its voyage and life. Similarly in table 4.6, a sailing vessel would change only navigational status and not ship type. The voyage related field of navigational status would vary on voyage depending on whether it is engaged in fishing or not. Conversely, in table 4.6, a tug would be shown as the static field of vessel type of "tug" when not involved with towing. When the tug picks up a tow, the so called static field of vessel type is changed from "tug" to "towing or "towing and length of tow exceeds 200 m or breadth exceeds 25 m" as applicable (that is the word "tug" actually means a "tug" not towing). The reason for this peculiar decision by AIS regulators is undoubtedly because the navigational status field can then be used by tug to show when it is additionally "restricted in her ability to manoeuvre" or not. Similarly a dredger would alter its ship type throughout its voyage. It is not clear if a pilot vessel should or should not change its vessel type when it is not engaged in pilotage duties.

This aspect of AIS data on "anti-collision" status is compounded by at least one manufacturer by providing a user manual that does not tell the navigator how to change any of the static data. This includes the vessel type field, which we have shown in some vessel types need to be changed on a voyage basis and not just by the installer.

It is important for the navigators to be aware and prepared for such ambiguities by specific AIS training both from the programming and from the interpretation perspectives, as indeed they are currently made aware for the intricacies of lights and shapes. Modification could be theoretically made to the number of AIS fields to improve the communications and the information provided, but this is not an option at this stage of implementation. The AIS fields do however convey the required information provided the navigators receive adequate training in the programming and interpretation of the AIS equivalent to that already provided for lights and shapes.

4.5.2.5 Length and Beam

Forty seven percent (47%) of the ships in the "VTS-based AIS study" displayed incorrect length and 18% of them displayed incorrect beam in their AIS information when compared with the VTS database or with the information reported on VHF. The vessels reporting incorrect lengths included:

- 6.4% that showed 0 for their length.
- 36.3% with an error of between 1 metre and 5 metres.
- 4.3% with an error of more than 5 metres.

The vessels reporting beam inaccurately included:

- 6.3% showing 0 for their beam.
- 8.5% indicating an inaccuracy between 1 metre and 5 metres.
- 3.2% indicating an inaccuracy of more than 5 metres.
- Another 67% of observed vessels indicated an error of less than 1 metre in beam, which has not been included in our inaccuracy figures for the beam. Although, no doubt, some discrepancies are due to rounding, the majority of cases had an inaccurate non-zero decimal figure (e.g. 23.7 instead of 23.3).

Some of these ships were contacted on the VHF to confirm their correct dimensions and the results confirmed that data shown by the AIS was not correct. In the "Data-mining AIS study", apart from non-availability of the length and beam, the errors identified were limited to an incorrect correlation between length and beam, such as beam being greater than length. Length and beam are static information on AIS and should be inputted to the equipment at the time of installation. This information would only need to be changed if structural modifications were to be made to the ship. This is an error of wrong data input by those who installed the AIS equipment on board ships.

4.5.2.6 Position

Full evaluation of the AIS positional information was not practical in the present studies. However in the "Data-mining AIS study" it was found that 1% had shown latitude of more than 90° and longitude of more than 180° or the position 0°N/S, 0°E/W. This could be because the position fixing system is not working or is improperly connected to the AIS equipment. Proper comparison of the position data from AIS with data from other means of positioning can further be investigated in the future to assess practical accuracy of the AIS position information.

In MARS report 200552 (The Nautical Institute, 2005c) which highlighted the discrepancies of AIS, such as the vessels transmitting AIS position 00°N 000°W, it has been strongly recommended that AIS should only be used as a situational awareness tool and not for collision avoidance.

4.5.2.7 Draught

An obvious discrepancy in 17% of AIS draught entries observed in the "Data-mining AIS study" is its non-availability or reporting of 0m draught. It was also observed that in 14% of the AIS entries draught is greater than length of the ship. Since the ship's draught is voyage related information it must be entered by OOW and must be updated before and possibly during the ship's voyage. Any inaccuracy in this field of AIS information could be OOW omission to enter or update the draught or his/her error of commission by entering incorrect figures. Further research is required to quantify the errors in draught and the frequency of update by the navigator, as the present study has not explored to a proper extent the errors in this field.

4.5.2.8 Destination and Estimated Time of Arrival (ETA)

The destination and ETA were not investigated during the "VTS-based AIS study" but they were investigated within the limitations of the "Data-mining AIS study". In the sample of 30946 AIS transmissions, 49% showed obvious errors in the fields of destination and ETA. Some of the vague or incorrect AIS entries for destination found were; a number instead of destination, a country name instead of port name, an abbreviated name difficult to interpret, the words "not available" or "not defined" or "null", mischievous input (e.g. "to hell") or a blank field. It should be appreciated that the study was only able to identify inconsistencies and many erroneous entries would be undetected. Conversely the vague entries for ETA and destination may actually be the vessel's best knowledge in a small number of cases. Accurate knowledge of the correct destination of other vessels on the AIS can be very useful in areas of high traffic congestion and in port approaches or at the entrance to inland waterways. Destination identification can improve navigation safety through enhanced planning for manoeuvrings with early prediction of other traffic's manoeuvrings such as alterations of course and/or speed. It was observed that ETA is also not updated in a number of AIS transmissions. Inaccuracies noticed in the ETA field were dates in the past or ETAs in the very distant future. Although these fields are optional, if it is to be of use, ships should maintain it accurately and regularly.

4.5.2.9 Heading, Course Over Ground (COG), and Speed Over Ground (SOG)

Unfortunately during this research it was not possible to investigate heading, COG, and SOG. Further research on accuracy of such fundamental AIS information is very important if AIS is going to be used for anti-collision purposes and allow successful data fusion with radar information. Some problems have been reported in this regard. According to one report (The Nautical Institute, 2006), a heading offset of 90 degrees or more was noticed in a vessel in a traffic separation scheme on a passage to Longview, Washington. The AIS inaccuracy in this case could be the result of a compass input problem or AIS equipment calibration, test, and maintenance not conforming with related directions and regulations.

4.5.2.10 Other AIS-Related Problems

Correct installation of AIS and its integration with other navigational equipment, accuracy of manual data being inputted to the system, and ability of the mariners to correctly interpret received information are great concerns if AIS is to be used to enhance decision making on the ship's bridge. Bailey (2005a) claims that 80% of AIS messages contain some error or inaccuracies. Installation of AIS and mariners training in the use of equipment are important issues that affect AIS operations, which have not been prioritised in the implementation of AIS. It has been argued (The Nautical Institute, 2005c) that AIS has the potential to be a useful navigational aid if correctly used, due to its high updating rates on the changes made by other ships. However, at present, the reality is that in many cases, information, which is being provided, is directly misleading. This is especially dangerous if the AIS information must be relied upon at critical times such as when visibility is restricted and when radar detection ability is limited.

Additionally, insufficient use of AIS is another identified problem in the literature, which was noticed in the case of the collision between *Amenity* and *Tor Dania* (MAIB, 2005b). The investigation concluded that, if the master of *Amenity* had referred to the existing AIS information, he would have been able to identify heading, direction and rate of turn of the other ship. This information, which has a 2 second update rate, could have corrected the wrong visual impression about the aspect of *Tor Dania.*

In the case of the accident between *Hyundai Dominion* and *Sky Hope* (Marine Accident Investigation Board (MAIB), 2005a) a safety text message was used to send a collision warning that was not identified by the addressed vessel. It is not clear whether text messages should be used for such purposes by the mariners. If they are to be used, both auditory and visual warning signals, with adjustable individual response parameters, could be incorporated to facilitate better and more appropriate responses (Hellier and Edworthy, 1999). Warnings can have an influential effect in reducing risk in dangerous situations (Baldwin and May, 2005). The warning signal could be in the form of a buzzer associated with a text message that could appear on the screen to inform the mariners about any incompatibility of the navigational status with speed. Graham (1999) pointed out that warning signals with iconic features that pass on information about different events in an everyday manner may be understood quicker and easier than unusual artificial sounds.

The investigation of the collision between *Cepheus J* and *Ileksa* (MAIB, 2005c) also found poor use of the AIS when the OOW on *Cepheus J* failed to notice the presence of *Ileksa* ahead of him. Solving negative aspects of AIS can increase its reliability and its users' trust level. If the regulatory authorities ever insisted that AIS is employed as an anti-collision aid then it is essential for correct information to be transmitted.

Contrary to intention, there is some evidence that AIS technology actually *increases* VHF calls between ships for the purpose of collision avoidance. Bailey (2005a) claims that about 90% of 245 cases of VHF calls recorded at Dover Coastguard Channel Navigation Information Service (CNIS) were concerned with collision avoidance. Precise identity (i.e. name, call sign, etc.) of target ships available via AIS will perhaps stimulate further use of VHF on board the ship. Consequently, this may cause more violations of the anti-collision regulations and reduce the ability of the OOW to take appropriate actions in ample time as required by anti-collision regulation. Thus, it could be a factor augmenting the risk of collision in some instances. Increased VHF calls can cause distraction and take the attention of navigators away from engaging in more urgent actions needed to avoid collision. In addition, they can cause confusion between two ships if they do not agree on specific actions required (Swift, 2004). The increased potential for local arrangements between ships over VHF may cause more confusion and breach of the rules of the road (ROR) (Farmer, 2004). In The Nautical Institute (2005a) there is an example of a request for an agreement in opposition to rule 15 of the International Regulations for Preventing Collisions at Sea (IRPCS) where a naval ship (give way vessel) navigating in international waters asked another approaching ship (stand on vessel) to alter her course 20 degrees to starboard. The IRPCS does not mention that VHF should be used for anti-collision purposes but it has been a routine practice by some navigators. This matter needs urgent clarification by the regulatory authorities.

4.6 Analysis

Using a system's approach, based on an application of a well-known model of system failure, failures at different levels of the AIS system are summarised. Table 4.7 shows failures observed in an AIS system. Suggestions for remedial action to reduce the likelihood of such errors and thus minimise accident opportunities are also shown. This study indicates that for the AIS to be successful in its proposed aims and objectives, further steps need to be taken by various stakeholders, including the regulatory organisations.

Level of Failures	AIS Problem	Remedial Action
Frontline operator failures. Mainly simple forgetting and inattention or omission of action by ship's navigating officers.	-Failures to update or change information. -Observed in dynamics and/or voyage related information of AIS such as length, beam, draught, destination, ETA, etc. -Incorrect information has been entered.	-A compulsory check list to be filled before, during and at the end of each voyage by navigating officers would be helpful.
Installation failures. Error associated with action of technicians installing the equipment.	-Error in static information set at the time of installation of the AIS.	-Installation of AIS equipment by certified competent technicians. -Proper calibration. and test of the equipment after installation.
Design failures or omissions. They result from the actions or inactions of equipment designers.	-Errors due to over simplification of predefined options available for some data fields, such as default categorisation of ship type or navigational status in the system.	-An interlink mechanism between speed and navigational status. -Interlink between other AIS and other navigational equipment. -Use of internationally standardised maritime professional terms and phrases according to IRPCS for menu-based fields of information.
Training and management failures. Lack of knowledge by navigators about the equipment and lack of management by masters to properly supervise the integrity of data.	-Lack of competency of mariners to use the equipment properly.	-Proper theory and practical training for mariners and operators ashore. -Regulations for requirement of the AIS user certificate. -Proper supervision from senior officers on board for integrity of AIS data. -More responsibilities by shipping companies for not sending navigator to sea without proper AIS training.
Regulatory failures. Lack of standardisation for equipment design. Inadequate regulation on training of navigators in AIS operations. Lack of supervision on the proper use and data accuracy of the equipment by local authorities.	-Wrong application of rules to define default list of options.	-Definition of specific unified standards for equipment design. -Following of agreed standards by different AIS designers and manufactures. -Proper regulation for compulsory training should make by international regulatory organisations. -Proper supervision on AIS operation on board ships by Local authorities. -Penalties for knowingly displaying incorrect information should be imposed consistently by regulatory authorities.
Violations. -Lack of supervision by local authorities on the accuracy of	-Observed in AIS field of destination. Poor design could	-International regulations are needed in this regard to authorise

Level of Failures	AIS Problem	Remedial Action
information transmitted by AIS.	also lead to inaccurate entries.	and engage local government agencies such as port state control (PSC) in inspection and examination of the accuracy of AIS data in their territorial waters.

Table 4. 7- Summaries of the human failures associated with AIS equipment

4.6.1 The "Swiss Cheese" Model of Accident for AIS

The original "Swiss Cheese" model of system failure was proposed by Reason (1990 & 1997). It shows how failures at various stages of a system may allow a problem to pass through gaps and weaknesses in various layers of that system's defences, but may be stopped by subsequent defence layers. However, in certain circumstances, the problem may have a clear trajectory through all of the system defences, which may result in accidents with potentially serious consequences. In figure 4.9, the "Swiss Cheese" model is modified for the AIS system. It shows a possible accident trajectory that may occur. In this model, two kinds of failure, active and latent, are important in accident development in an AIS system. Active failures usually involve unsafe acts of frontline operators in direct contact with the system, for example, ship's officers or pilots, whose effects are immediate. However, in the immediate operating context of the system, these acts might appear to be wholly appropriate to the operator. Latent failures, on the other hand, are generally associated with actions and decisions of those who are remote and indirectly connected with the control of the system, such as high-level decision makers, designers, rules and procedures makers, and maintenance workers (Wang and Trbojevic, 2007; Reason, 1990; Noyes, 2001; Wittingham, 2004). Significant latent errors can be seen in the case of the "*Herald of Free Enterprise*" disaster in 1987 in which 189 out of 459 people lost their lives due to system error, management error, and design error (Reason, 1990). Defence penetration could be due to a combination of both types of failure in the system.

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Figure 4. 9- The "Swiss Cheese" model of human error in AIS system, contributing to accident (adapted from the generic model of Reason, 1990, 1997)

4.7 Conclusion

The findings of the present studies, and previous research show that the data provided by AIS are not reliable in many cases and therefore mariners cannot wholly trust the equipment. This could lead to further deterioration in AIS usage and data quality.

The list of options available should be standardised according to different types and navigational statuses of the ship (as defined in the International Regulation for Preventing Collisions at Sea) such as in the IALA (2002) guidelines on AIS. This will overcome the current differences in number and phraseology of options available in AIS equipment made by different manufacturers.

There is an assumption by some navigators and accident investigators that the AIS is an aid to safe navigation by providing additional information for anti-collision purposes. The use of AIS fields to show anti-collision status has some peculiarities for some vessel categories not dissimilar to some of those in the use of lights and shapes. Understanding the use of lights and shapes is a familiar part of navigator training and similar AIS training needs to be introduced. This training would also encourage the use of the narrow definition of the word "sailing" in the context of the AIS message and in the IRPCS.

It is not clear whether the safety text messaging, available in AIS equipment, could or should be used for anti-collision conversations between vessels. IMO needs to clarify the regulations about this. Should this method of collision avoidance be approved, the existence of an effective audio-visual warning signal to notify the receipt of safety text messages would also help. Further training for navigators is also needed on these matters.

It was noticed during this research that many of the input errors in the field of ship's navigational status are due to memory slips or omission to execute an action. The AIS equipment could easily have self-checking mechanisms and links to other equipment to detect obvious inconsistencies. For example, an interlink mechanism between speed and navigational status would be helpful. In cases where the speed of the ship, which is automatically being inputted to the system from GPS or from a speed log, exceeds a certain level a warning signal could prevent the navigational status from showing conditions such as moored or at anchor. The existence of a warning signal would alert navigators, of erroneous conditions in early stages of development. Use of warning signals could also be extended to include a link with the ship's navigational light system in such a way that a signal could warn the navigator in case of any conflict between the actual navigational status of the ship and status shown in AIS data. Indeed, the logical step is to have one button for both tasks.

The automation of AIS is mainly related to the transmission and reception of data and the integrity of the system are dependent on many manual inputs. The current unreliability of AIS data is a critical issue mitigating against the use of AIS as a trustworthy navigational aid in collision prevention activities. Proper supervision, surveillance of accuracy, and enforcement of quality of AIS data by competent maritime authorities would enhance its efficacy in all navigation operations.

Proper training of navigators and operators ashore on the use of AIS, its capabilities, and limitations is an important issue as demonstrated in the *Hyundai Dominion* and *Sky Hope* (Marine Accident Investigation Board (MAIB), 2005a). Lack of familiarity of the navigators with AIS equipment is likely to reduce the confidence of navigators in using it in their normal anti-collision activities. An international mandatory training course including theory and practice of AIS equipment would improve its use at sea.

It is apparent that some optional fields of AIS information, such as destination and ETA, are not considered important by the mariners as in most cases they are not updated.

Navigators need more encouragement to maintain the data showing on their equipment. It will also give them more confidence in AIS data broadcasted from other ships.

This study has concentrated on the main AIS fields that are inputted manually and has not specifically considered information relayed automatically from shipboard sensors, such as speed, position, heading, etc. Further research is required to examine any human error issues in the setting up and the interpretation of shipboard sensor information by navigators.

4.8 Summary

This chapter examined accuracy of the AIS information by conducting 3 AIS studies and analysed the level of human failures associated with AIS. The chapter further suggested remedial actions for reducing such error in order to improve AIS usefulness in enhancing safety of navigation operation.

The first section, after introduction, discussed the role of the human element in marine accidents, and the growing concern of human factors as a result of significant implication of human error in accidents.

The second section suggested a hierarchical socio-technical system for management of safety and risk in marine navigation.

The third section discussed human factors in marine navigation. This section covered management of different elements in the human factors model, need for research on human factors, description, classification, and type of human error and failures, and performance shaping factors.

The next section evaluated human errors and failures associated with ship borne AIS applications. It described the 3 AIS data studies performed during this research, and finding of the studies for individual AIS fields of information.

This chapter also analysed the findings of the AIS data studies in the fifth section. The results of the analysis led to the development of an accident model for AIS based on Reason's (1990, 1197) "Swiss Cheese" model of human error. This model summarises the human failure associated with AIS.

Chapter 5

AIS Questionnaire

5.1 Introduction

AIS was introduced in 2002 and its phased implementation programme completed in December 2004. Some problems still exist in its reliable use for anti-collision and other navigational activities. In the AIS data studies conducted and discussed in chapter 4, some signs of the system's inaccuracy and misalignment were observed such as:

- Lack of use of AIS.
- Transmission of ambiguous, incorrect, and in some cases, misleading data, which can cause misinterpretation of information that could lead to serious error with unpleasant consequences.
- Navigators' lack of knowledge and skills required to properly use, maintain, and interpret the data received by AIS.

The aim of this chapter is to assess the navigators' view on AIS application for navigation, and significance of some of the argued issues in their feedback. It does this by analysing the results of a bespoke questionnaire designed to assess the navigators' feedback on AIS perception after implementation, under the SOLAS Convention. Firstly, the methodology of the questionnaire is covered in section 5.2, and then the questionnaire preliminary analysis is covered in section 5.3. The results of analysis for variables considered in the questionnaire and impact of demographic factors in terms of differences between subsets of population in their responses are given in sections 5.4 and 5.5, respectively. Section 5.6 contains the discussion and conclusion for this chapter.

5.2 Methodology

This questionnaire survey is carried out to explore and evaluate navigators' views, if and how AIS contributes to navigational efficiency and safety, where navigating officers, and usage of the AIS technology become objects of the research. This, in turn, will help to determine AIS effectiveness, advantages, and disadvantages.

5.2.1 The Sample

The study population was selected from multinational officers of two shipping companies, National Iranian Tanker Company (NITC) and Islamic Republic of Iran Shipping Lines (IRISL), with more than 100 ocean going tankers and dry cargo ships, manned with multinational crews, based in Iran, and some deck officers who attended simulation training at Lairdside Maritime Centre of Liverpool John Moores University in Liverpool, UK. The total number of the research sample (N) is 116. In order to avoid samples of convenience and to represent a fairly suitable study sample, with minimum partiality, the respondents were selected from many different nationalities. The way of selecting study sample takes into account differences in respondents' educational and cultural backgrounds, their different ranks, sea experience, etc. The sample consisted of different ranks of deck officers such as master mariners, chief officers, second officers, and third officers (see section 5.3.1). Other important information about the population sample is also given in section 5.3.1of this chapter.

5.2.2 The Questionnaire

A survey questionnaire was prepared to collect perceptions of the navigators about important issues that were highlighted in the literature review. The test of questionnaire for being clear and understandable and for its usability for the research objectives was carried out through expert judgement. Therefore, the survey questionnaire was reviewed according to the feedback that was obtained from the experts supervising the research, other experts in the maritime department, and experienced simulator instructors at Lairdside Maritime Centre of the Liverpool John Moores University. Finally, a total of 47 items are included in the questionnaire, grouped by the content under 7 subtitles. The group of personal information was included to gather demographic data on the participants. This will correlate response sets between different groups of navigators that could be used for checking consistency of responses across groups. The final questionnaire, which is reproduced in appendix B.1, consists of an introduction about the aim of the survey with names and contact details of the researcher and director of study for this research, and e-mail and postal addresses to return completed questionnaires. The questionnaire also thanked respondents for their cooperation and guaranteed that information given by them would remain strictly private and would not be individually passed on to third parties. Some of the questionnaires were handed in to deck officers in Liverpool-UK, and some of them were sent to the shipping companies mentioned in section 5.2.1 in an electronic format in April 2005 with a reminder during July 2005. A total of 116 completed questionnaires were received. Some of the responses were received in electronic format via e-mail and some of them were in paper form received through the postal mail from April 2005 to May 2006.

Questions included in the questionnaire are organised in 7 groups. The relevant groups are:

Section A: Personal Information consists of 6 questions.
Section B: Perceived Usefulness of AIS consists of 13 questions.
Section C: Perceived Ease of Use of AIS consists of 6 questions.
Section D: Perception of AIS Information Display consists of 10 questions.
Section E: AIS Training consists of 5 questions.
Section F: AIS and Use of VHF consists of 3 questions.
Section G: Disadvantages of AIS consists of 4 questions.

5.2.3 The Questionnaire Codebook

A questionnaire codebook was prepared before entering the questionnaire data into an SPSS data table. The codebook is a summary of the instructions that were used to convert the information obtained from the questionnaires into SPSS format. A copy of the questionnaire codebook that was developed for the survey questionnaire is shown in appendix B.2.

5.3 Preliminary Analysis

The data analysis was carried out with the aid of computer software SPSS version 14. The data table for AIS questionnaire survey is given in appendix B.3.

5.3.1 Breakdown of Respondents Experience

Figures 5.1 to 5.5 show descriptive statistics on information such as rank, certificate of competency held, type(s) of AIS display available, total sea time, and sailing experience with AIS for total 116 respondents in the population sample. The figures also show the number of missing data for each measure. According to the statistics, the breakdown of respondents' ranks is 12.3% for master mariner, 26.3% for chief officer, 25.4% for second officer, and 36% for third officer (figure 5.1). Actual certificates of competency held by the valid number of participants are 24.8% master mariner, 20.0% chief officer, and 55.2% second officer. Of the total number of respondents 10% did not specify their certificates of competency (figure 5.2).

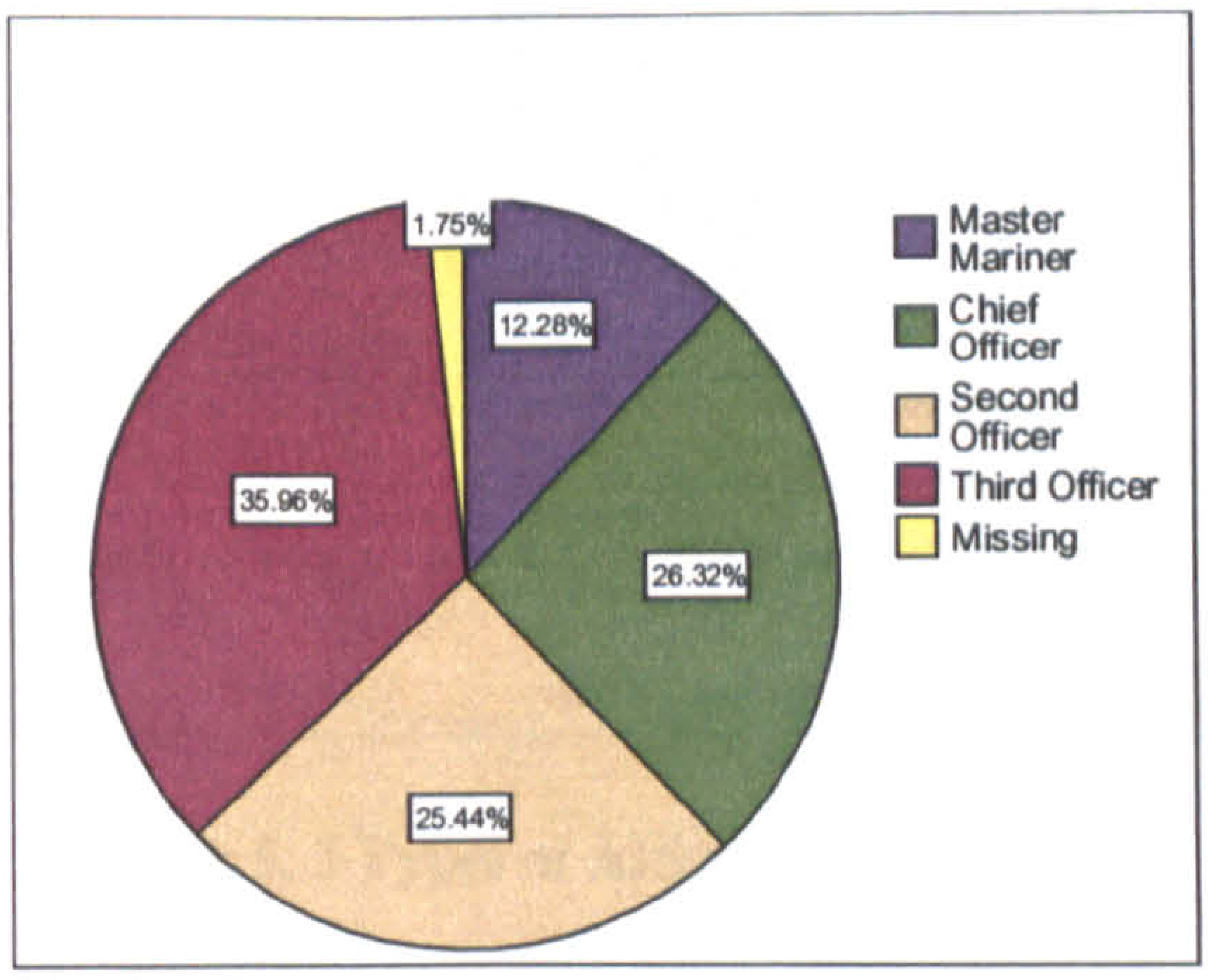

Figure 5. 1 Rank (A2) composition

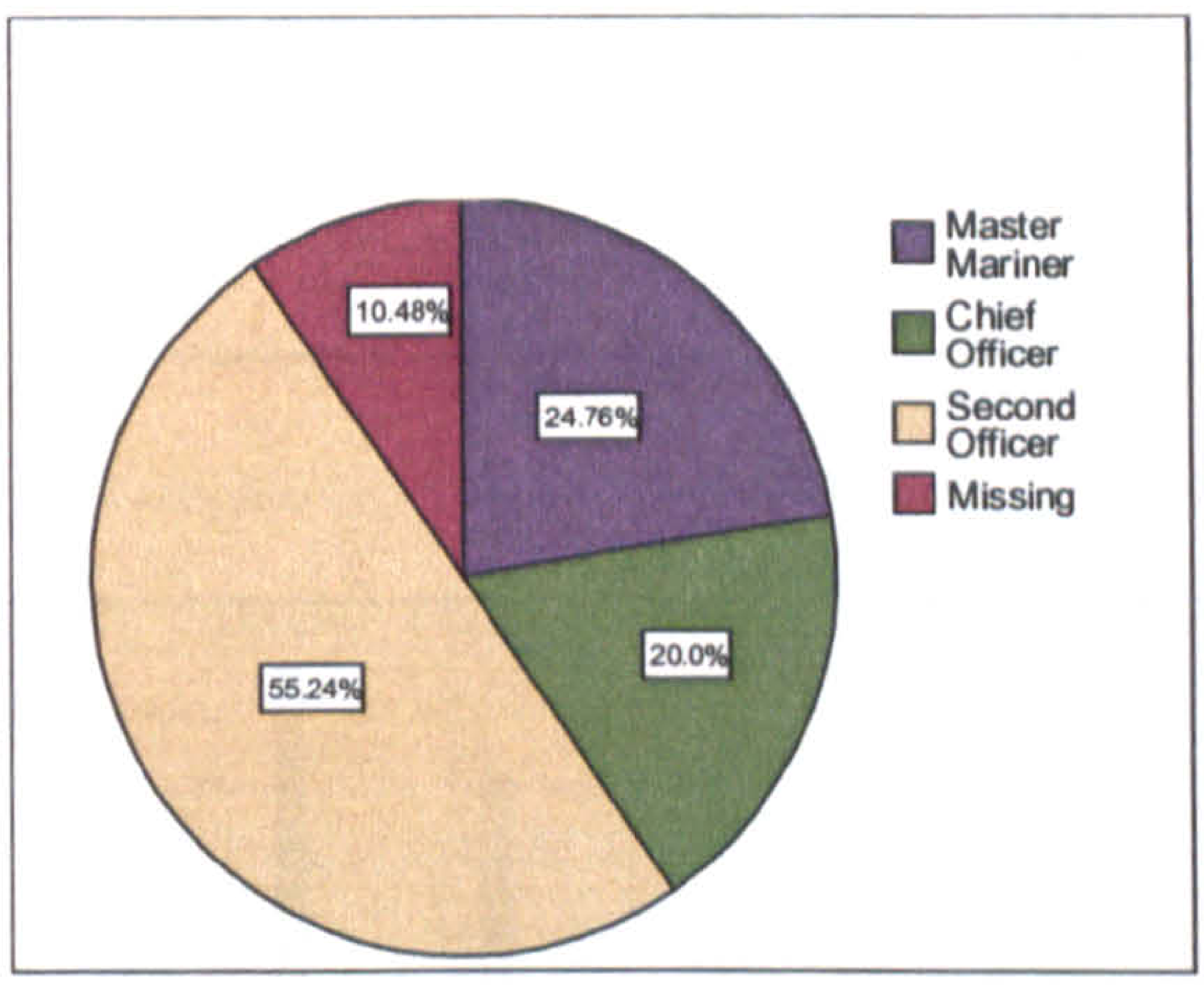

Figure 5. 2 Certificate of competency held (A3)

According to figure 5.3, valid figures for types of AIS display available to the respondents were 21.2% Minimum Keyboard & Display (MKD), 6.2% stand-alone graphical display, 15% integrated with radar, 4.4% integrated with ECDIS, and 53.1% more than one type. The figures for the available AIS display show that more than half of the respondents had the opportunity to compare the way in which the AIS information is presented by two different types of display. Of those who have experienced only one type of AIS display, the majority of them have been using MKD type.

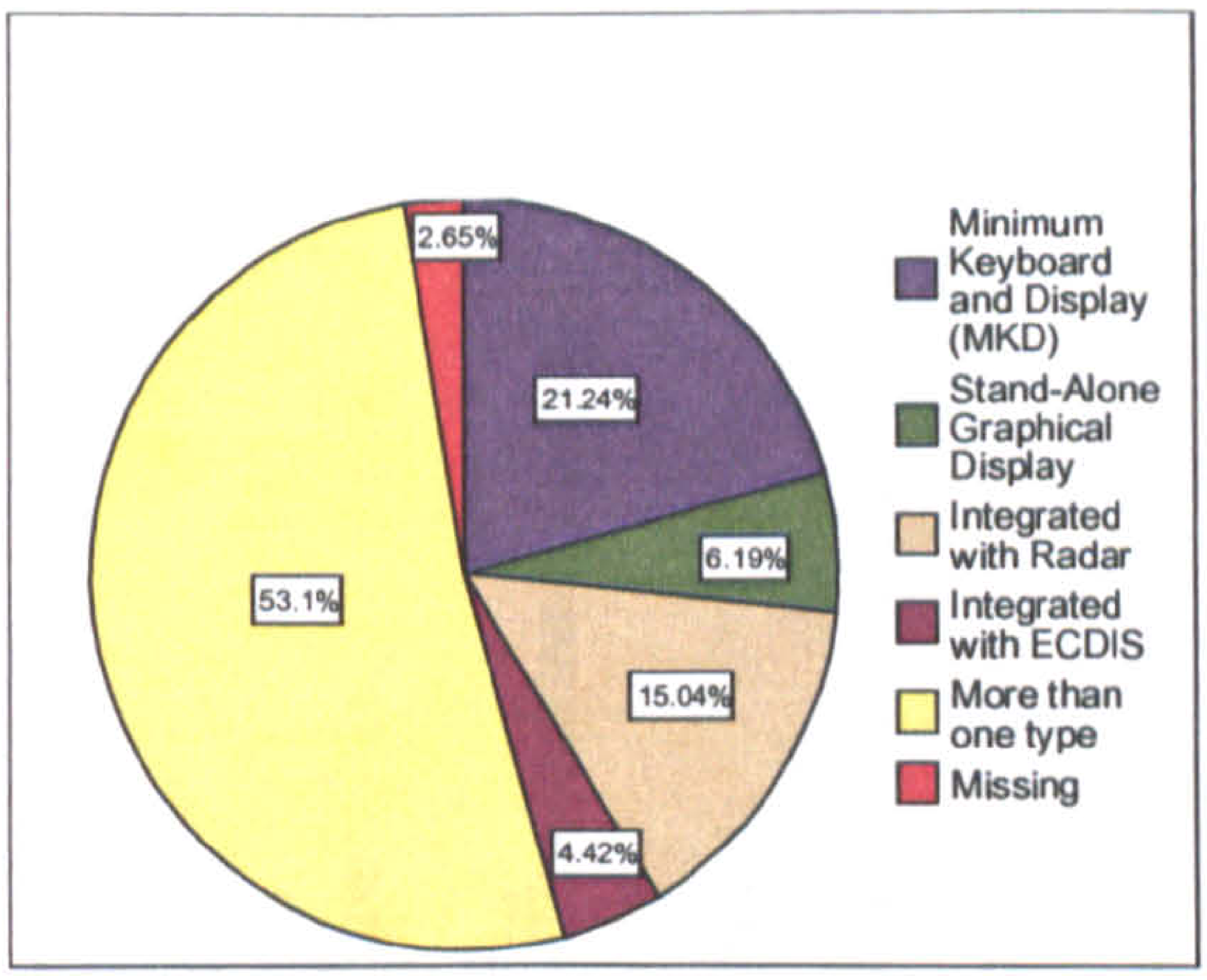

Figure 5. 3 Types of AIS display (A6)

5.3.2 Respondents Seatime

According to figures 5.4 and 5.5, information from 116 respondents shows that the range of total sea time is from 0.3 year to 37 years, with a mean of 8.346 years. The range of sailing experience with AIS is from 1 month to 70 months, with a mean of 16.8 months.

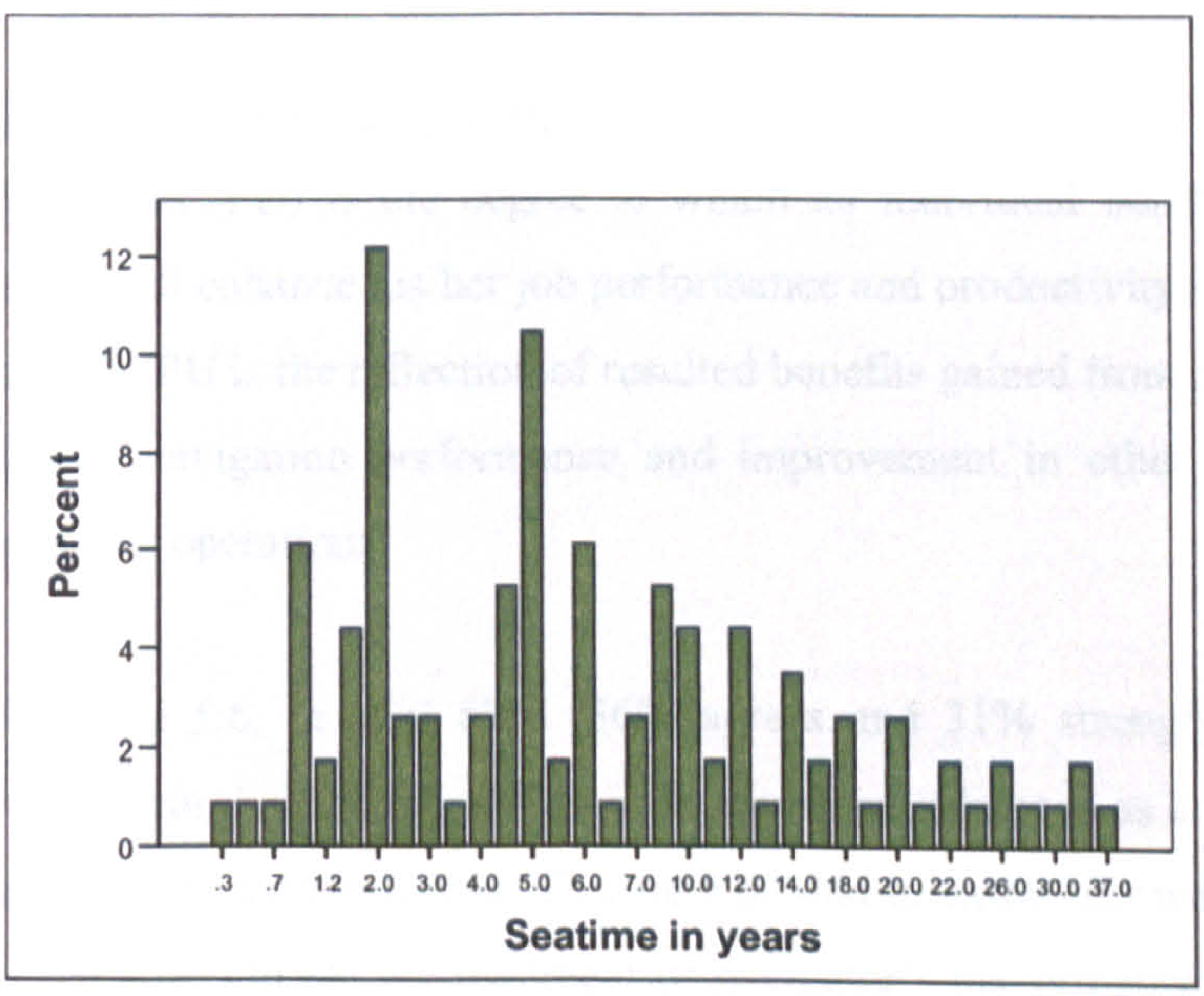

Figure 5. 4 Participants total sea time

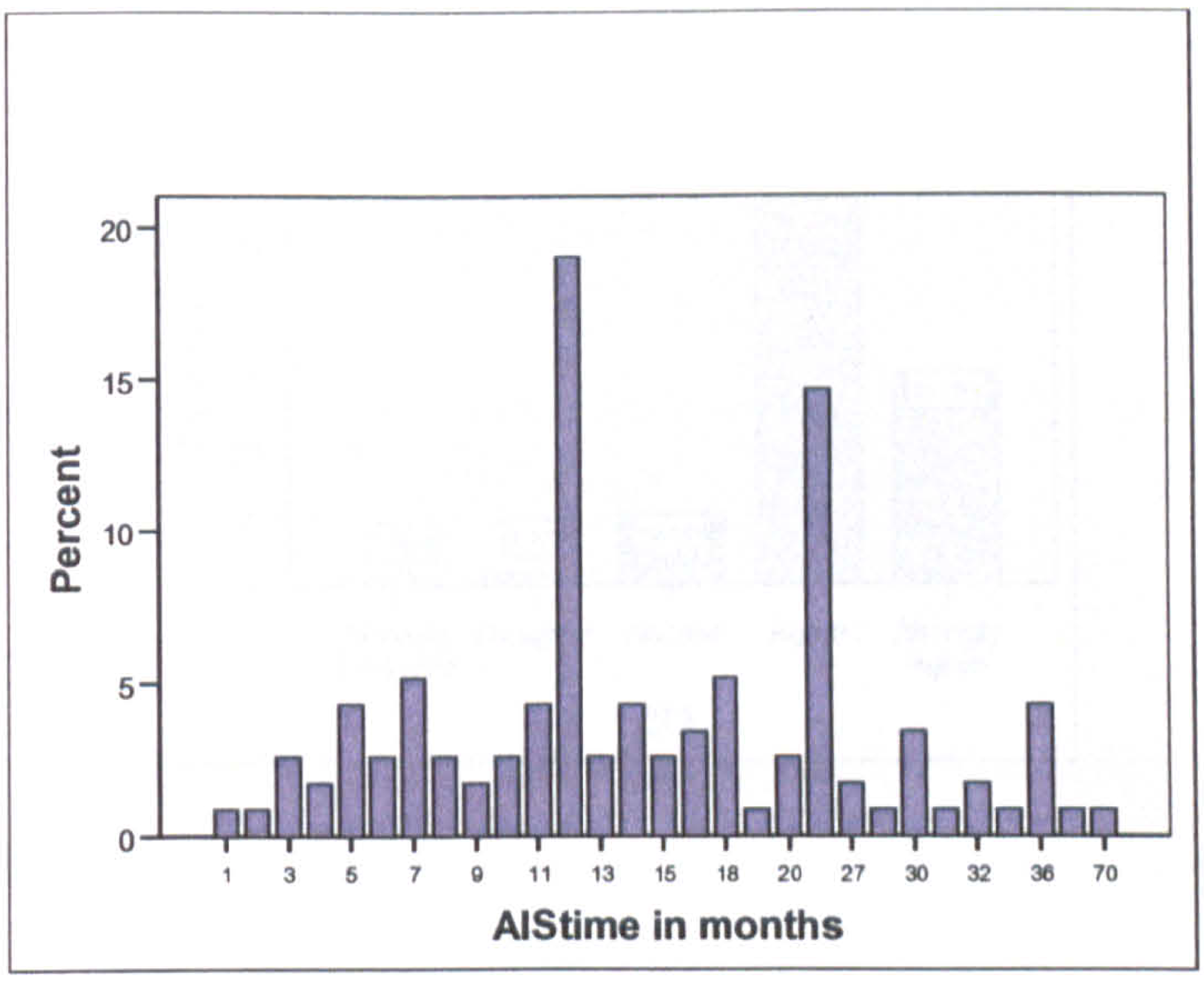

Figure 5. 5 Participants sailing experience with AIS

5.4 Results of Analysis for Measured Variables

The measured result of the questionnaire analysis for main variables of B to G is given in this section.

5.4.1 Perceived Usefulness of AIS

Perceived Usefulness (PU) is the degree to which an individual believes that using a particular system will enhance his/her job performance and productivity (Davis, 1986 and 1989). For the AIS, PU is the reflection of resulted benefits gained from applying the AIS technology to the navigation performance and improvement in other aspects such as quality and safety of operations.

According to figure 5.6, in total 87% (56% agrees and 31% strongly agrees) of the navigators believe that their situational awareness will be enhanced as a result of a better situation display of the marine traffic. This may be due to extra information provided to the bridge by the AIS. On the improvement of navigator's performance in anti-collision operation by AIS, figure 5.7 shows that about 45.7% of them are agreed and about 19% of them are strongly agreed (total of 64.7%). The level of agreement of navigators on the AIS ability to improve their efficiency in anti-collision operation is about 65% (42% agrees and 24% strongly agrees), which is approximately the same as that of the ability to improve their performance in anti-collision, see figure 5.8.

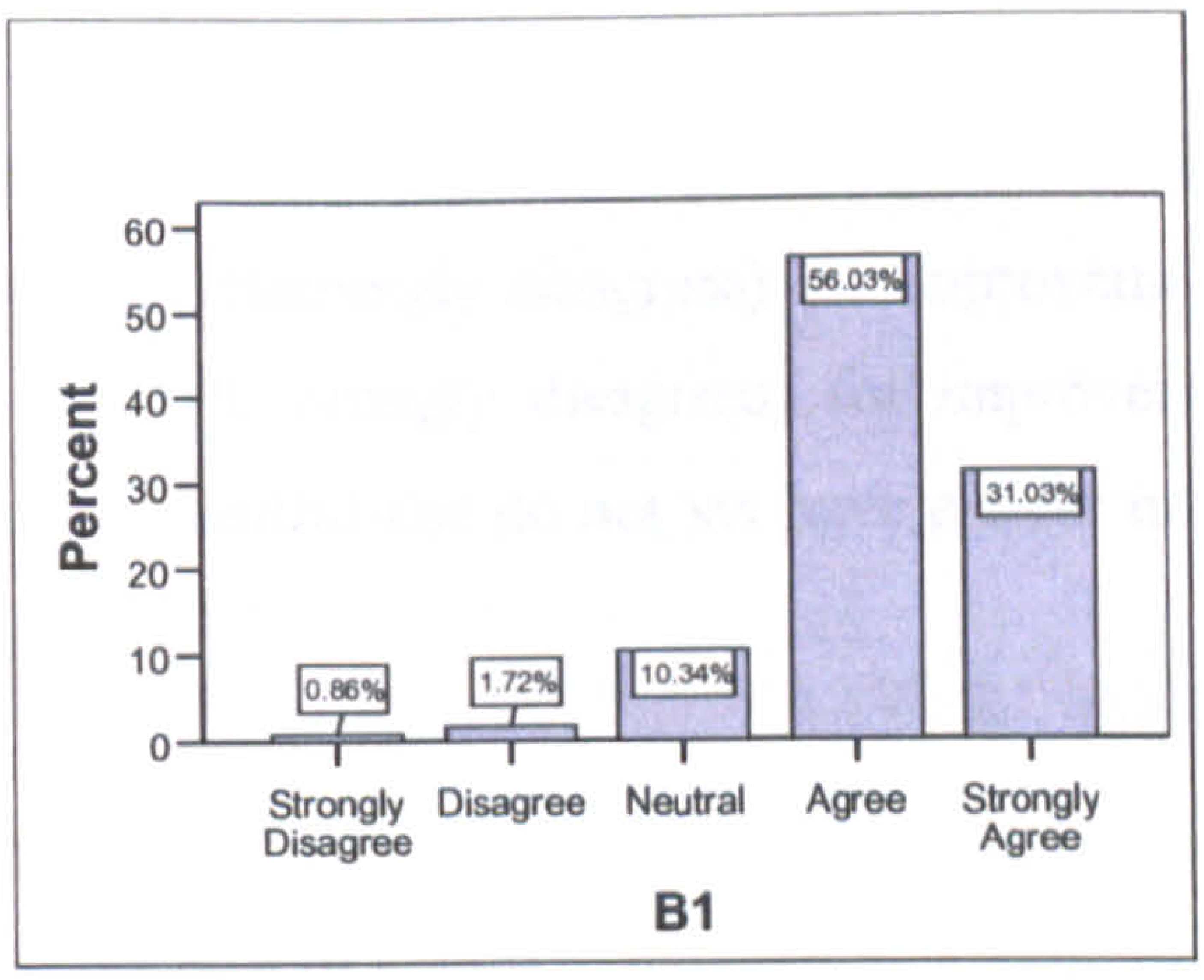

Figure 5. 6 Enhanced situational awareness by the AIS due a better situation display of the traffic

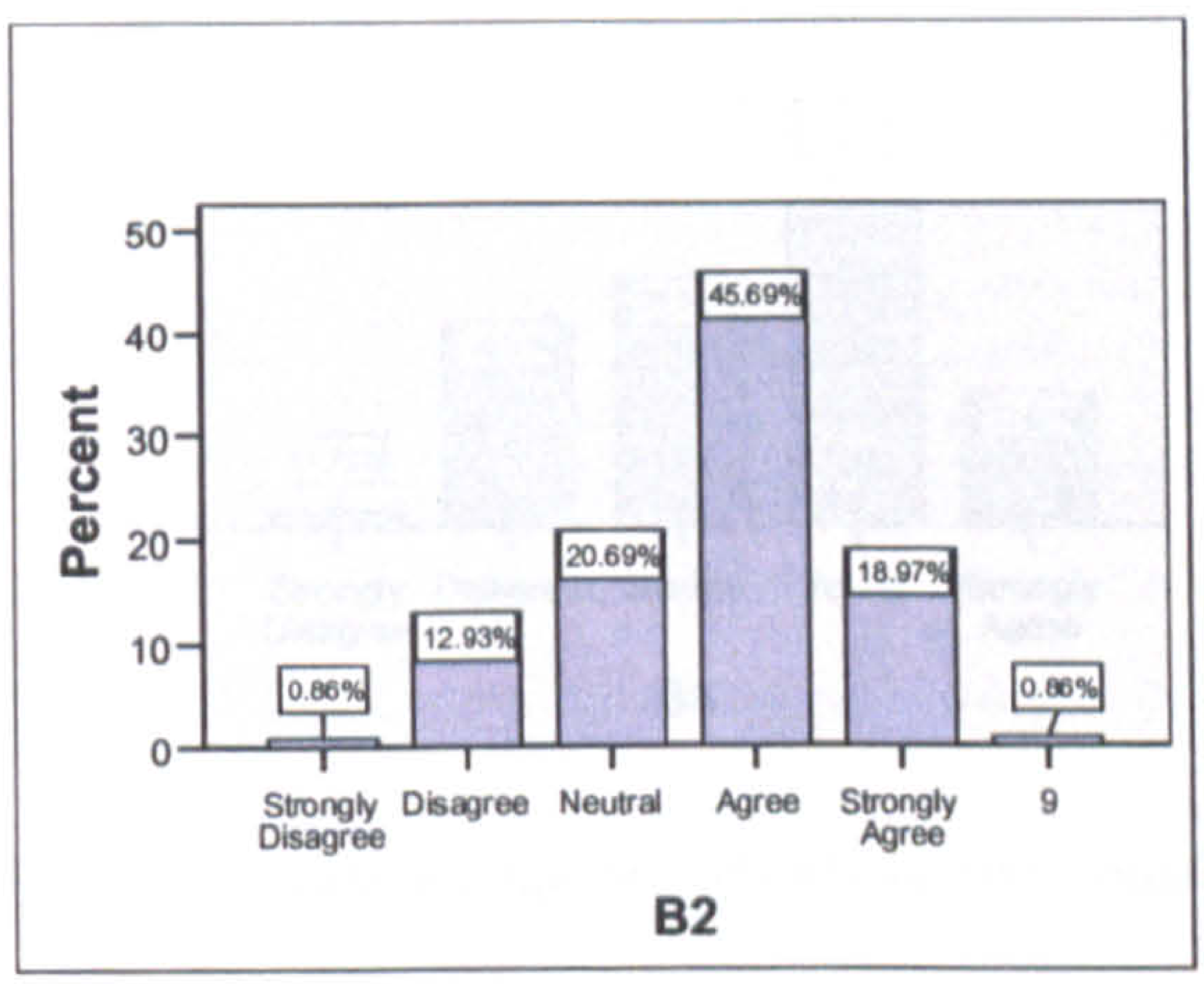

Figure 5. 7 AIS ability to improve navigator's performance in anti-collision operation

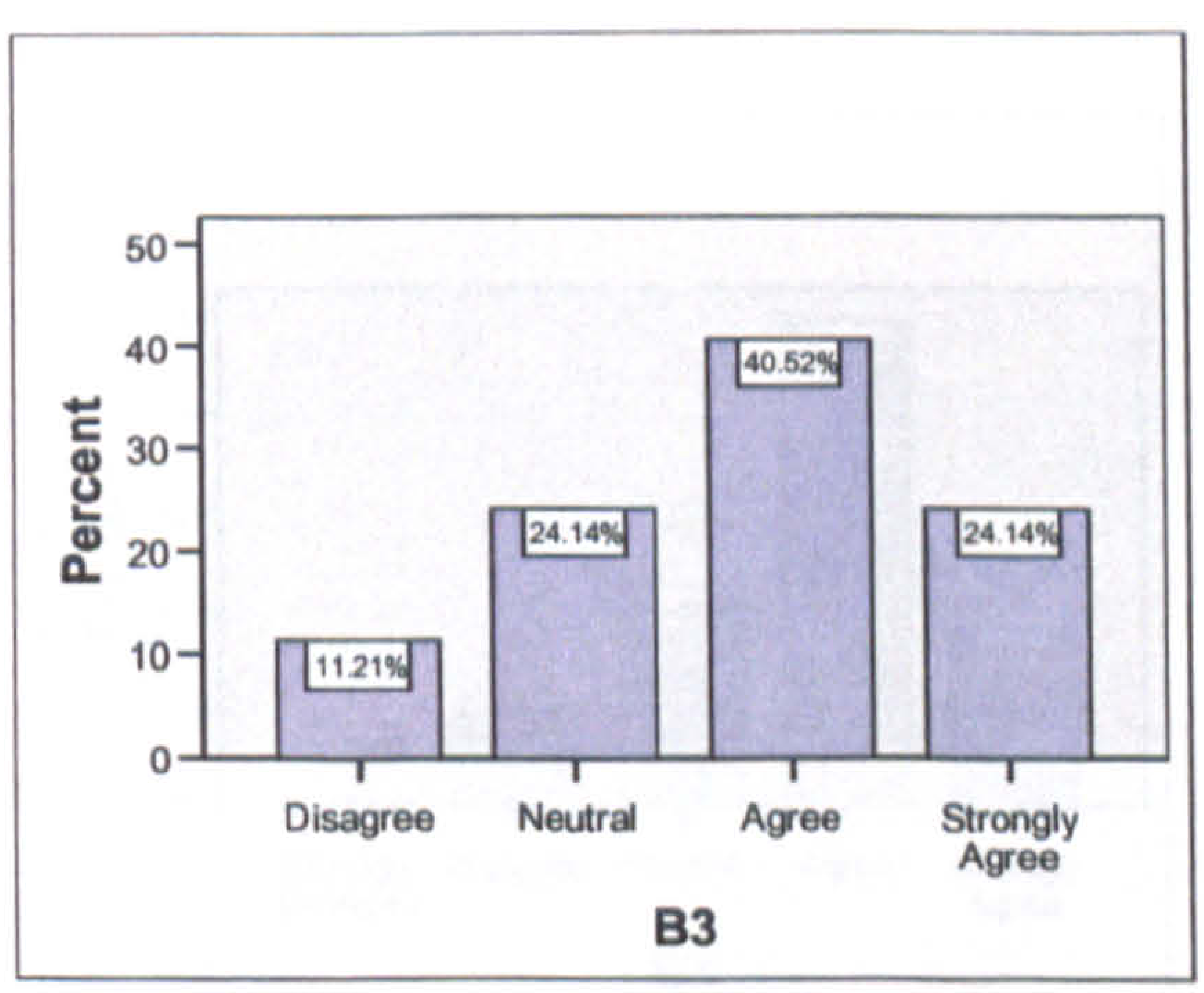

Figure 5. 8 AIS ability to increase navigator's efficiency in anti-collision operation

In all three of the above cases, the level of disagreements is about 3% (about 2% disagrees and 1% strongly disagrees) for improvement of situational awareness, 14% (about 13% disagrees and 1%strongly disagrees) for improvement of performance, and 11% (11%disagrees and 0% strongly disagrees) for improvement of efficiency, and remaining percentages are neutral and do not yet have a clear image of the AIS in these regards.

Figure 5.9 shows that 64% of navigators (41% agrees and 23% strongly agrees) believe that AIS has increased the overall ability of navigators in anti-collision operation. Having more information helps in correct decision making and effectiveness of required action.

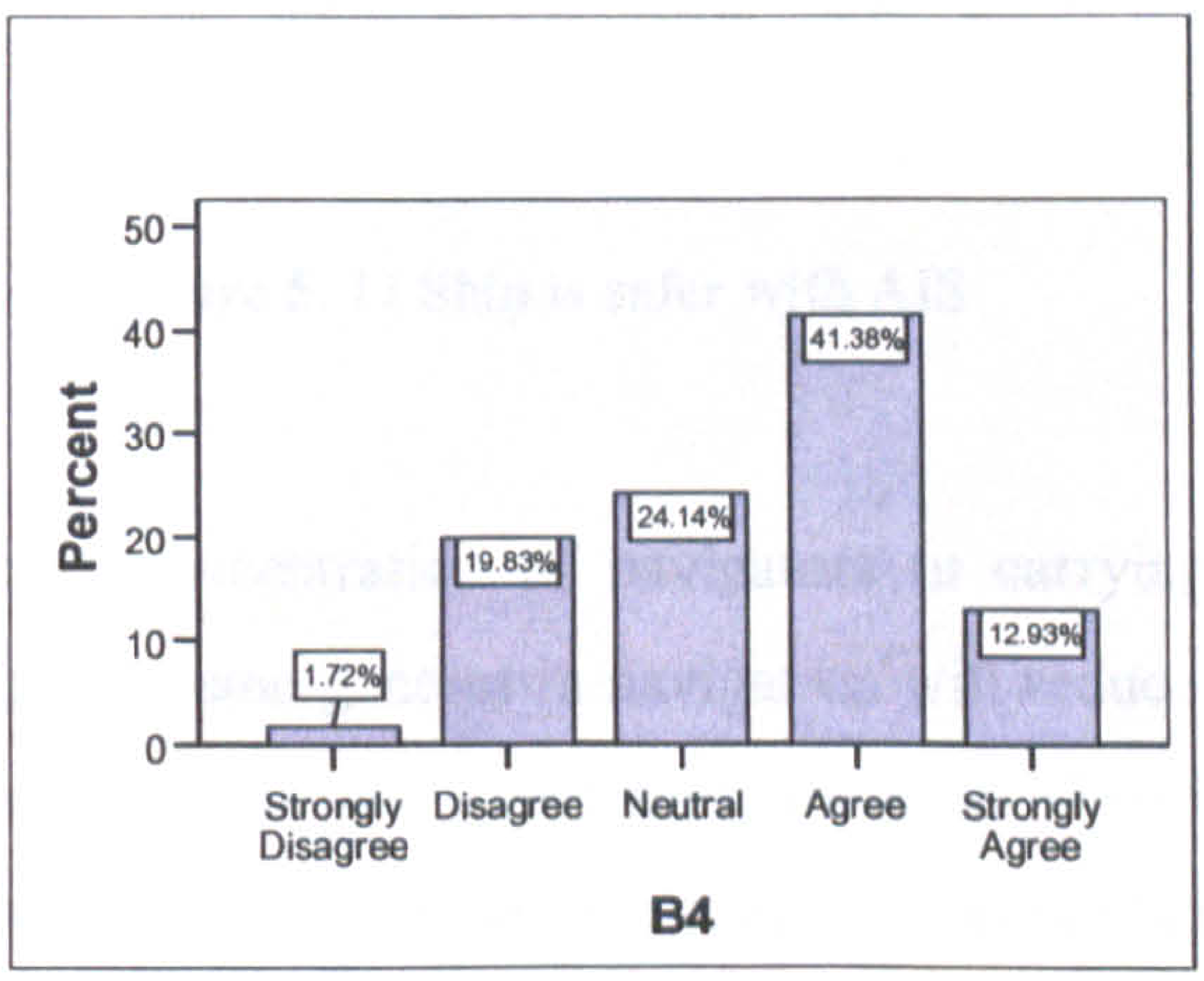

Figure 5. 9 AIS ability to increase navigator's ability in anti-collision operation

Figure 5.10 shows that AIS would increase such sense of being in control of operation, as a majority of 67% of the navigators were in favour of such belief with a ratio of 49% agrees and 18% strongly agrees.

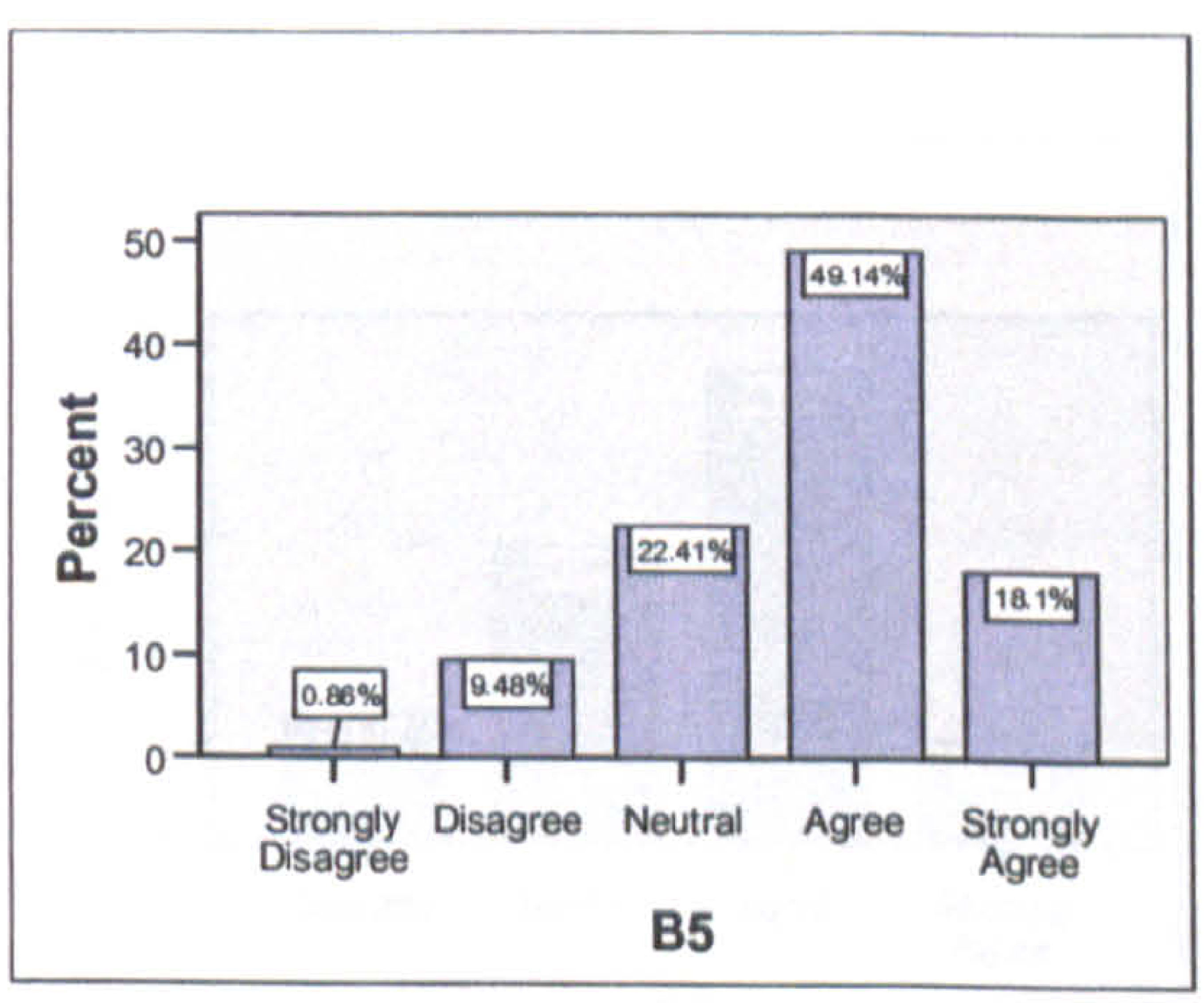

Figure 5. 10 Navigator feels more in control of anti collision operation

Evidence from figure 5.11 shows that 53% of the navigators felt their ship would be safer with AIS. 39% of them were agreed and 14% of them were strongly agreed with such a statement.

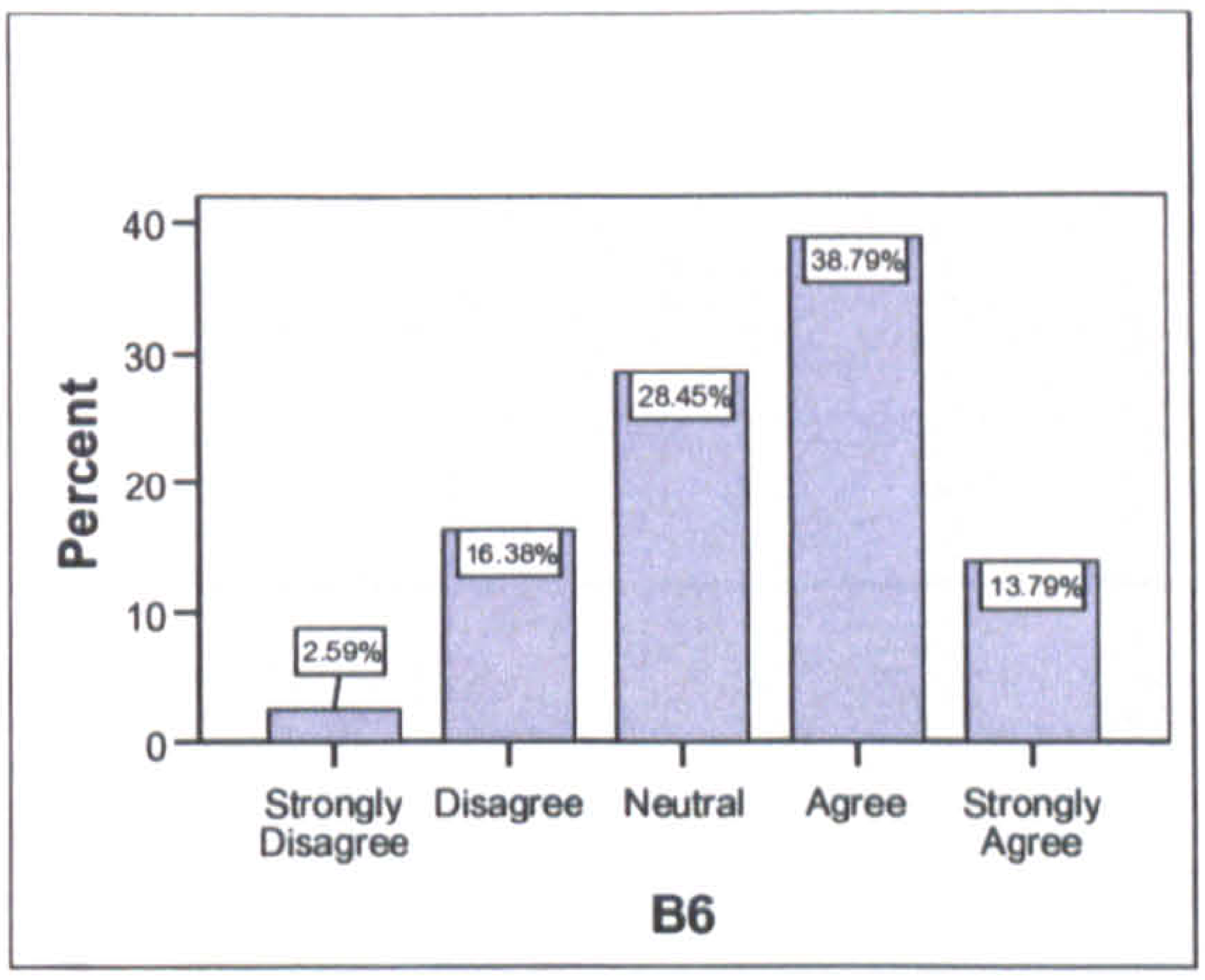

Figure 5. 11 Ship is safer with AIS

Distraction and loss of concentration of navigators in carrying out the anti-collision operation and dealing with emergencies in navigation will reduce the available time, and consequently, the chances for human errors might increase. Therefore, it is very important for the AIS to be merged with other navigational aids on the bridge with the minimum possible distraction. The result of the questionnaire analysis in figure 5.12 shows that the AIS inconvenience of disturbing the normal anti-collision operation is believed to be relatively high. Navigators' response to probability of disruption of normal anti-collision operation by AIS was 47% agrees, and 10% strongly agrees. Therefore, a total of 57% of the navigators thought about AIS as a technology that might disrupt the ship's normal anti-collision operation, but with the different degree of emphasis.

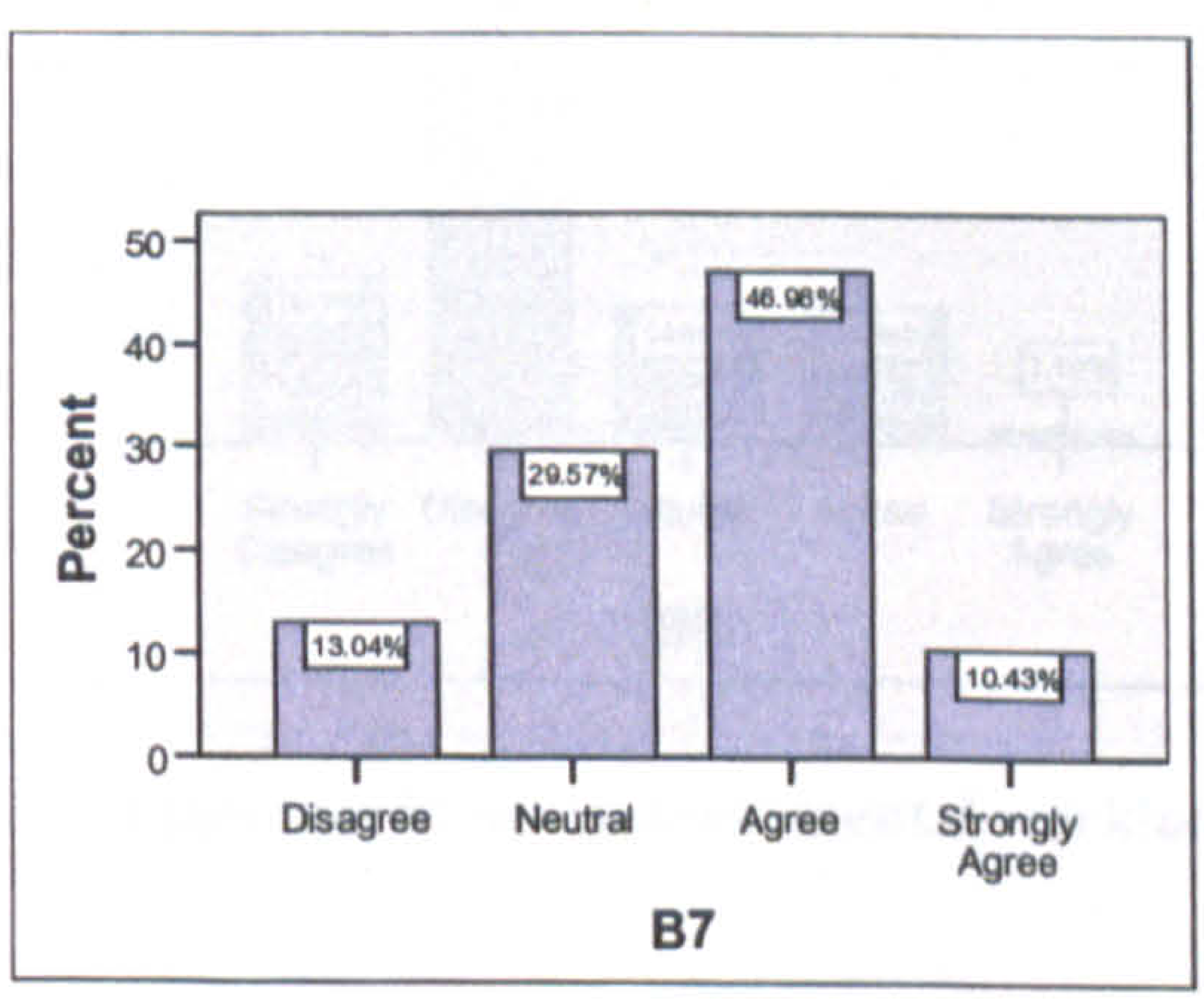

Figure 5. 12 AIS disrupts the normal anti-collision operation

The impact of AIS on the navigators' workload, physically and mentally, is also very important in AIS success as a navigational aid. The questionnaire survey included the issue of AIS to estimate navigators' perception of possible change in their workload due to AIS implementation. The AIS survey result for increase in workload shows dissimilarities with the result for disruption. The result shows that 49% of the navigators disagreed and 18% strongly disagreed that AIS increases their physical workload (see figure 5.13).

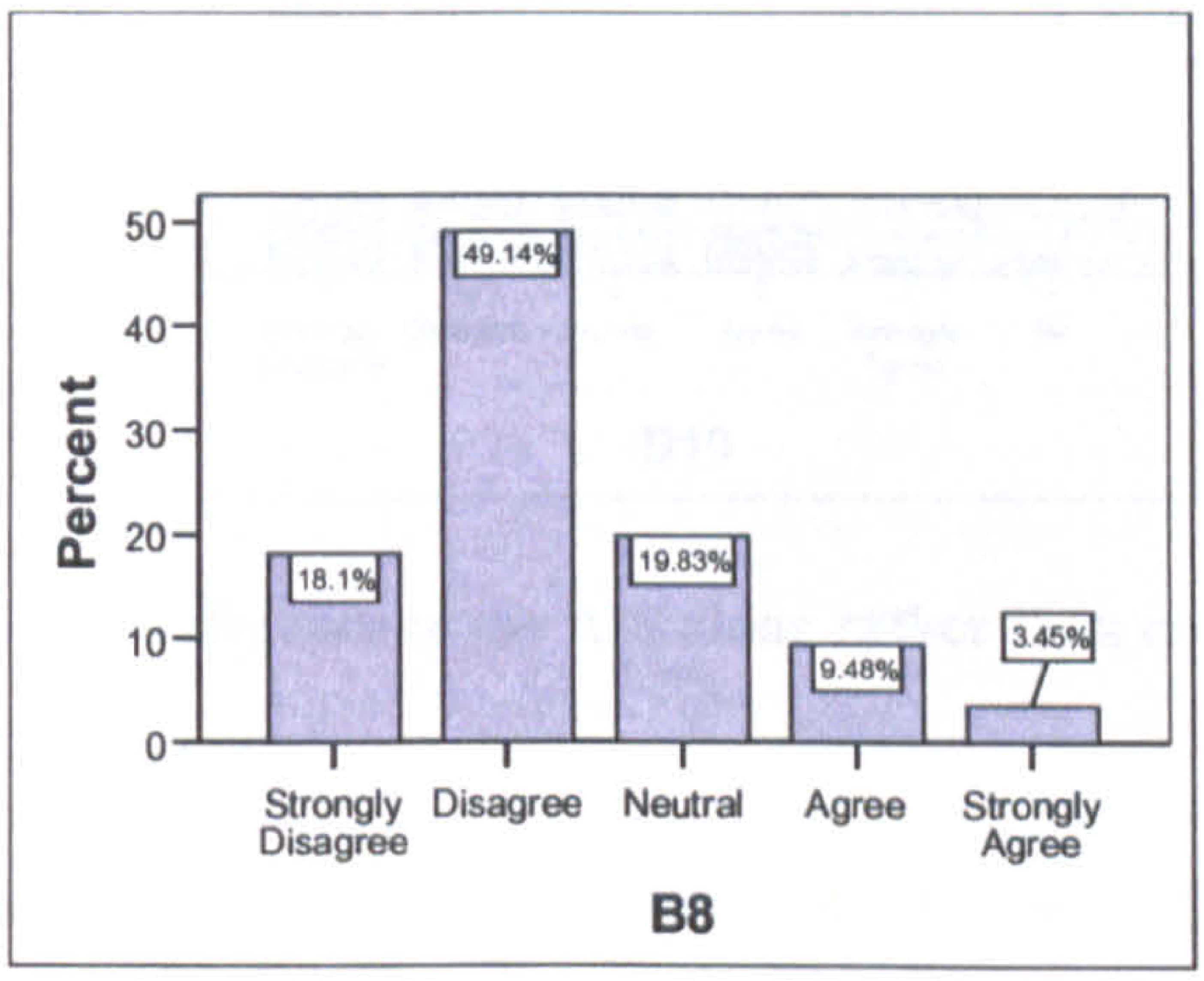

Figure 5. 13 Increase in navigators' physical workload

Figure 5.14 shows that the majority of navigators generally thought that using AIS did not increase mental workload, with 69% disagreement consisting of 51% disagrees and 18% strong disagrees.

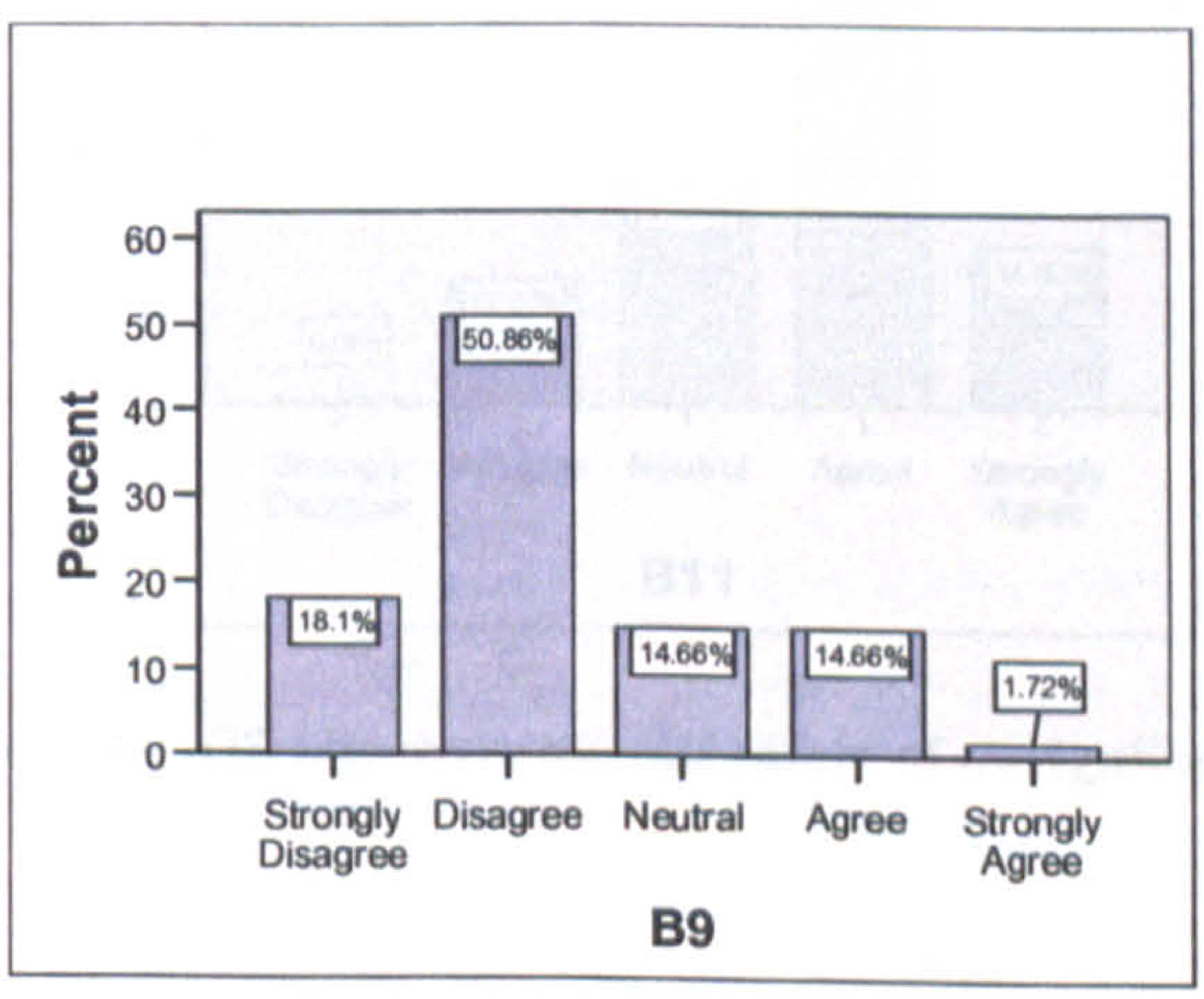

Figure 5. 14 Increase in navigators' mental workload

Figure 5.15 shows that 83% (36% disagrees and 47% strongly disagrees) of the navigators do not prefer to use AIS alone rather than radar and only 6% (4% agrees and 2% strongly agrees) of them would prefer to use AIS independent of the radar.

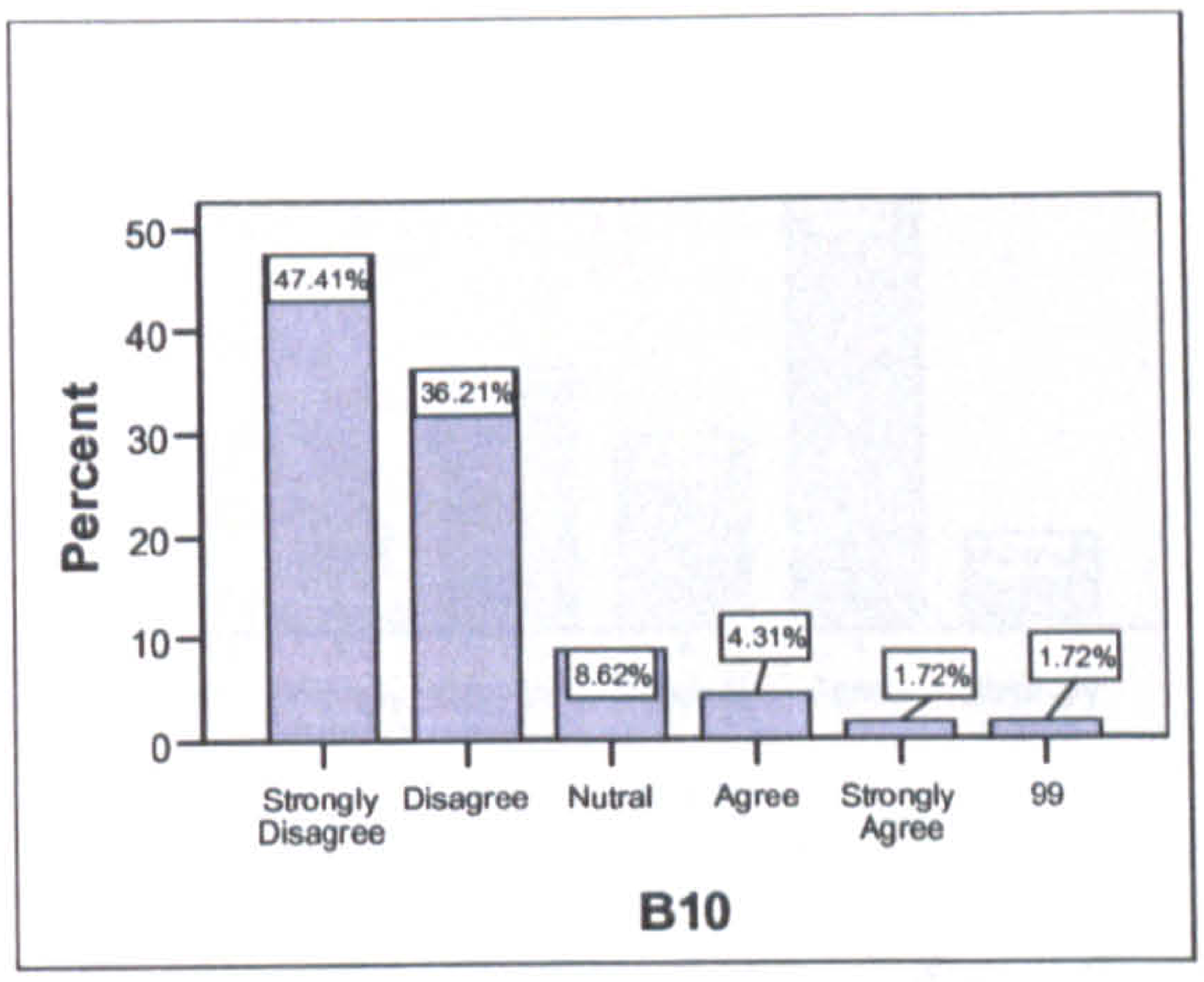

Figure 5. 15 Preference to use AIS alone rather than radar

The survey result shows that 66% (50% agrees and 16% strongly agrees) of navigators are in favour of AIS usefulness to improve overall safety of navigation, and only 13% (12% disagrees and 1% strongly disagrees) are against (figure 5.16).

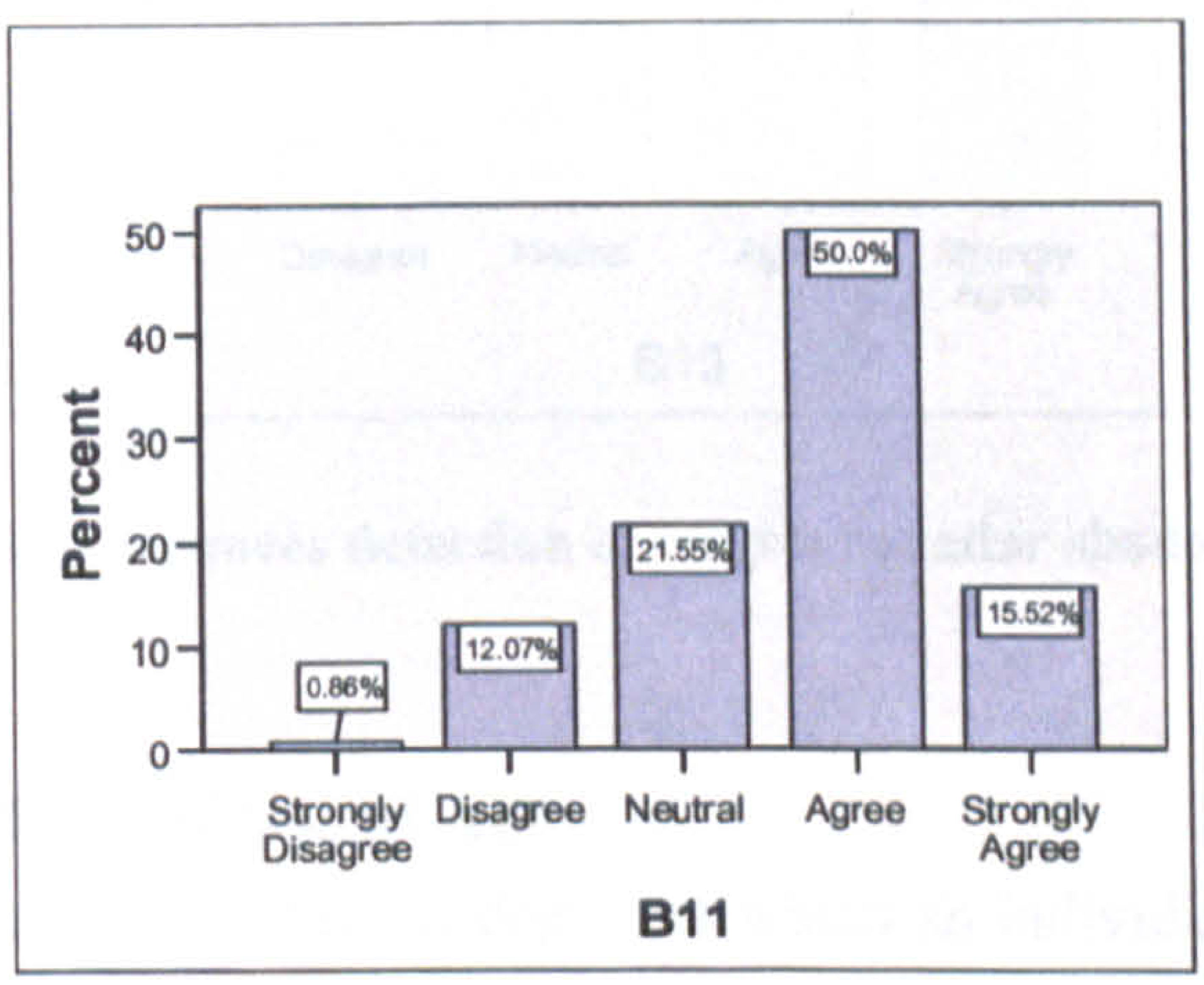

Figure 5. 16 AIS improves overall safety of navigation

In a comparison of AIS information with radar information, 52% (43% agrees and 9% strongly agrees) believed that AIS information was clearer and continuous than those from radar (see figure 5.17). According to figure 5.18, most of the navigators believe that some of the radar blindness in target detection will be removed or reduced by AIS. About

68% (42% agrees and 26% strongly agrees) of the navigators were in favour of the statement that the detection of target in radar shadow areas is improved with AIS.

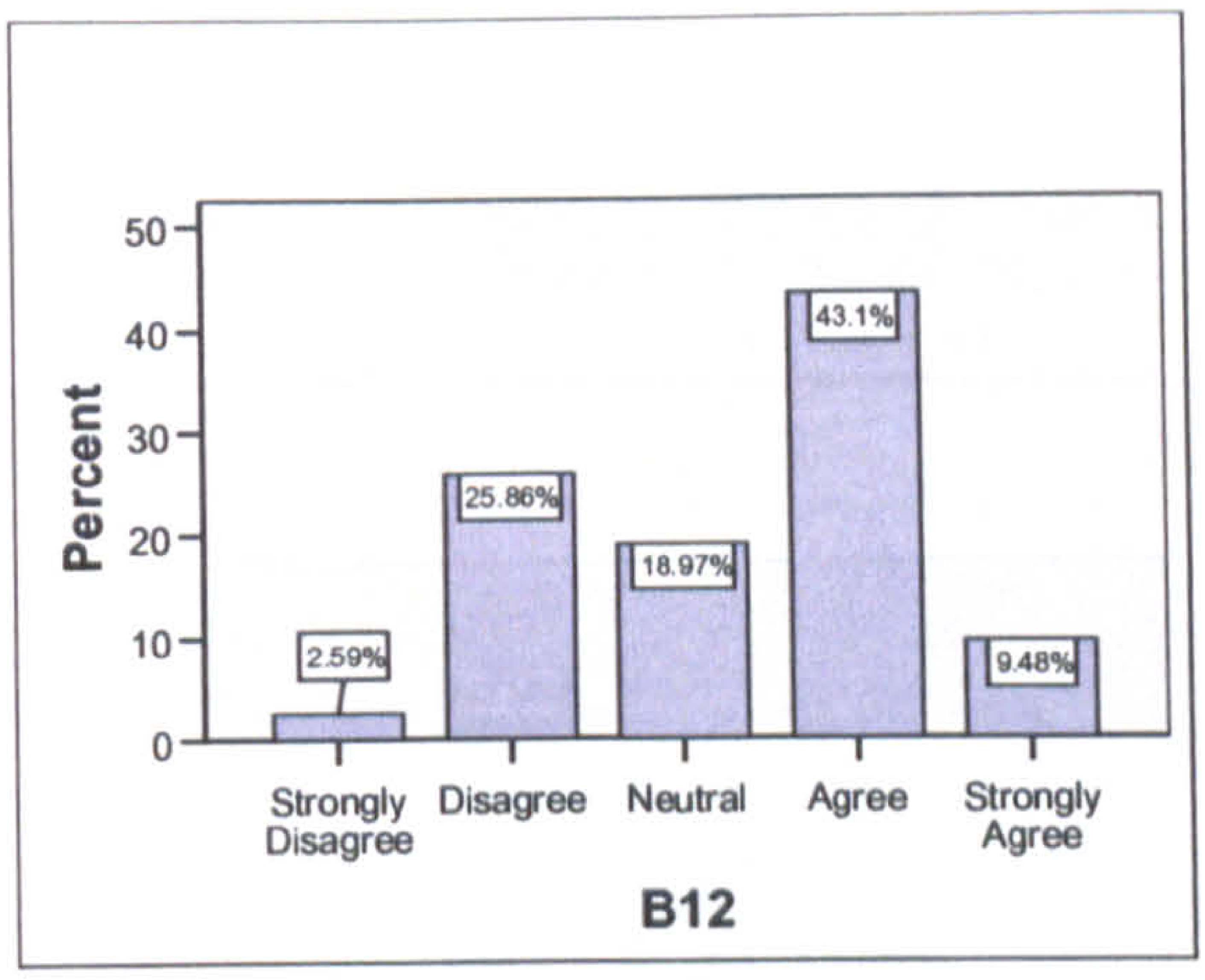

Figure 5. 17 AIS provides clearer and continuous information than radar

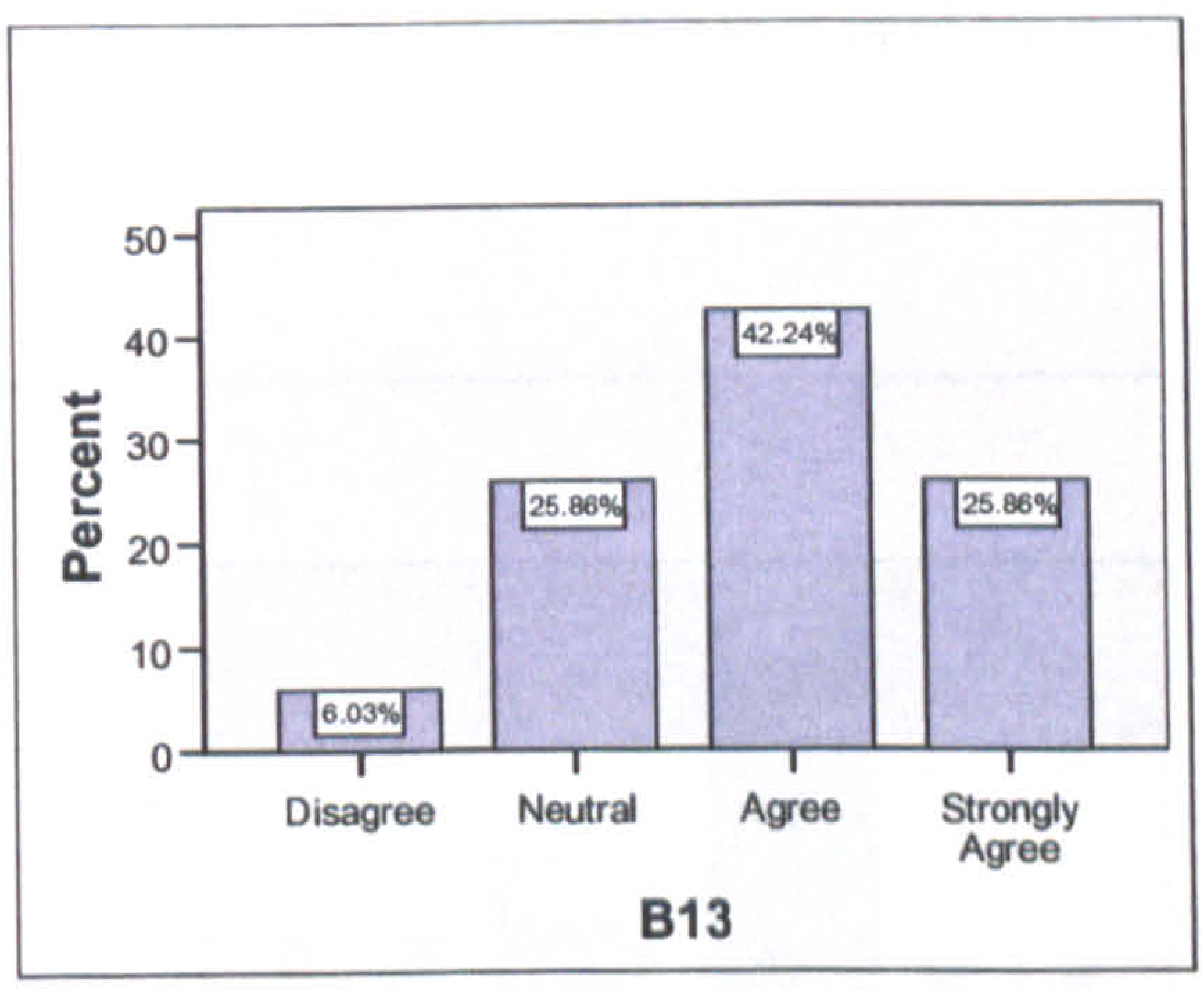

Figure 5. 18 AIS improves detection of targets in radar shadow areas

5.4.2 Perceived Ease of Use of AIS

Perceived Ease of Use (PEOU) is the degree to which an individual believes that using a particular system will be free of effort (Davis, 1986 and 1989). For the AIS, it reveals the possible difficulty of using the equipment on the ship.

In this section the questionnaire analysis for this measure is discussed for each question, as was done for PU.

On the feasibility of the navigators self-learning to operate AIS, 42% of them disagreed and 8% strongly disagreed (half of the total) that it is hard to learn to operate AIS on their own (see figure 5.19). Only 18% of them believed that self-learning is hard. It is also apparent from figure 5.20 that 60% of navigators perceived that it is easy to become skilful at using AIS.

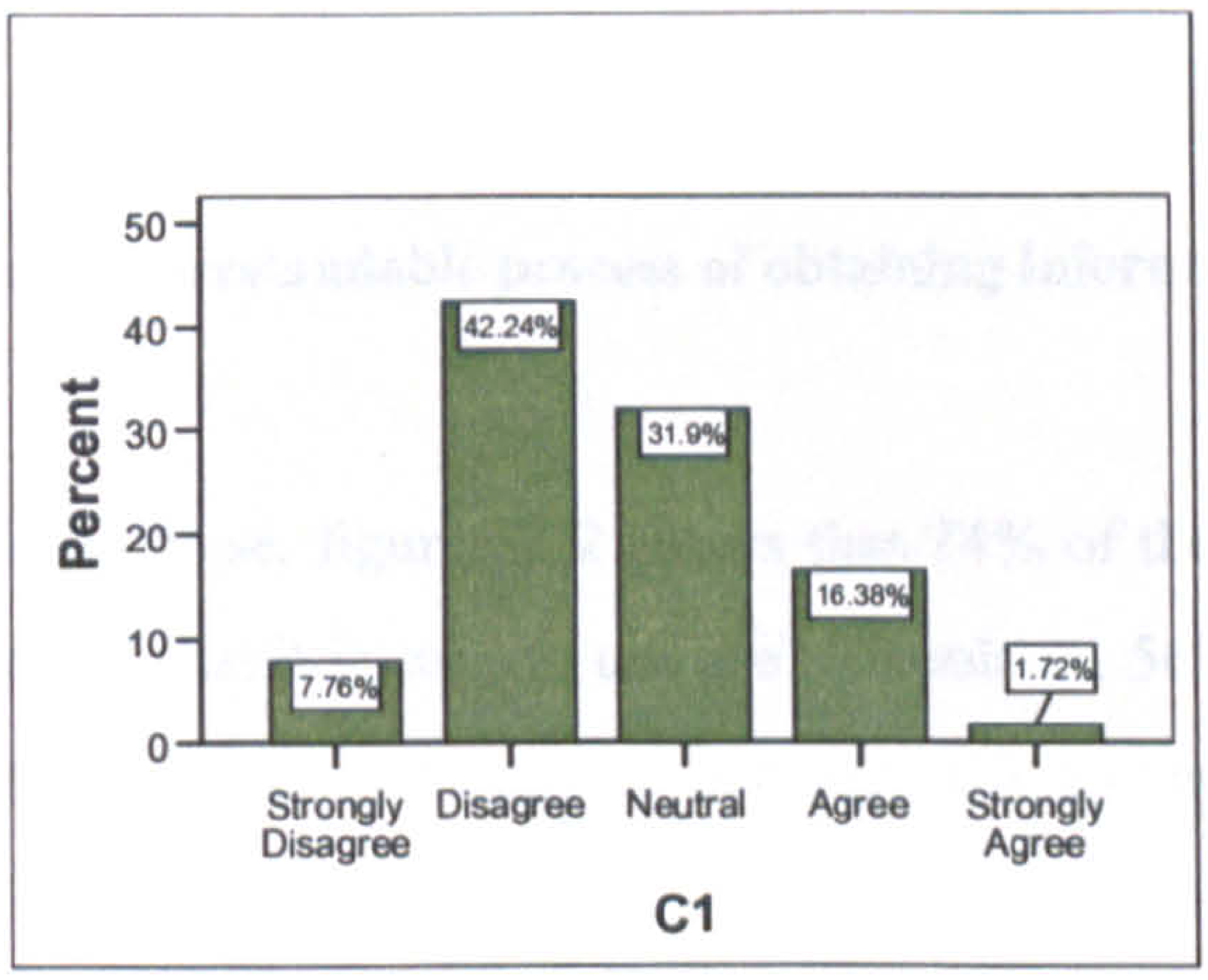

Figure 5. 19 Self –learning to operate AIS is hard for navigators

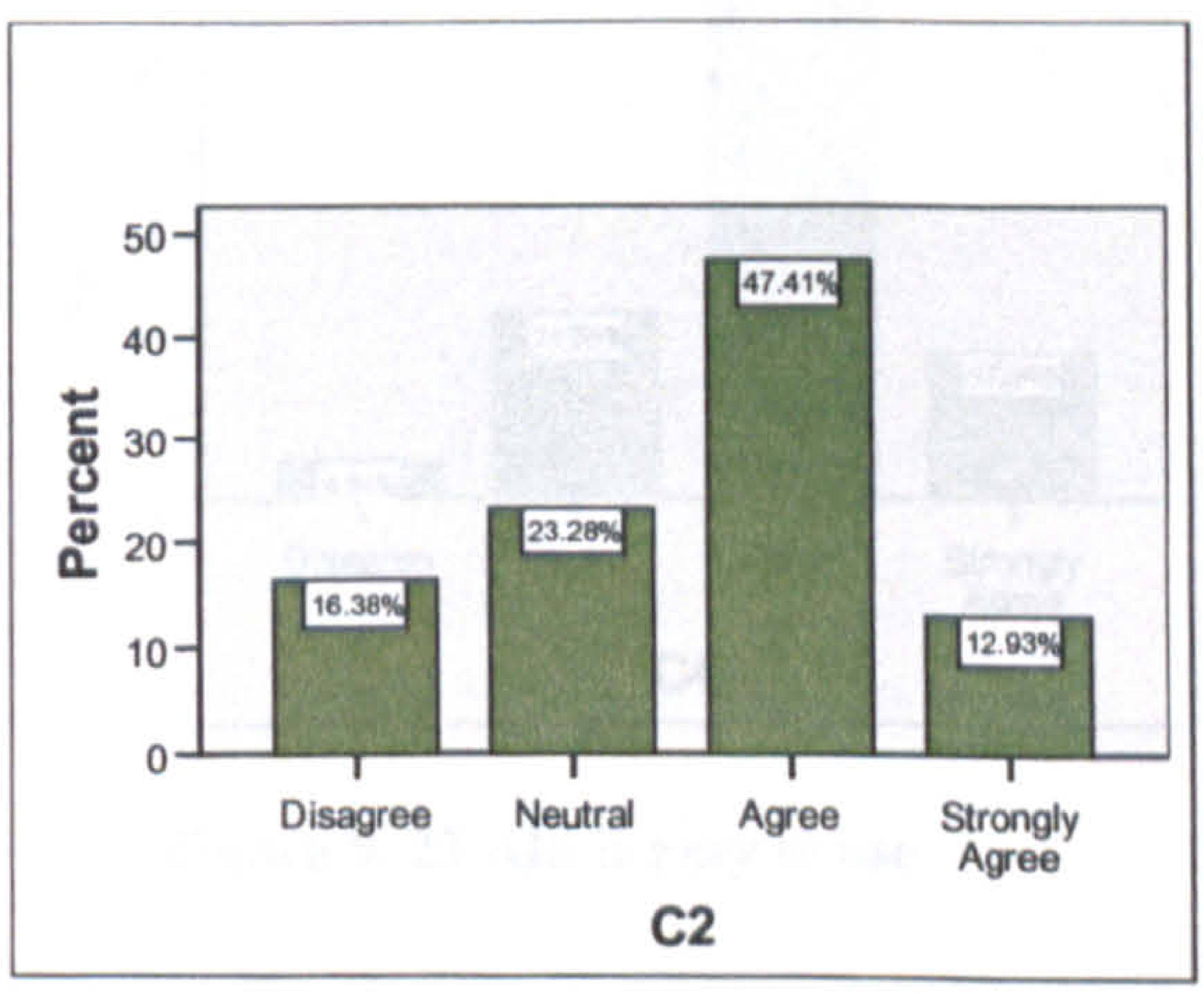

Figure 5. 20 Easy to become skilful at using AIS

A total of 68% of navigators are positive that the procedure for getting information from AIS equipment is clear and understandable, according to figure 5.21.

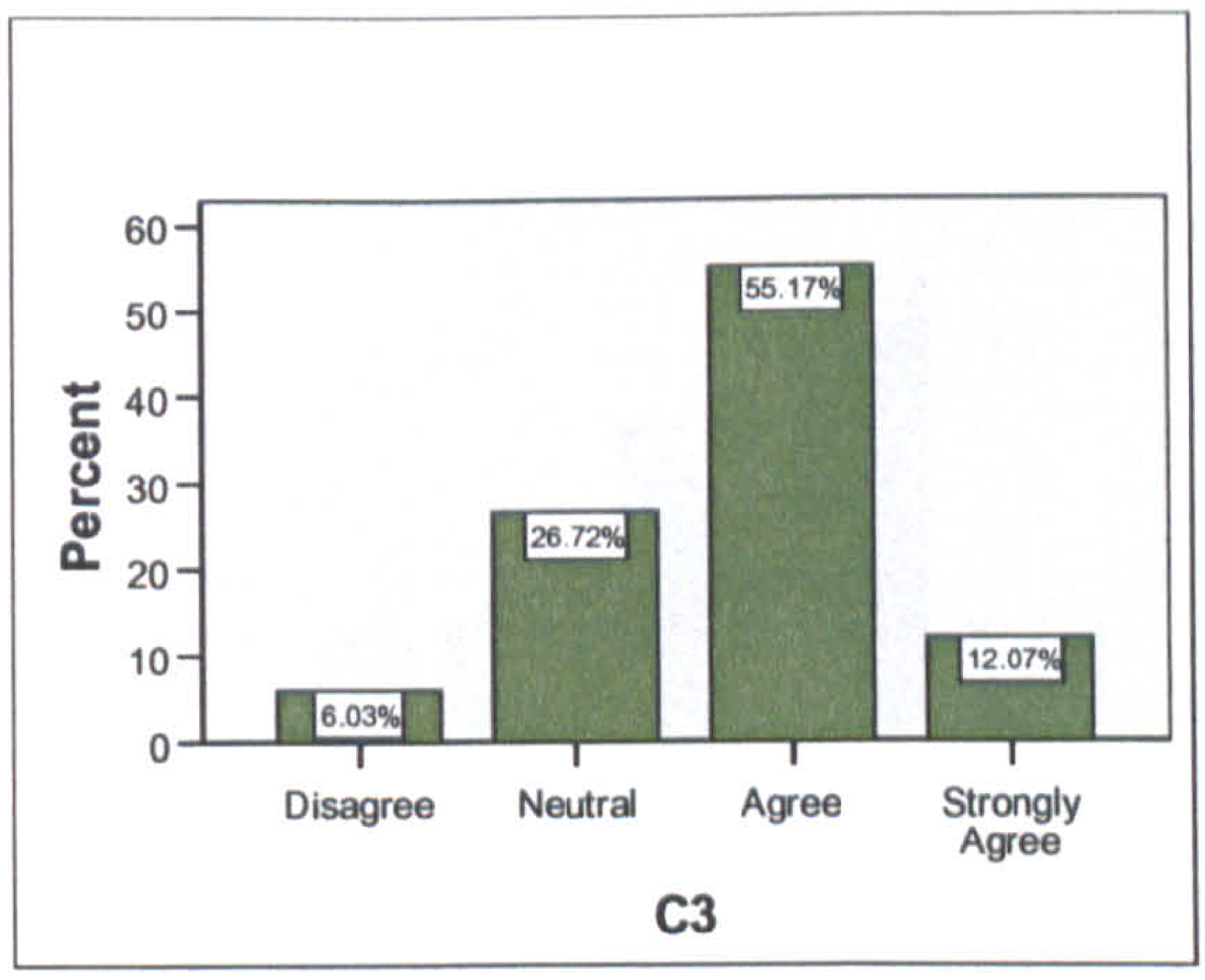

Figure 5. 21 Clear and understandable process of obtaining information from AIS

Further on the AIS ease of use, figure 5.22 shows that 74% of the navigators were either agreed or strongly agreed that it is easy to use the technology. 56% percent of them were agreed or strongly agreed that it is easy to use the AIS technology for anti-collision operation (see figure 5.23).

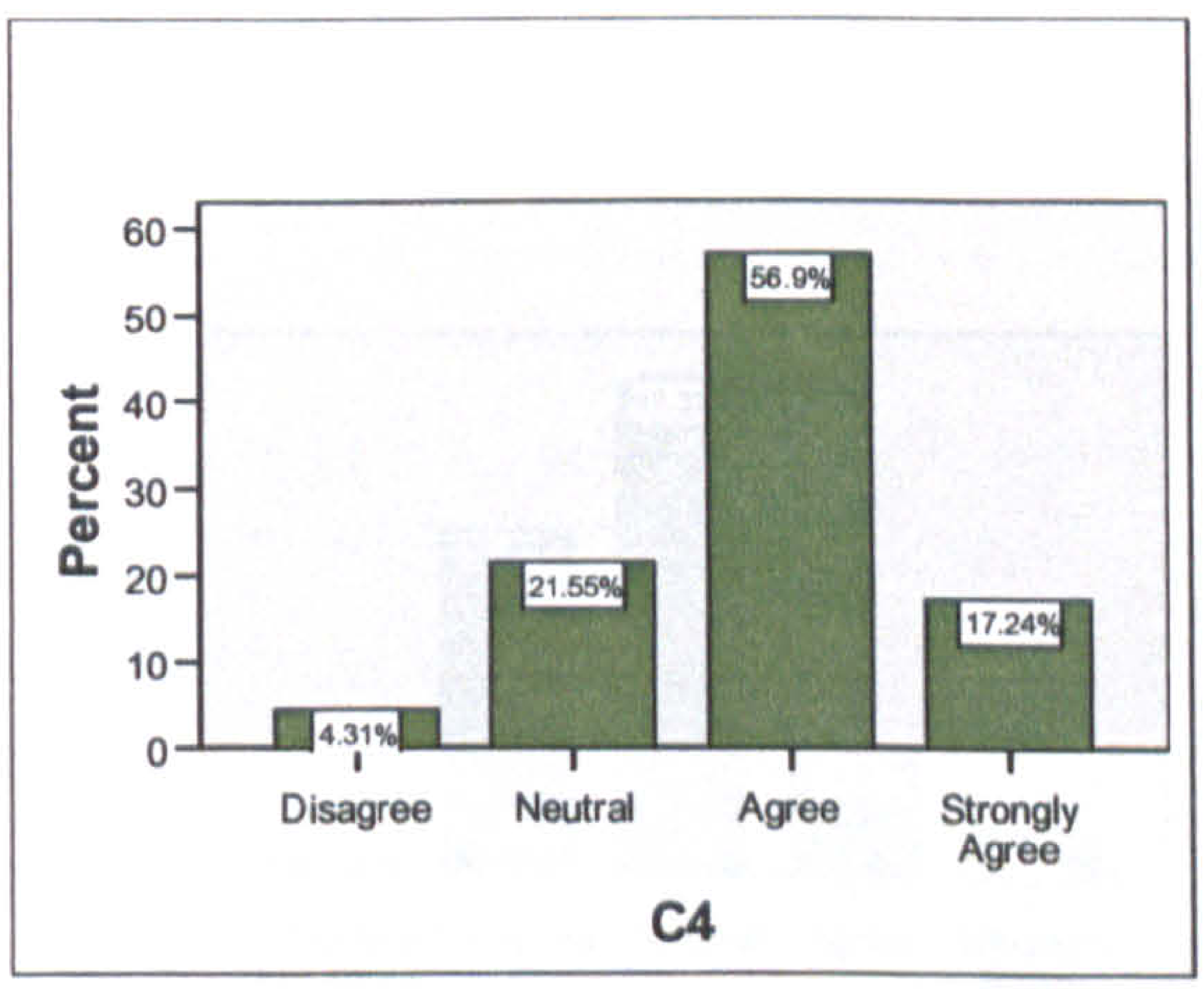

Figure 5. 22 AIS is easy to use

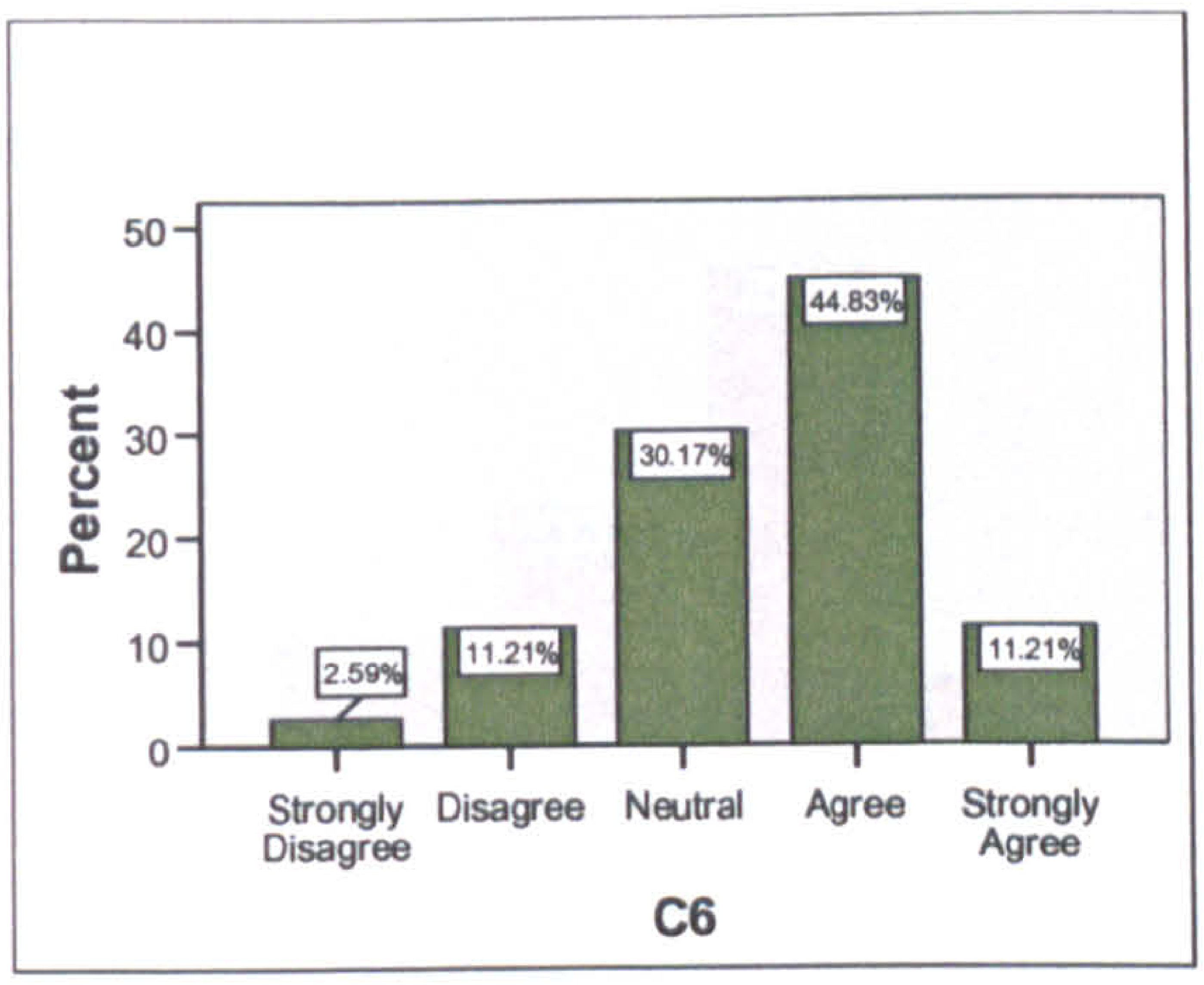

Figure 5. 23 It is easy to use AIS for anti-collision operation

According to figure 5.24, about 34% of the navigators believed that there is not any problem in AIS response time to data input. These are the data that do not need frequent updates. A larger majority of them either believed that AIS response to data input is slow (16%) or they did not have a specific idea about it (48%). In addition, about 48% uncertainties of the navigators were on whether AIS response to data input is slow or not.

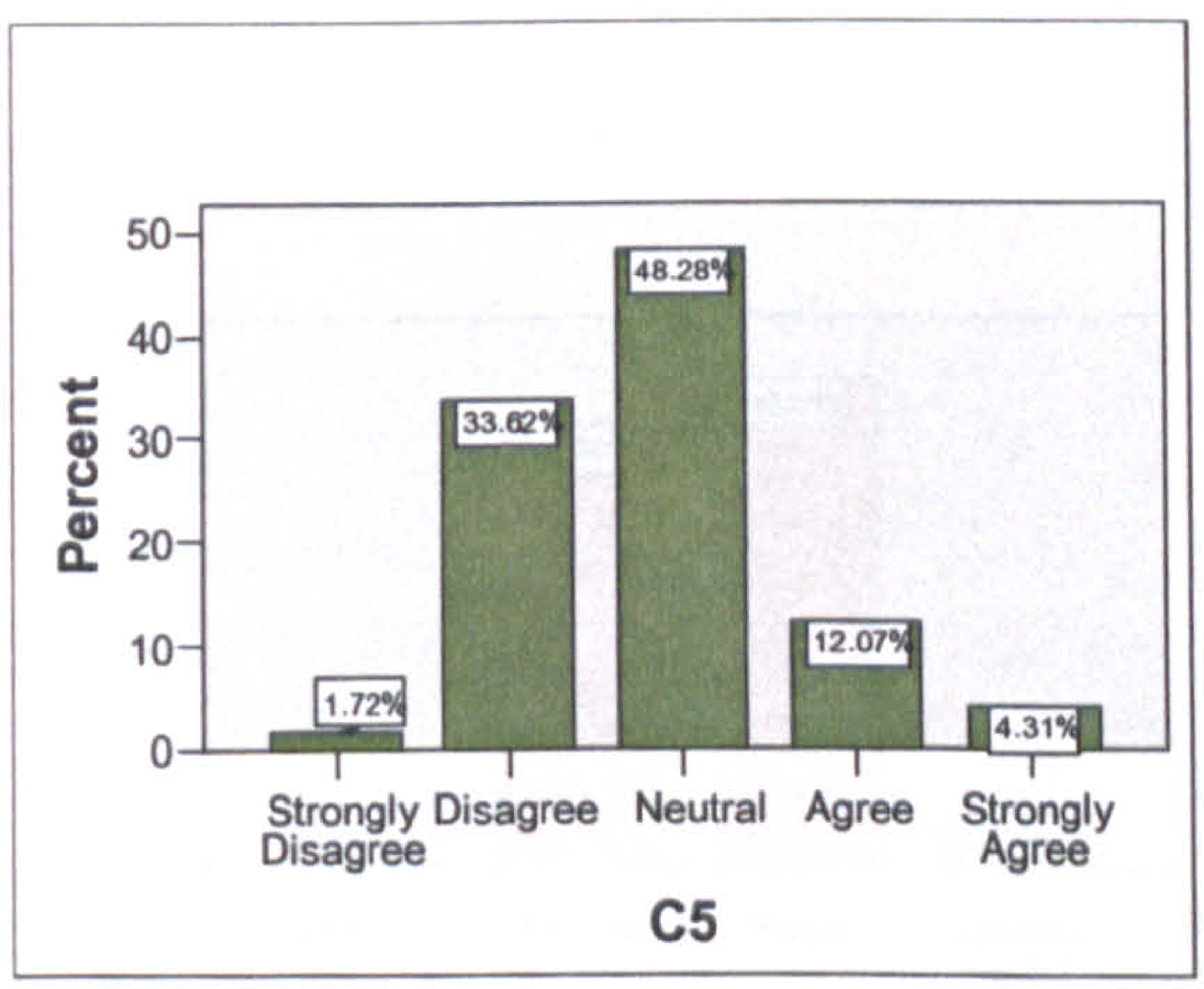

Figure 5. 24 AIS slow response to data input

5.4.3 Perception of AIS Information Display

The way in which AIS information is displayed and controlled is investigated in this section of the questionnaire survey.

On the value of the AIS display in navigator's performance, 64% (54% agrees and 7% strongly agrees) of the respondents considered it as a valuable factor that could affect their performance (see figure 5.25).

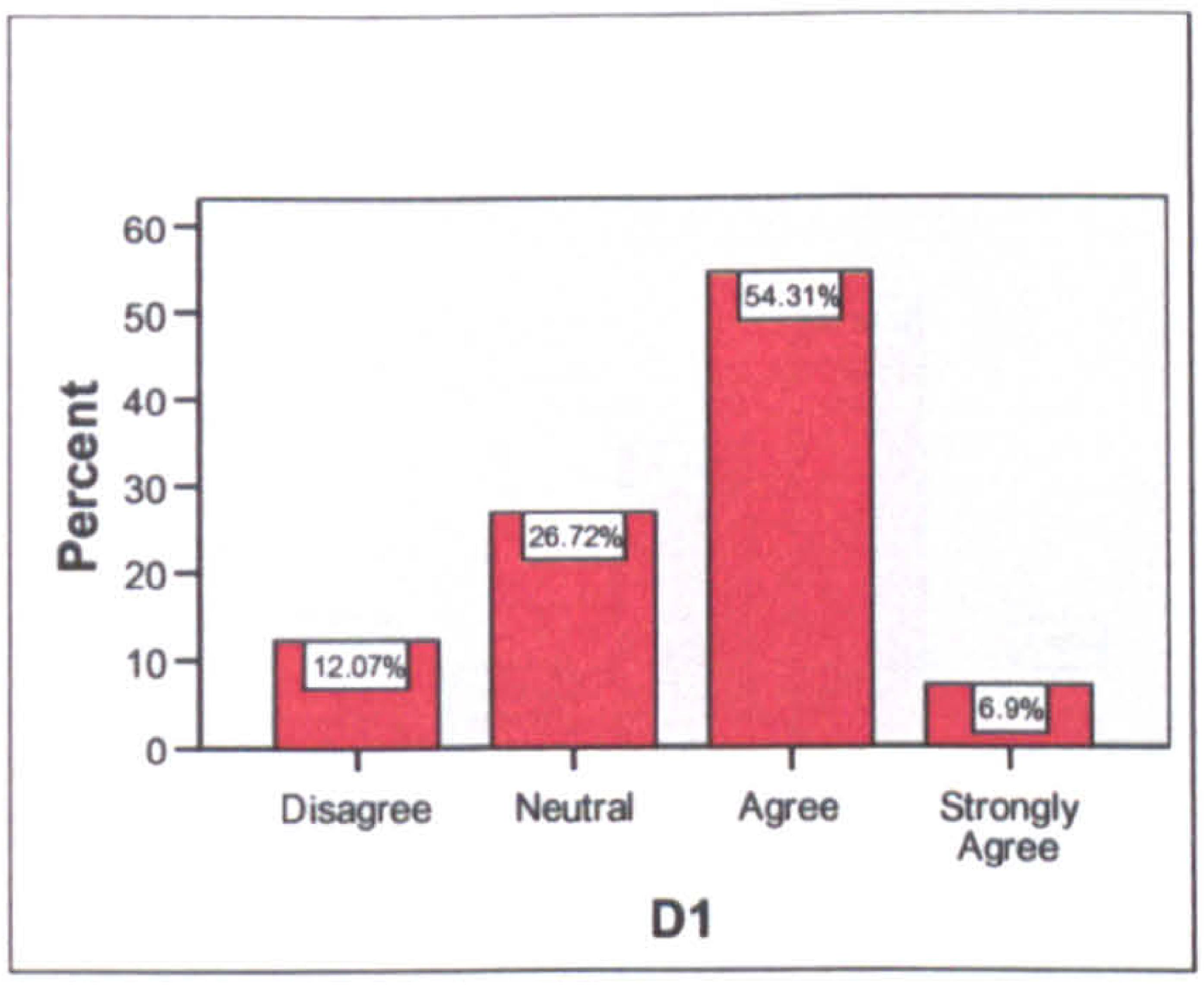

Figure 5. 25 AIS display is valuable in navigator's performance

The opinion about the AIS symbols in AIS display, as in figure 5.26, shows that 52% of the navigators believed the symbols are efficient. However, 42% of them were neutral on the efficiency of AIS symbols in their responses. Efficiency of the controls and keyboard is an influential factor on the usefulness of any technology. Therefore, the questionnaire included user-friendliness of the AIS keyboard to find out views of the navigators in this respect.

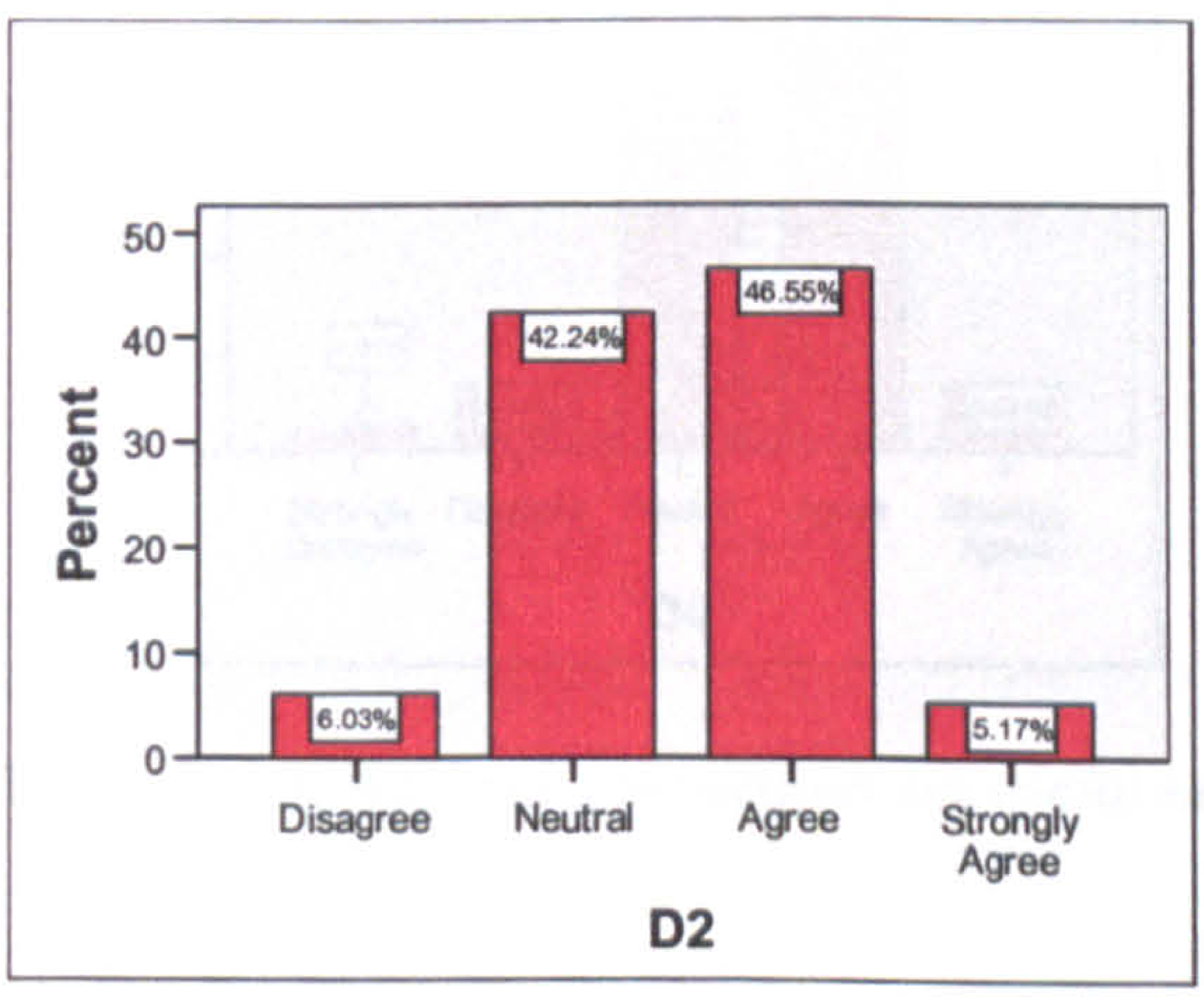

Figure 5. 26 AIS display symbols are efficient

According to figure 5.27 about 54% of the navigators showed their agreement (either agree or strongly agree) that the AIS keyboard is user-friendly, but again a relatively big percentage (34% neutral) of them were uncertain about this matter.

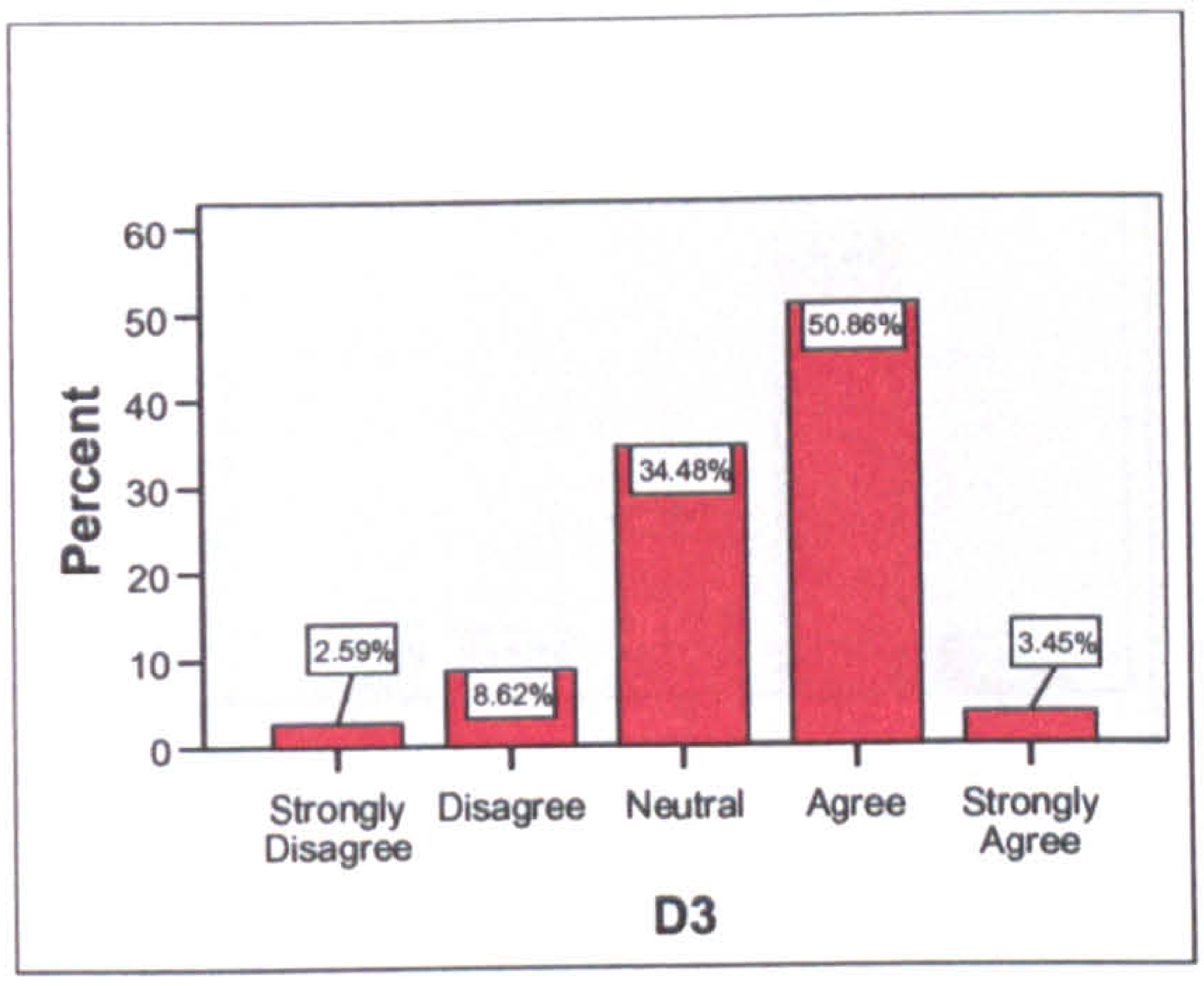

Figure 5. 27 AIS keyboard is user-friendly

The availability of an AIS unit help for the users to solve any problem during operation and use was considered to be important. About 47% of the mariners agreed and 7% strongly agreed that the AIS unit help and instructions are useful and clear. About 37% were still neutral on this respect (see figure 5.28).

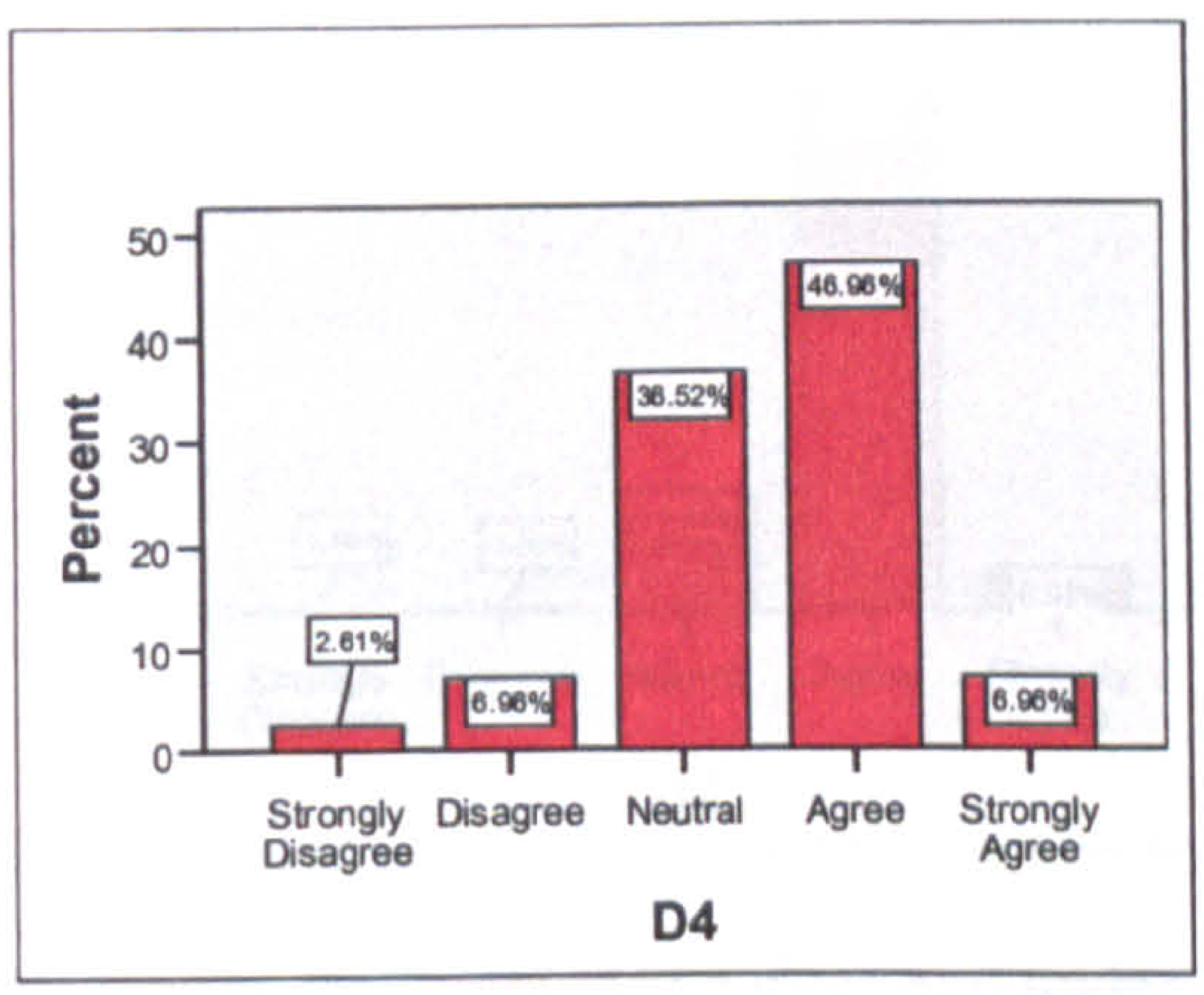

Figure 5. 28 The AIS unit help and instructions are useful and clear

Getting the required information from the AIS on the right time by the navigators on the ship's bridge can play a major role in taking accurate action in the navigation operation especially in a close quarter situation where the time margin is small. Figure 5.29 shows that the majority of the navigators thought that it requires a long time to learn to extract information from AIS. This assumption is shown by the navigators' 64% agreement (agree or strongly agree) that it takes a long time to learn to extract AIS information. Only 9% of them seem to have no problem in this regard, and the remainder of them (37%) did not have a specific view.

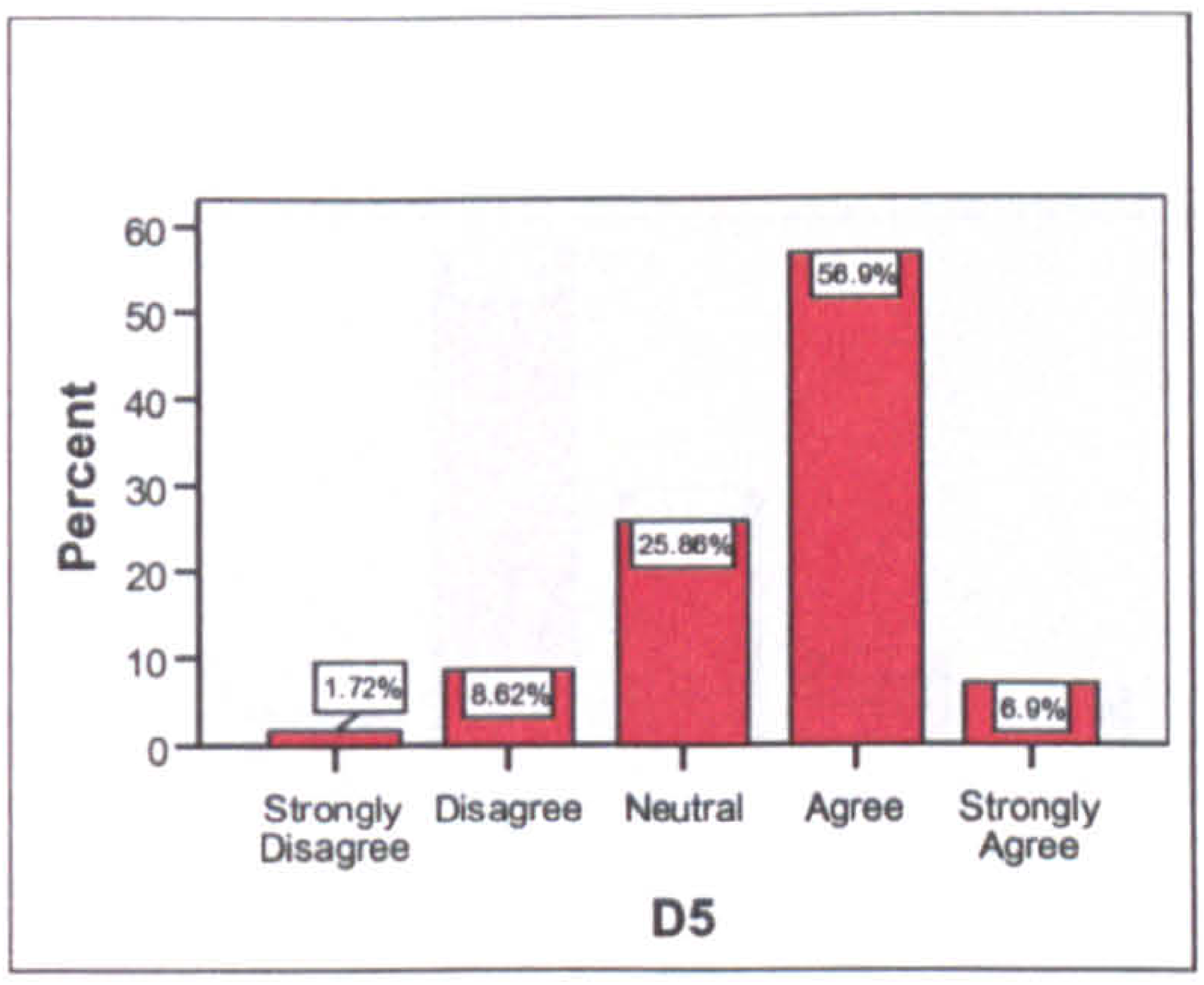

Figure 5. 29 It takes a long time to learn to extract AIS information

Contrary to the time needed to learn how to extract the AIS information, figure 5.30 shows that 81% of the navigators believed that the AIS information is presented in a clear and understandable manner.

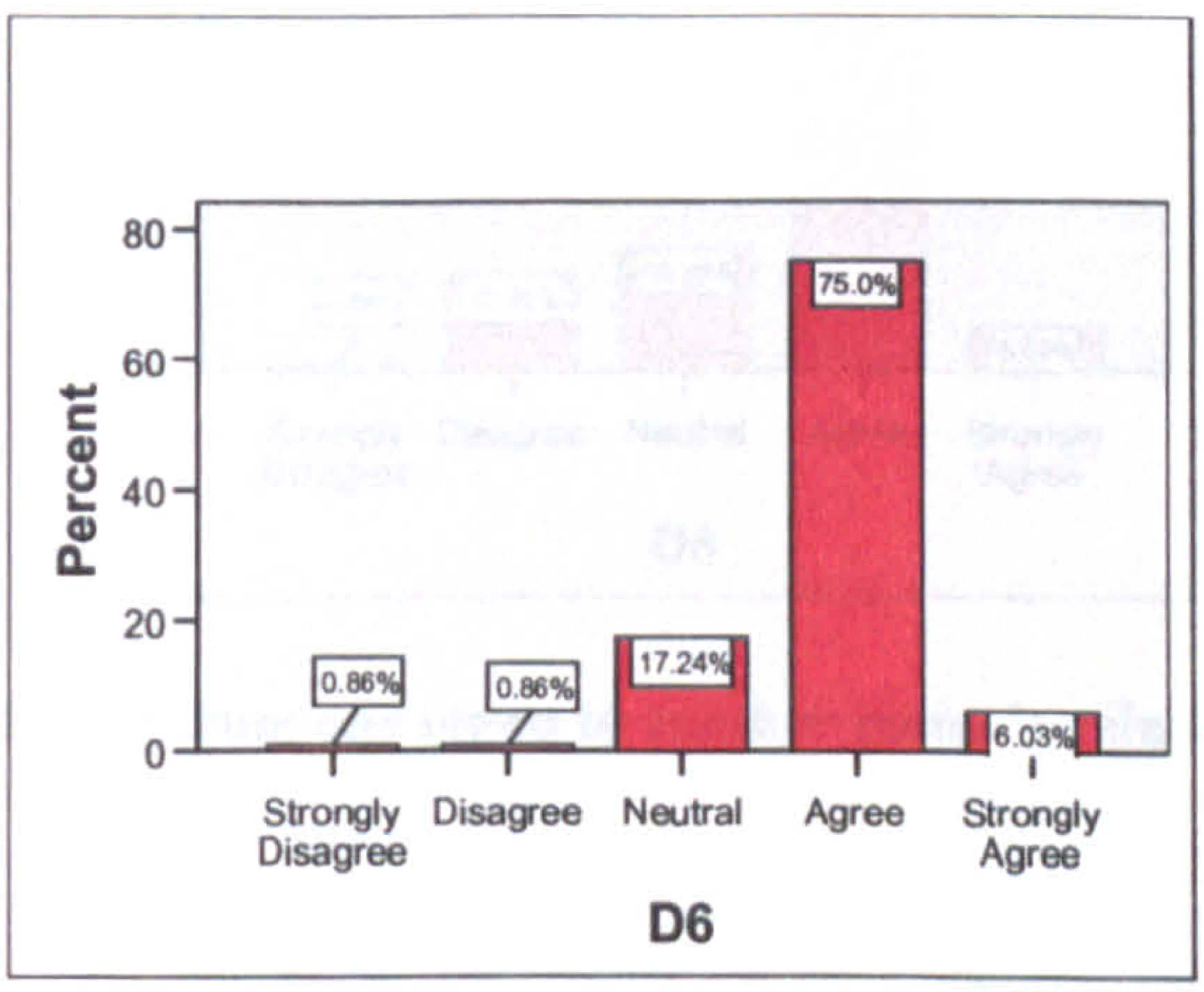

Figure 5. 30 AIS information is presented in a clear and understandable way

On the matter of unnecessary information on the AIS display, figure 5.31 shows that 59% of the navigators were negative (disagreed or strongly disagreed) that some of the information on the AIS display is unnecessary, and only 15% were positive (agreed or strongly disagreed) on this regard. It is relatively easy to move from one AIS menu to another one as shown from the navigators' responses in figure 5.32 with a strong support of 70% (64% agrees and 6% strongly agrees).

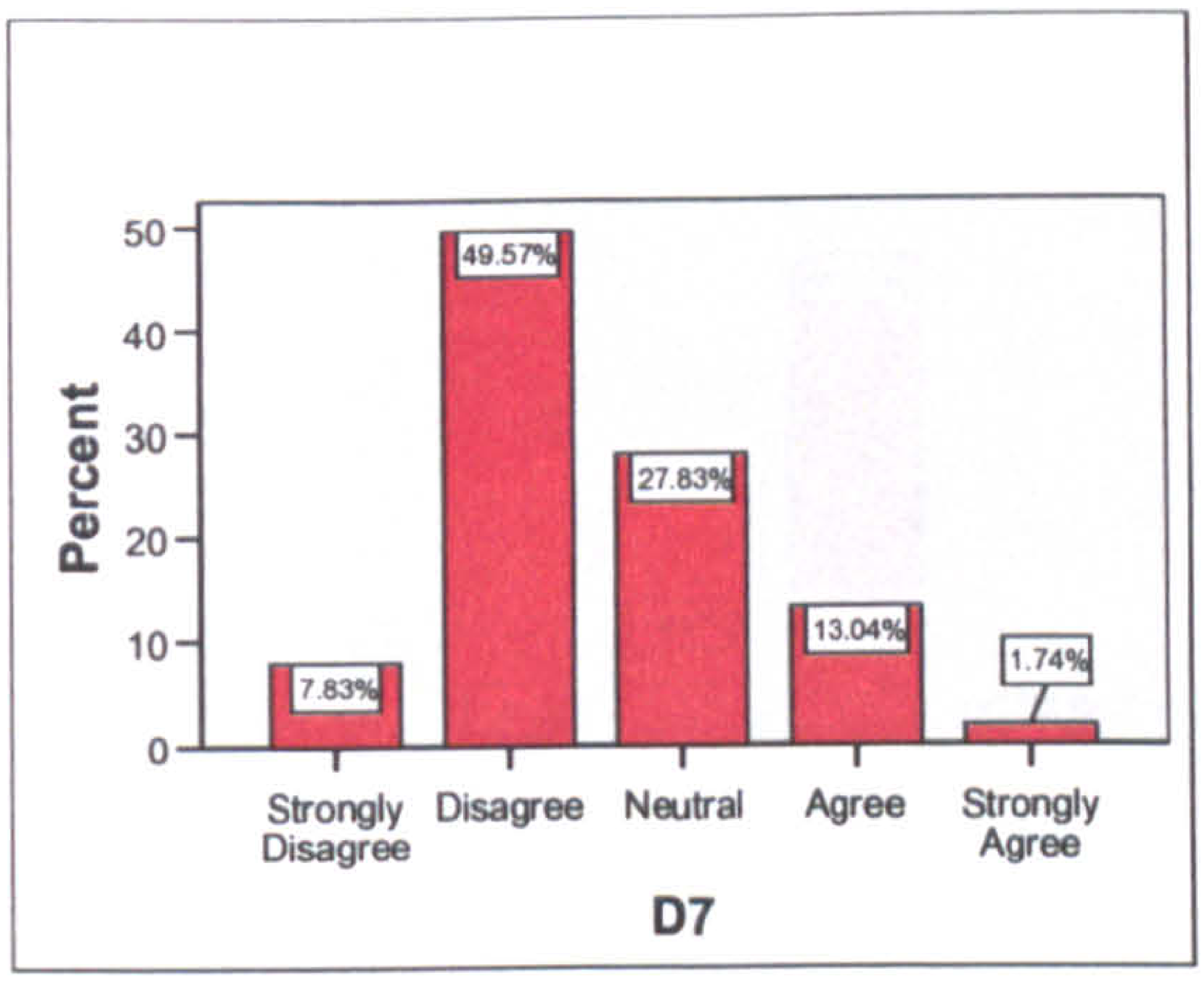

Figure 5. 31 Some of the AIS display information is unnecessary

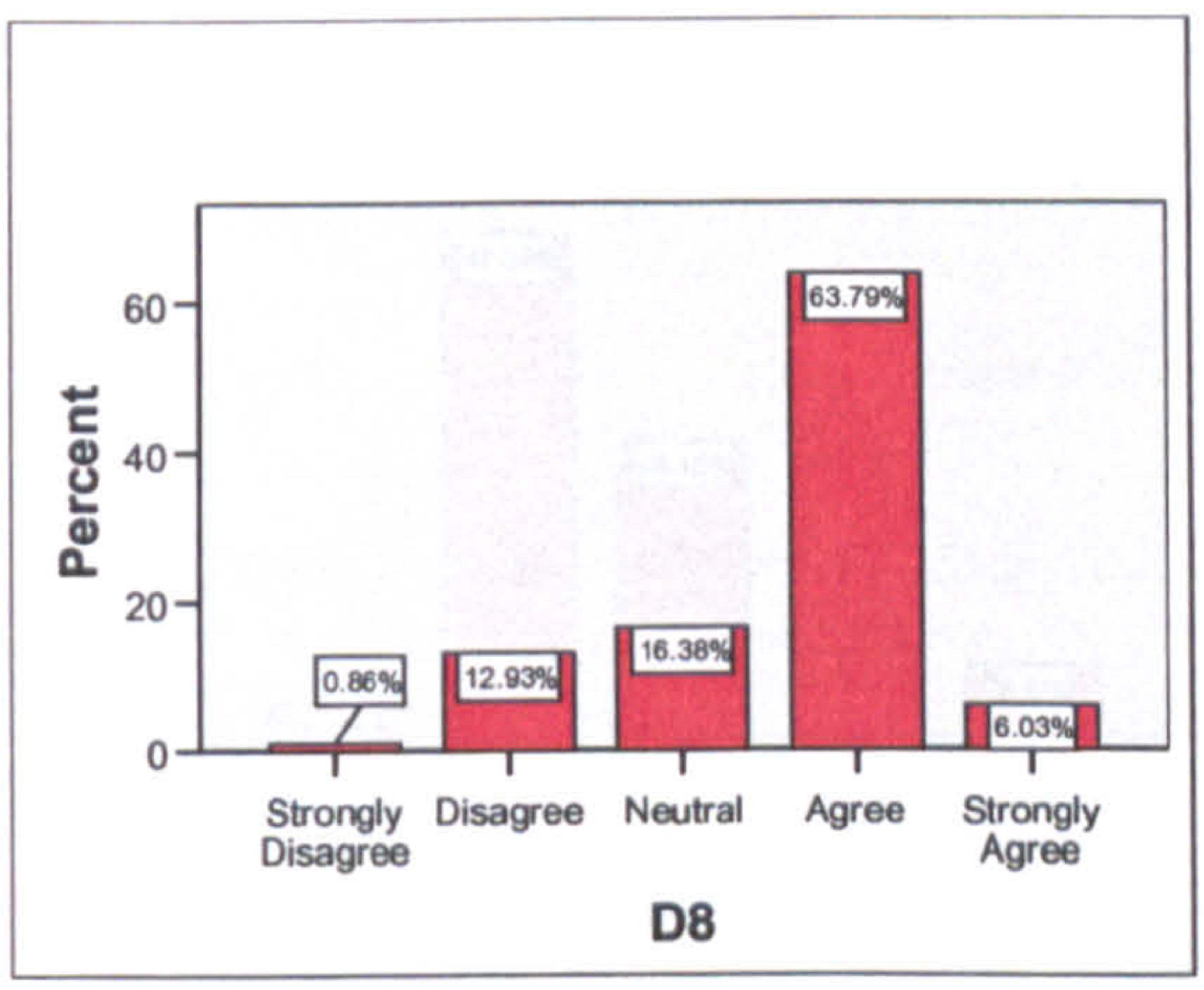

Figure 5. 32 Moving from one menu to another menu is relatively easy

Seventy one percent of the navigators were in favour of the AIS data input and output mechanism as 66% of them were agreed and 5% strongly agreed that getting data in and out of the AIS is easy (see figure 5.33). About half of the respondents (51%) did not believe that overlay of radar echoes with AIS data may cause confusion (see figure 5.34), the remaining 49% were either positive or neutral.

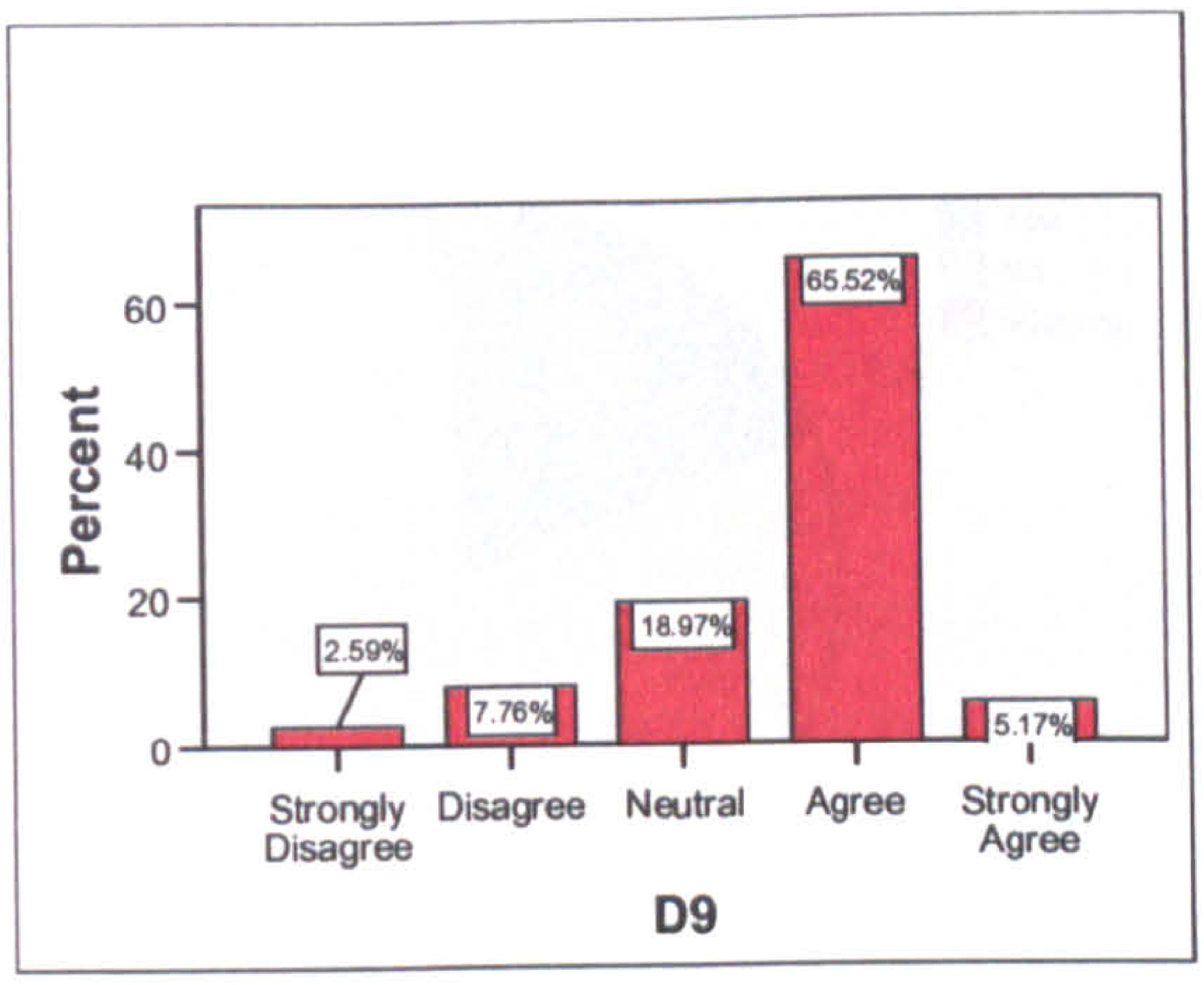

Figure 5. 33 Getting data in and out of AIS is easy

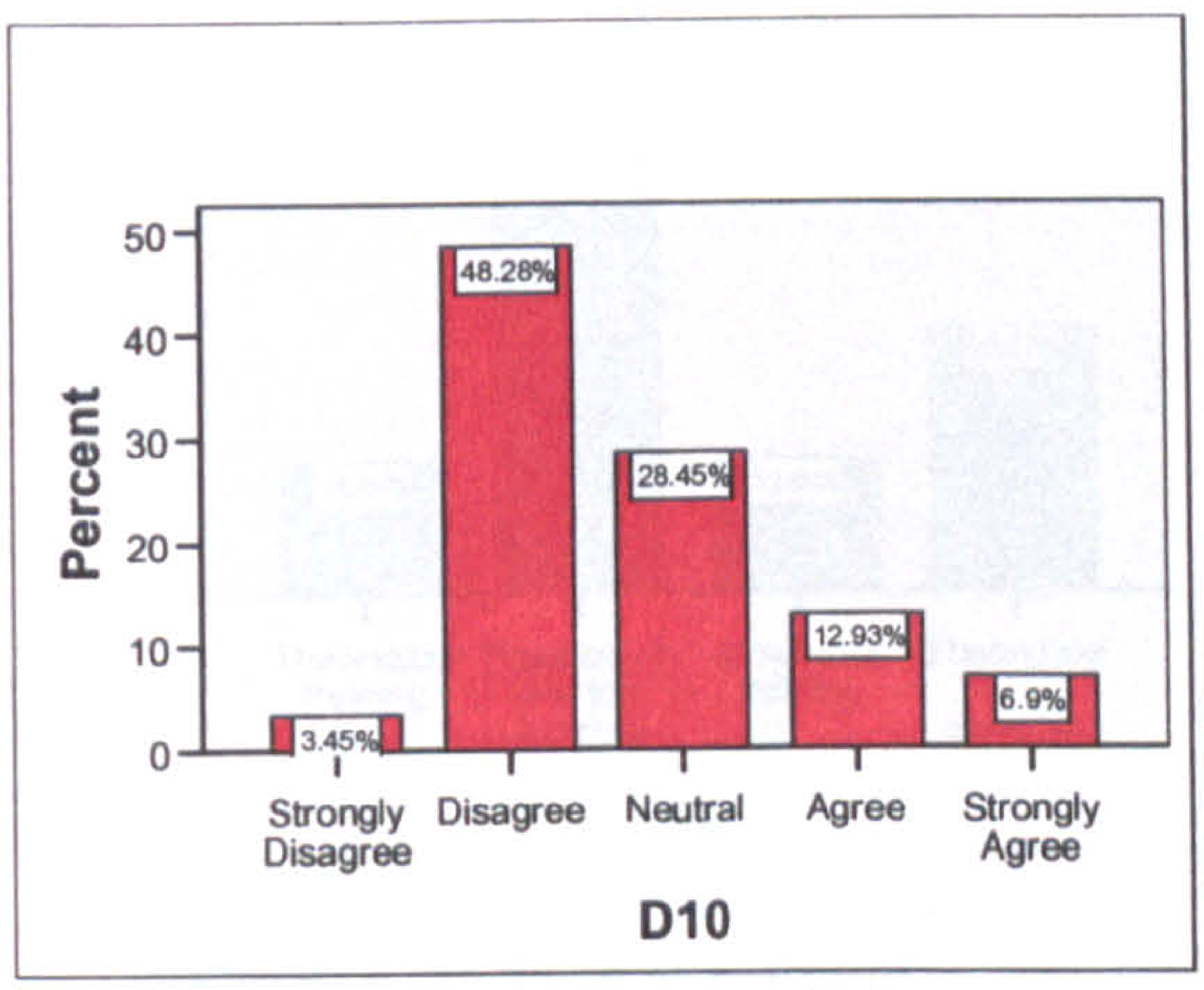

Figure 5. 34 Confusion due to overlay of radar echoes with AIS data

5.4.4 AIS Training

Proper training of navigators on the use of AIS, its capabilities, and limitations is an important issue as sufficient familiarity of the navigators with AIS technology is expected to increase their confidence level in using the AIS in the navigation operation. Although training is considered to be very important in successful implementation of new technologies, according to figure 5.35, only a small percentage of 19.1% of the respondents have completed a formal training course on the basic operation of AIS, but a majority of 80.9% did not have any AIS training. Of those who have completed such formal training for AIS, 13.6% of them had theoretical training, 45.5% practical on the job training, 13.6% simulation training, and 27.3% combined theoretical and practical training (see figure 5.36).

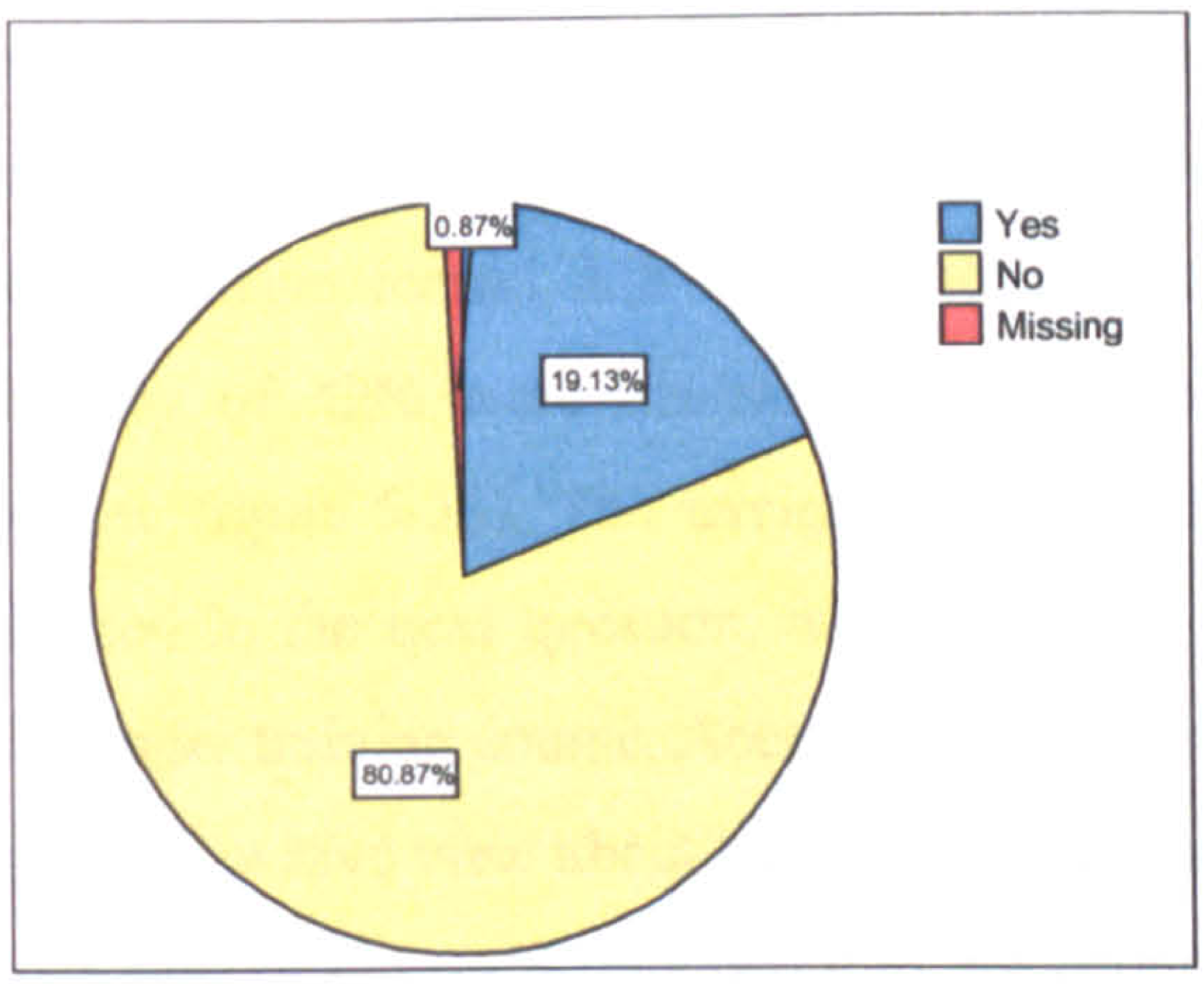

Figure 5. 35 Formal training of basic operation of AIS

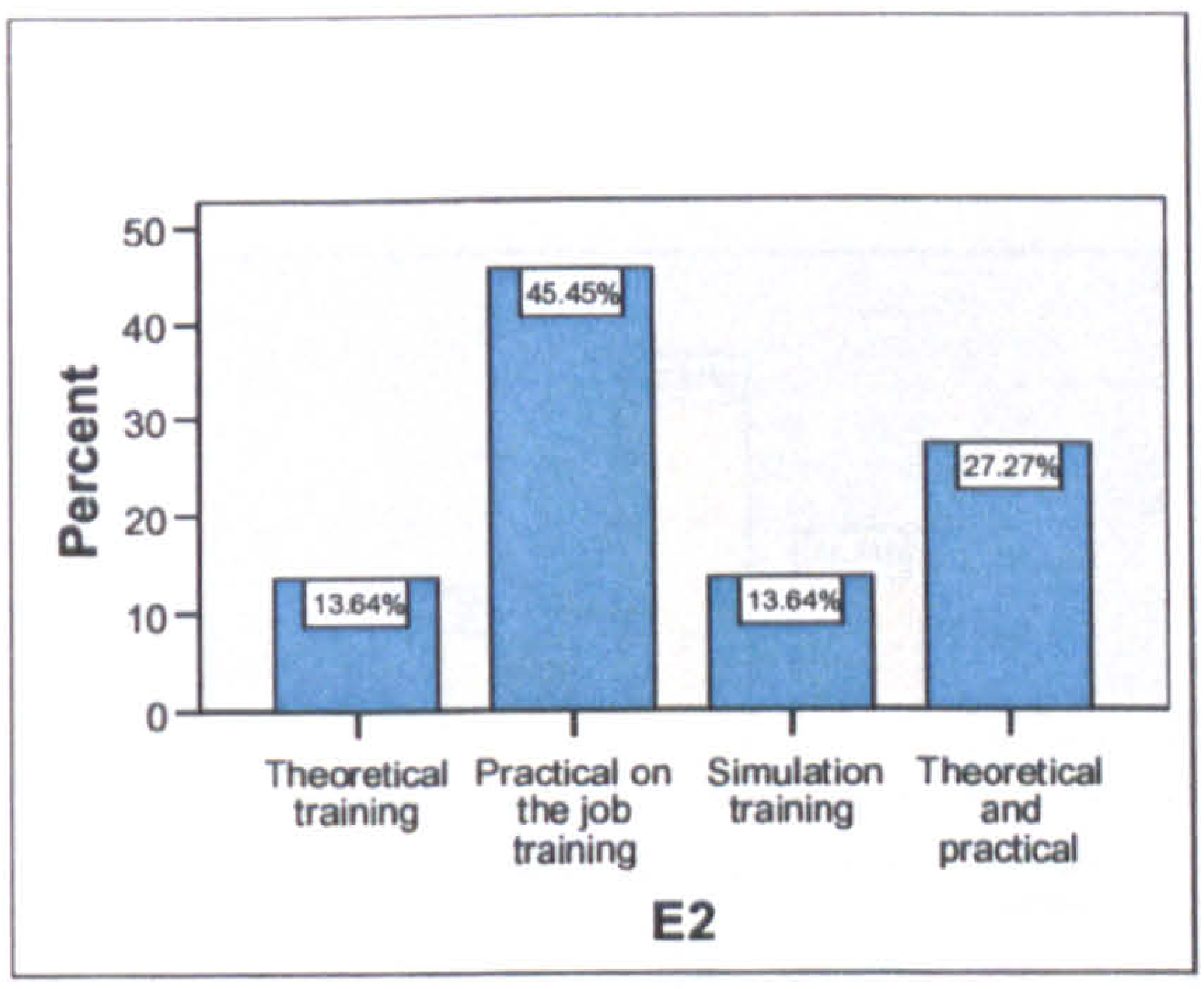

Figure 5. 36 Type of training

Figure 5.37 shows that only 40% of the navigators thought their training (if any) is adequate to safely perform their tasks in anti-collision operation on the bridge using AIS.

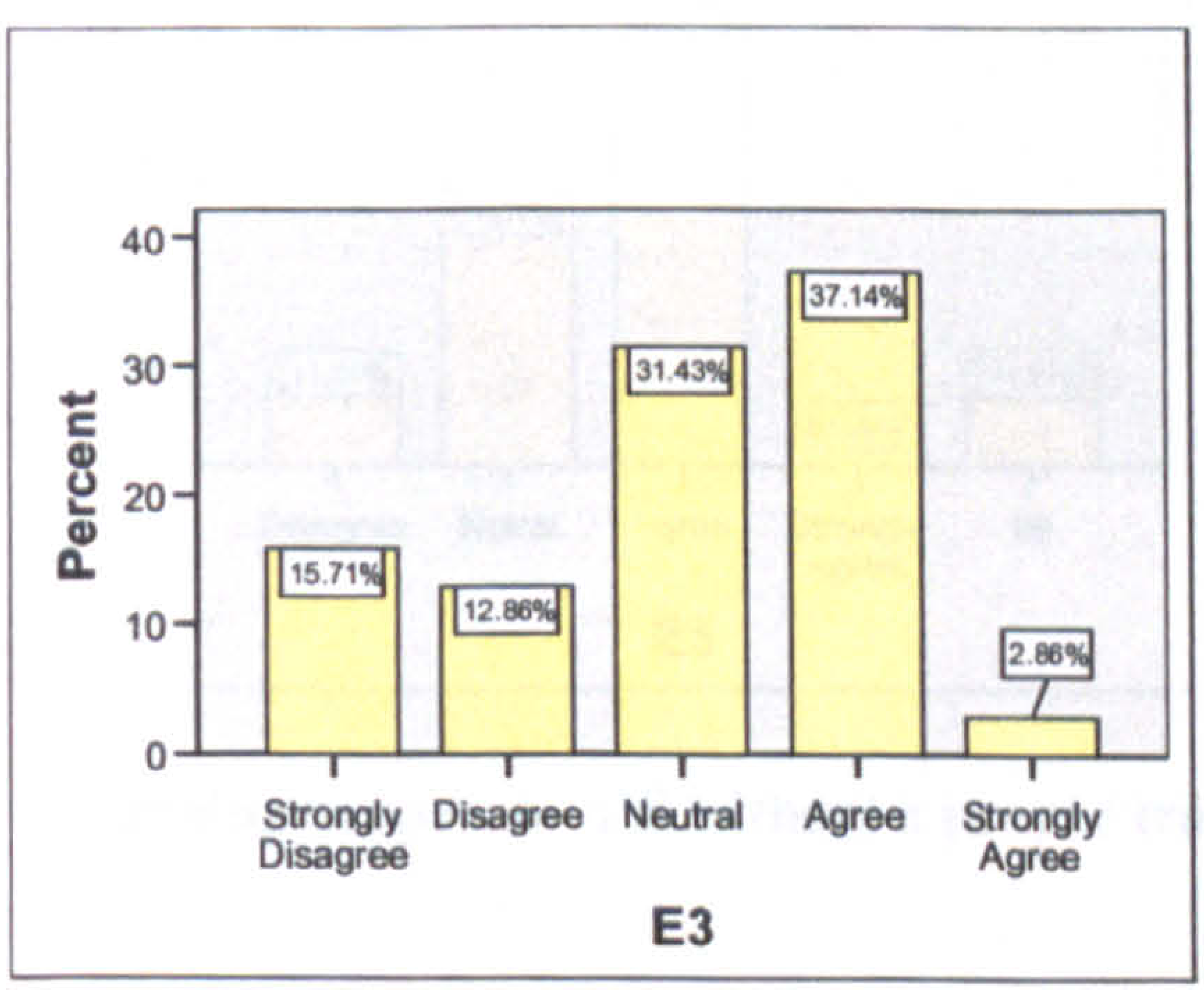

Figure 5. 37 Adequacy of training to safely perform anti-collision operation

The other 60% were either unsure or believed that their training does not fulfil the requirement to adequately perform their duties in that respect. When asked if it was a necessity for navigators to have formal AIS training for safe operation in a collision situation, a large majority of 42% were neutral, 34% were positive, and only 24% responded negatively (see figure 5.38). The navigators' view about a need for formal training has been reflected in the next question, which is about the ease of learning to operate AIS without a proper training course. According to figure 5.39 only about half of the navigators (51%) had a positive view about whether learning to operate AIS without a proper training course is easy or not, 11% regarded it as not being easy, 27% did not have a clear view about it, and the remaining 11% failed to answer this question.

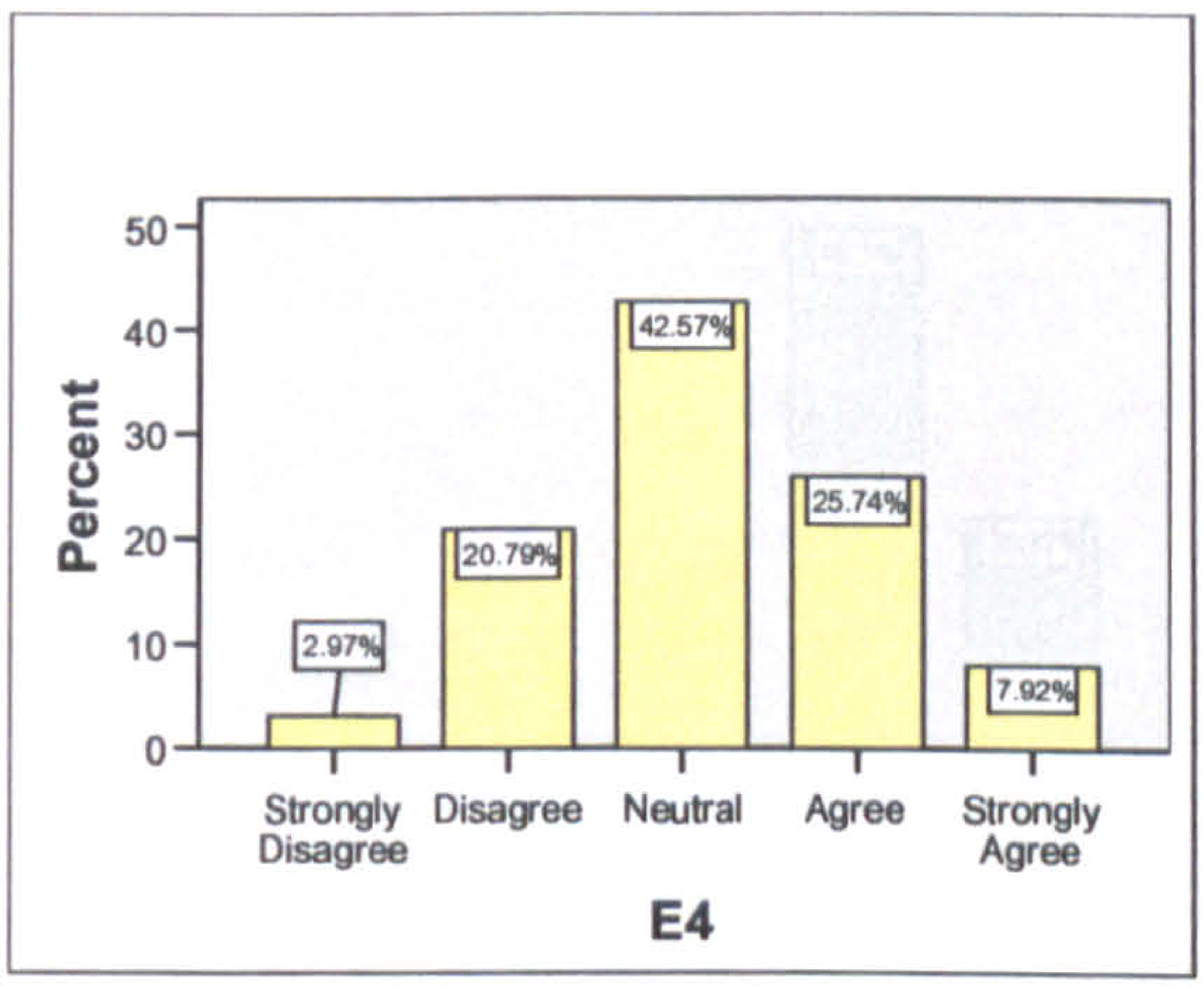

Figure 5. 38 Essentiality of AIS training for safety of anti-collision operation

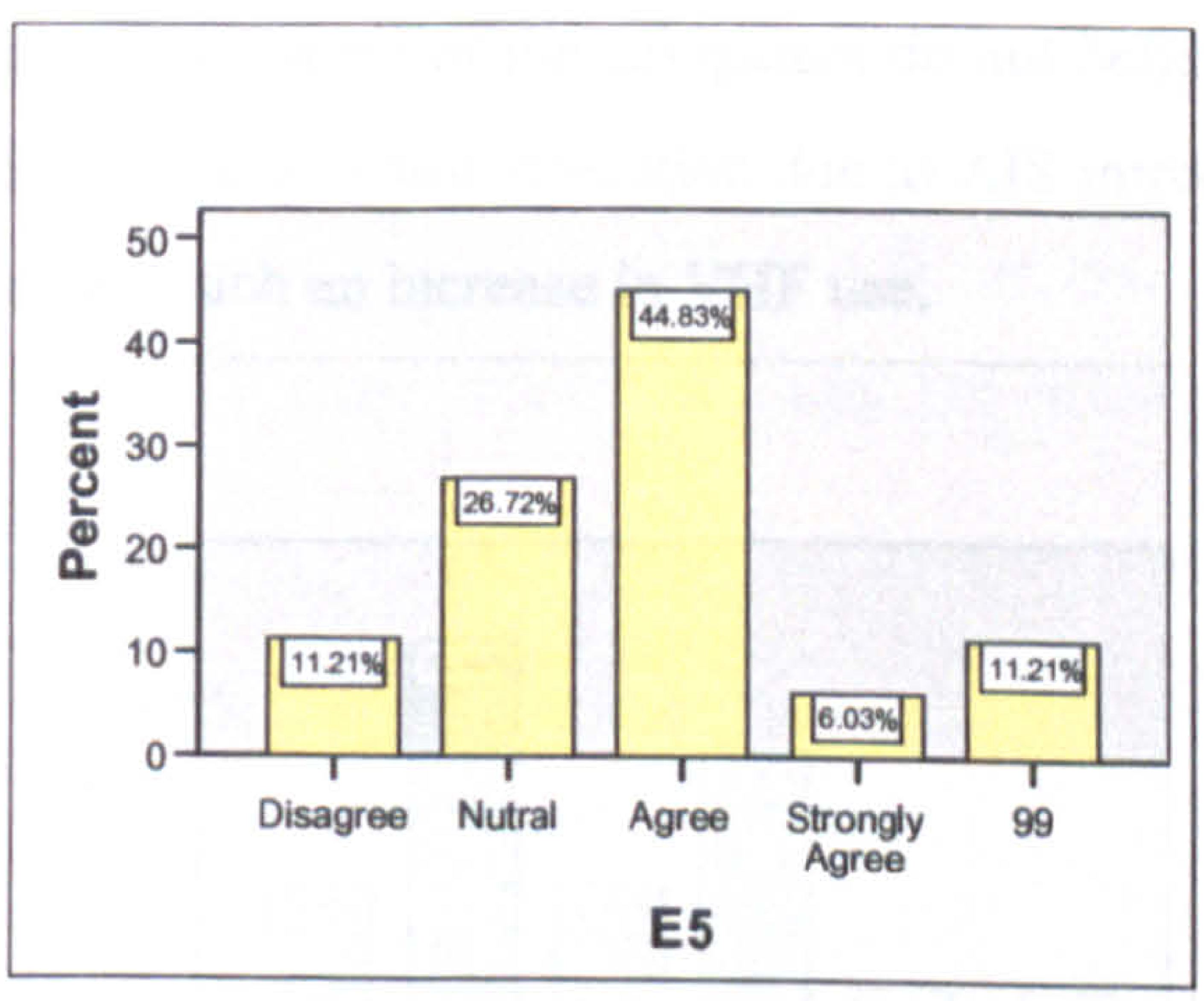

Figure 5. 39 Ease of learning to operate AIS without a proper training course

5.4.5 AIS and Use of VHF

The introduction of AIS, in common with any other new technology, might have some unforeseen impact on other equipment on the bridge. One potential impact highlighted in chapter 2, section 2.3.6, was the impact of AIS on the use of VHF radio. Accordingly, in the research questionnaire, there were also some questions on AIS and the use of VHF. In figure 5.40 most of the navigators perceived that AIS decreases overall VHF traffic congestion as 70% of them were in favour (49% agree and 21% strongly agree), only 12% were against such belief, and the other 18% were neutral. Even though the survey showed a perceived decrease in overall VHF traffic congestion, AIS may cause an increase in use of VHF for anti-collision operations (i.e. for agreement for action between vessels).

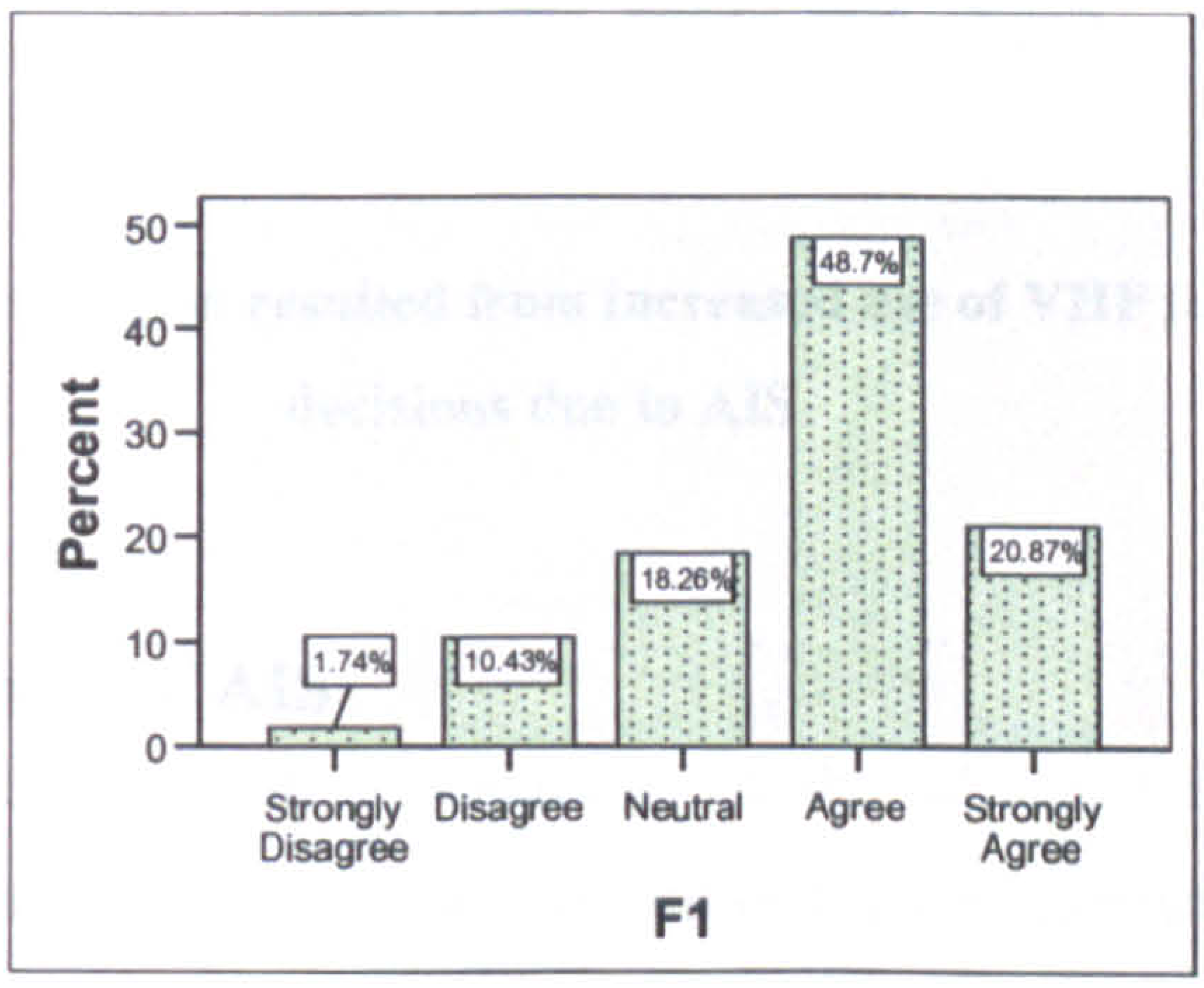

Figure 5. 40 AIS decreases overall VHF traffic congestion

Figure 5.41 shows that 40% percent of the navigators do not believe that it has caused an increased use of VHF for anti-collision operation due to AIS introduction, but about 34% believed that it had caused such an increase in VHF use.

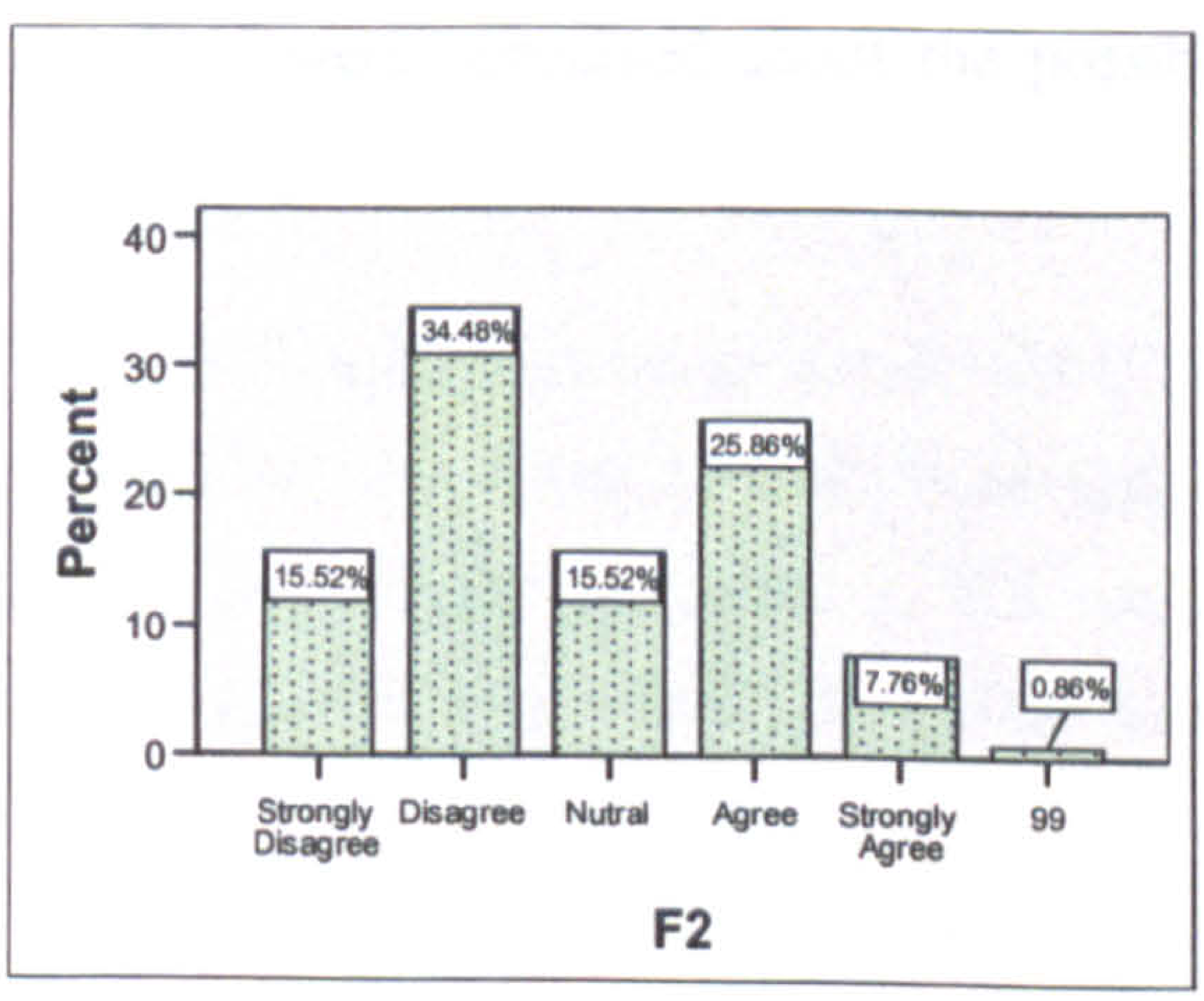

Figure 5. 41 AIS increases use of VHF for anti-collision operation

The concern that increased VHF use may cause increased violation of IRPCS was assorted with 42% (disagreed and strongly disagreed) of the navigators against, 26% (agreed and strongly agreed) in favour of, and 33% uncertainty (see figure 5.42).

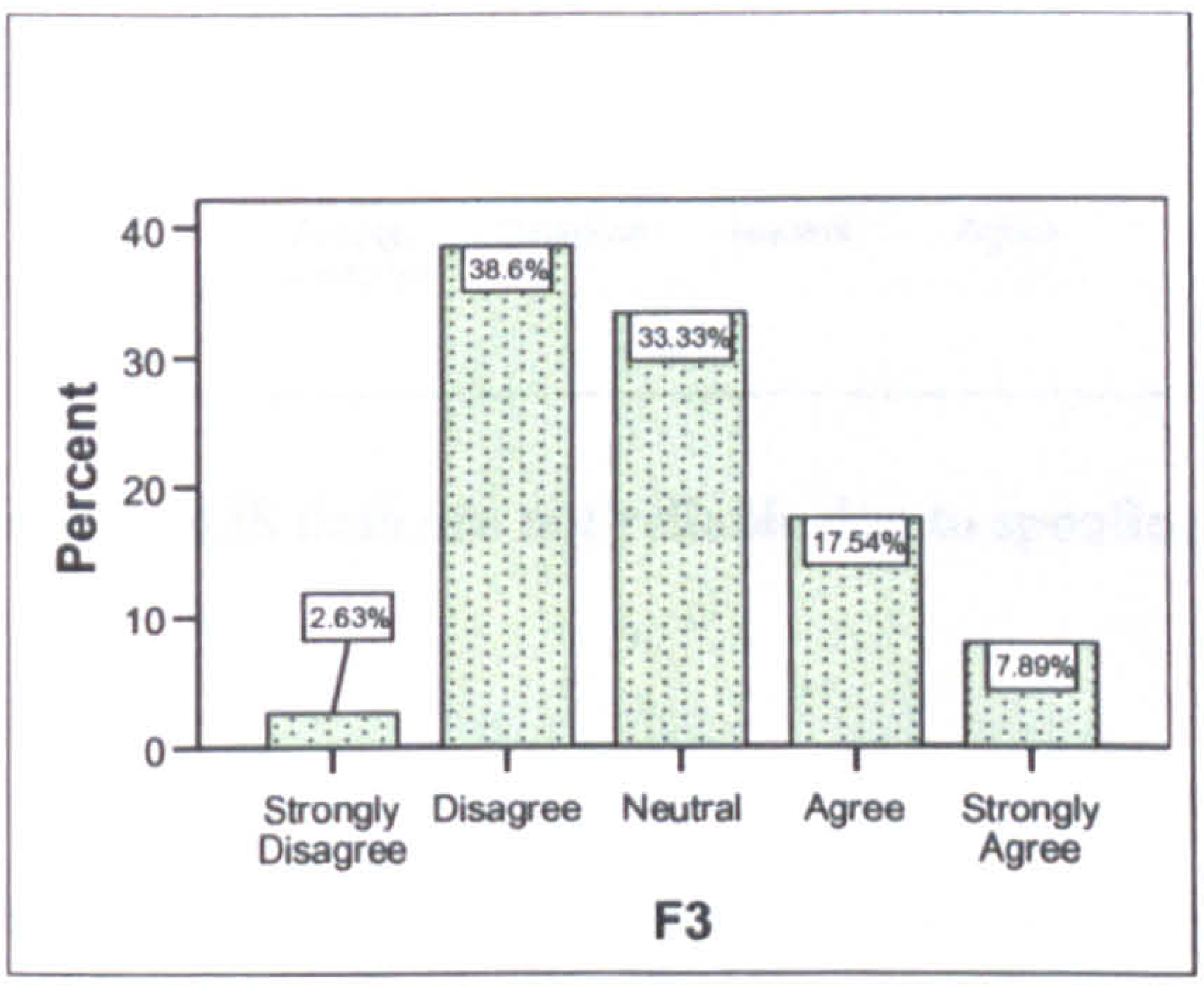

Figure 5. 42 IRPCS violation resulted from increased use of VHF for anti-collision decisions due to AIS

5.4.6 Disadvantages of AIS

Disadvantages associated with a technology might influence the application and the extent of use of such technology. This section of the questionnaire aimed at finding the views of the navigators about some of the important possible disadvantages of AIS technology. Reliability of the data received by AIS is an important issue in safety and security of marine navigation. Since the AIS stations have little means of assessing the reliability of data received, the information received from target ships might not be reliable due to spoofing. Figure 5.43 shows the navigators' response on the issue of unreliability of AIS information due to spoofing. 44% of the navigators were neutral, 40% were against, and 17% were concerned about the possible unreliability of data received.

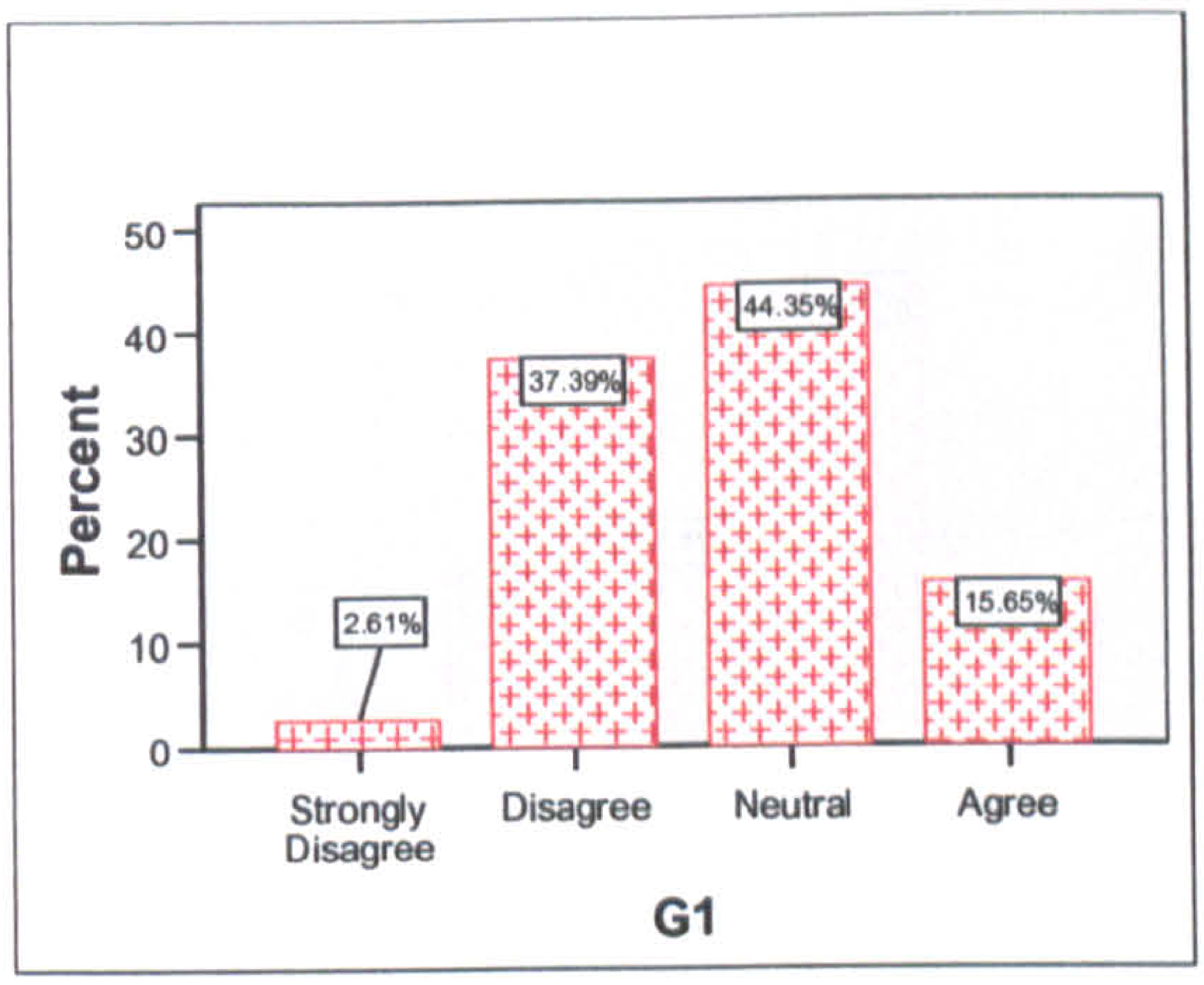

Figure 5. 43 AIS data are not reliable due to spoofing

On a similar issue, AIS vulnerability due to jamming of the AIS itself or GPS jamming, the majority of the navigators (51%) were uncertain, 29% were agreed, and only 20% were unconcerned (see figure 5.44).

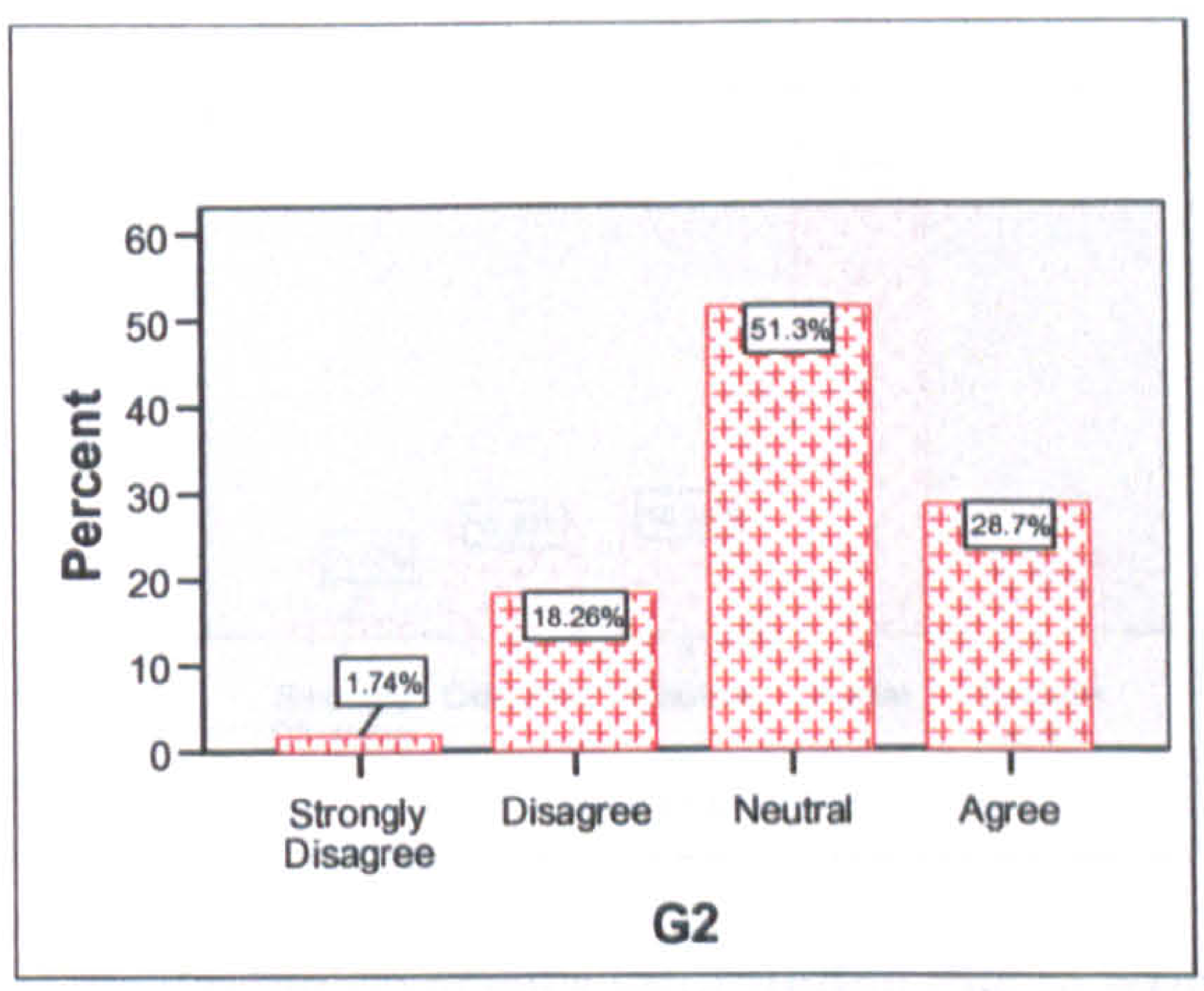

Figure 5. 44 AIS is vulnerable due to jamming

Figure 5.45 shows the results of the questionnaire survey about the increase in the piracy risk level in areas of piratical activity. About 58% of the navigators believed in increased likelihood of such danger, and only 20% rejected it. The remaining 22% were of no specific view. It was observed, in chapter 4, sections 4.10.1, 4.10.2, and 4.10.3 that in a number of cases data transmitted by AIS was associated with incorrect information.

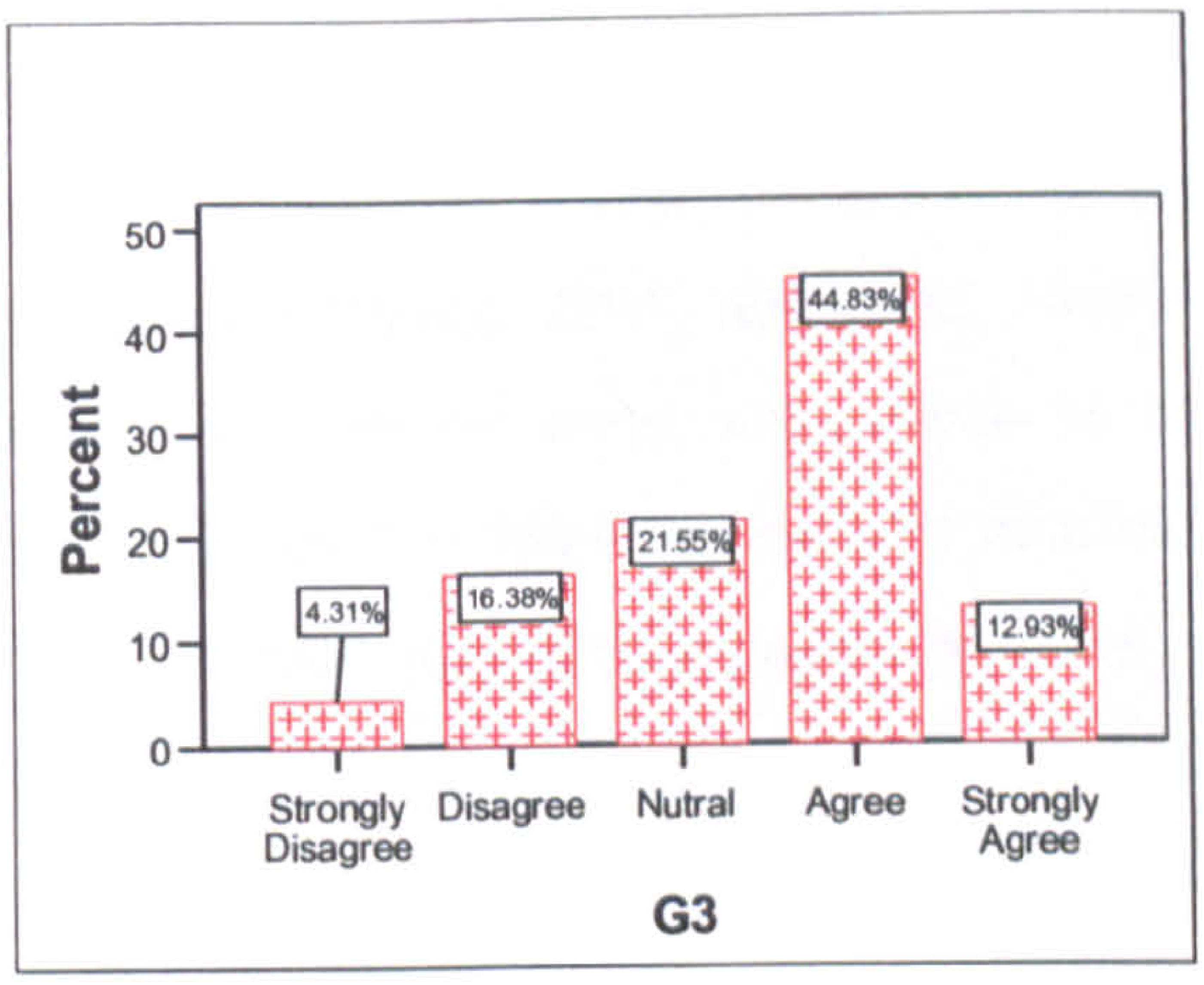

Figure 5. 45 Increased danger of piracy in areas of piratical activity

The possibility of erroneous information displayed by AIS due to wrong data input was assessed in figure 5.46. About 66% believed that such risks exist, 18% rejected such claim, and the remaining 16% were neutral.

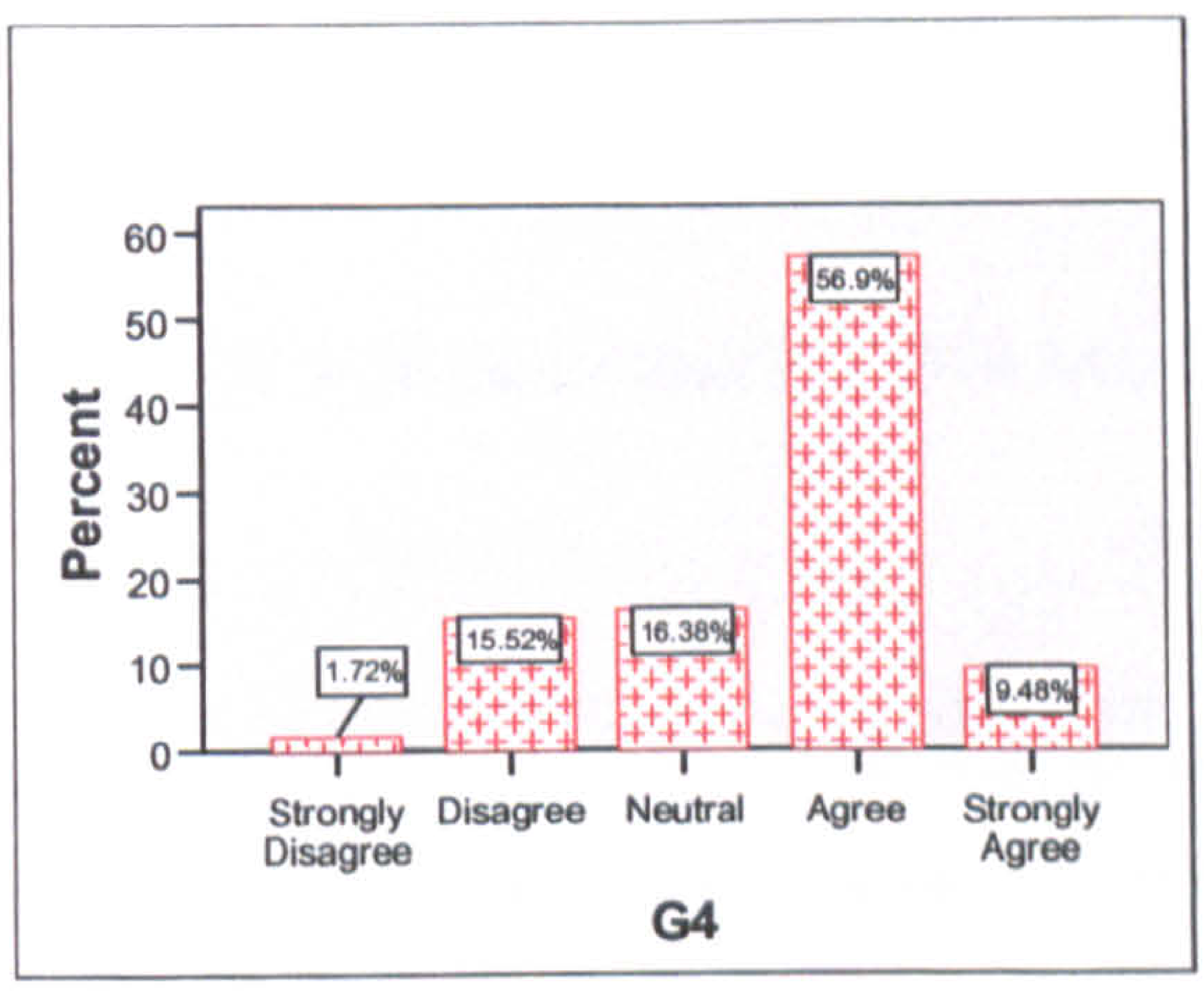

Figure 5. 46 Risk of displaying erroneous information due to wrong data input

5.5 Differences Between Subsets of Population

This section covers the differences between subsets of population in order to assess the impacts of demographic factors (identified in Personal Information section of the questionnaire) such as navigators' ranks, sea experience, sailing experience with AIS, and training, and type of AIS display available on navigators perceptions about different aspects of AIS.

Assessment of significant differences between subsets of population has been carried out with the Kruskal-Wallis Test. The Kruskal-Wallis Test, sometimes referred to as the

Kruskal-Wallis H Test, allows comparing the scores of continuous variables for 3 or more groups. It is a 'between groups' analysis, which converts scores into ranks and compares the mean rank between groups (Pallant, 2004; and Field, 2005). According to Pallant (2004), the highest mean rank for any group corresponds to the highest score on a continuous variable for that group. The important parts of information from the Kruskal-Wallis Test are Chi-Square value, significance value (both the asymptotic and Monte Carlo significance should be investigated, and if they differ we should consider the Monte Carlo significance value), and confidence interval for significance. Statistically significant differences in continuous variables across groups is indicated by the significance values of less than 0.05, and by the boundary of confidence interval for significance that does not cross 0.05 (Field, 2005). Since the Kruskal-Wallis Test is for 3 or more groups, the Mann-Whitney U Test has been done to test for differences between 2 groups of trained and untrained navigators.

This section only shows the results of the test for variables, which were statistically significant across different groups. The result will refer to the variables according to their section named alphabetically and sequence number in the section, shown in the questionnaire sample in appendix B.1 and also in the SPSS codebook in appendix B.2.

The findings of this section will be discussed later in section 5.6 of this chapter.

5.5.1 Training

The Mann-Whitney U Test (table 5.1) for impact of the training on navigators' responses between the two groups of trained and untrained navigators shows following results:

a) There is a very highly significant difference in scores for item B7 (AIS will disrupt the normal anti-collision operation) between the trained and the untrained groups of navigators ($P < 0.0005$). The mean rank of 63.09 for the untrained navigators is higher than the mean rank of 36.48 for the trained navigators. Therefore, navigators who had an AIS formal training had a higher level of confidence in item B7 than the untrained navigators.

b) The difference in scores for item C1 (self-learning to operate AIS is hard for navigators) between the 2 groups of navigators is significant ($P < 0.036$). The mean rank of scores for the untrained navigators is 60.99, which is higher than the mean rank of scores of 45.35 for the trained navigators. Since the scores for this item have been reversed during initial data manipulation, therefore the mean perception score of the trained navigators about item C1 was higher than the untrained navigators.

c) There is a highly significant difference in scores for item C5 (AIS responds slowly to data input by navigators) between the 2 groups ($P < 0.002$). The mean rank of scores for the untrained group is 62.35 and for the trained group is 39.59. Since the scores for this item were also reversed, therefore the mean score for the trained navigators were higher than the mean scores for the untrained navigators. This means that the mean score for optimism of the trained navigators about item C5 were higher than the untrained group.

d) The difference in scores for item C6 (it is easy to use AIS for anti-collision operation) is also highly significant between the 2 groups ($P < 0.007$). The mean ranks of scores are 74.05 and 54.20 for the trained and the untrained groups, respectively. This shows that the mean score for perception of the trained navigators in item C6 was higher than the mean score of the untrained ones.

e) The statistical significance of difference in scores for item D1 (AIS display is valuable in navigator's performance) between the 2 groups is also evident as $P < 0.041$. A mean rank of 69.77 for the trained group is higher than a mean rank of 55.22 for the untrained group. Therefore, awareness of the trained navigators about statement of item D1 was higher than the untrained navigators.

f) The statistical difference in scores for item E3 (I think my training on the use of AIS is adequate to safely perform anti-collision operation on the bridge using AIS) between the 2 groups is very highly significant ($P < 0.0005$). The mean rank of 49.91 for the trained group is higher than the mean rank of 28.90 for the untrained group. Therefore, the optimism mean score of the trained navigators in the adequacy of their training to safely perform anti-collision operations on the bridge using AIS was higher than the untrained navigators.

g) There is a statistically significant difference in scores for item F1 (AIS decreases overall VHF traffic congestion) between the 2 groups ($P < 0.013$). The mean rank of 72.73 for the trained group is higher than the mean rank of 54.52 for the untrained group. Therefore, mean confidence of the trained navigators in the overall decrease of VHF traffic congestion by AIS was higher than the untrained navigators.

	Training	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Asymp. Sig. (2-tailed)
B7	Yes	22	36.48	802.50	549.500	.000
	No	93	63.09	5867.50		
	Total	115				
C1	Yes	22	45.36	998.00	745.000	.036
	No	93	60.99	5672.00		
	Total	115				
C5	Yes	22	39.59	871.00	618.000	.002
	No	93	62.35	5799.00		
	Total	115				
C6	Yes	22	74.05	1629.00	670.000	.007
	No	93	54.20	5041.00		
	Total	115				
D1	Yes	22	69.77	1535.00	764.000	.041
	No	93	55.22	5135.00		
	Total	115				
E3	Yes	22	49.91	1098.00	211.000	.000
	No	48	28.90	1387.00		
	Total	70				
F1	Yes	22	72.73	1600.00	699.000	.013
	No	93	54.52	5070.00		
	Total	115				

Table 5. 1 Ranks of scores and the Mann-Whitney test for trained and untrained groups

As the importance of basic training for navigators emphasised in section 2.3.9 of the chapter 2, there are some significant differences between perception of the mariners who had an AIS training and those who did not have such training. It was argued in section 2.3.3 of chapter 2, the way in which AIS data along with other navigation information is presented to a navigator on the bridge is very important in effectiveness of AIS for navigation performance. The very highly significant difference between the two groups of navigators in their perception about disruption of normal anti-collision operation by AIS indicates a weakness in this regard. As it was expected the AIS training is crucial according to the higher level of difficulty in self-learning reflected in the trained navigators' attitude. Training also improves the level of ease of use of AIS for the anti-collision operation. Recognition of the value of the AIS display in the navigator's performance was also significant by the trained navigators. It was also observed that with AIS training the overall VHF traffic will be reduced, which could be due to realising the risk associated with VHF use for anti-collision agreements, and possibly improved use of AIS without requirement for VHF use.

5.5.2 Type of Training

The Kruskal-Wallis H Test (table 5.2) for impact of type of training on navigators' responses between four groups (theoretical training, practical on the job training, simulation training, and theoretical and practical training) shows the following results:

a) There is only one statistically significant difference in scores for item B6 (navigators feel their ship is safer with AIS) between 4 groups of navigators with a $P < 0.038$ (note that because there is a difference between the Asymp. sig. and Monte Carlo sig., therefore, Monte Carlo significance should be taken as the probability figure). Theoretical training with a mean rank of 16.0 had the highest and practical on the job training with a mean rank of 8.40 had the lowest rank between 4 groups of training. Therefore, the results suggest that navigators who had the theoretical training think that their ship is safer with AIS more than the others, and those who had the practical on the job training had the lower optimism about item B6 than the others.

	Type of Training	N	Mean Rank	Chi-Square	Asymp. Sig.	Monte Carlo Sig.
B6	Theoretical training	3	16.00	7.776	.051	.038
	Practical on the job training	10	8.40			
	Simulation training	3	9.00			
	Theoretical and practical	6	15.67			
	Total	22				

Table 5. 2 Ranks of scores the Kruskal-Wallis test for type of training

The result of this section shows that a theoretical AIS training programme could be the most effective type of training. Theoretical AIS training will enhance navigators' knowledge and skill on the operation, and understanding of capabilities and limitations of AIS more than other 3 types of training under consideration.

5.5.3 Certificate of Competency

The results of the Kruskal-Wallis H Test (table 5.3) for the impact of navigators' certificate of competency on their response scores across 3 groups (master mariner, chief officer, and second officer) are as follows:

a) There is a statistically significant difference in scores for item B1 (AIS enhances navigator's situational awareness with a better situation display of the traffic) across 3 groups of certificate of competency ($P < 0.02$). The mean rank of 57.14 for second officer is highest and the mean rank of 39.83 for master mariner is the lowest. Therefore, the results suggest that there was a significant difference in perception level of navigators holding different certificates of competency. The mean ranks for the groups suggest that the junior officers had the highest optimism mean score on item B1 than master mariners.
b) There is a statistically significant difference in scores for item B3 (using AIS would increase navigator's efficiency in anti-collision operation) across the 3 groups with a $P < 0.02$. Therefore, the mean ranks for the groups suggest that the second officer had the highest optimism mean score and the master mariner had the lowest optimism level about B3.
c) There is a statistically significant difference in scores for item B5 (using AIS would let the navigators feel more in control of anti-collision operation) across the 3 groups with a $P < 0.01$. Therefore, the mean ranks for the groups suggest that the second officer had the highest confidence level and the master mariner had the lowest confidence level about B5.
d) There is a statistically significant difference in scores for item B6 (navigators feel their ship is safer with AIS) across the 3 groups with a $P < 0.04$. Therefore, the mean ranks for the groups suggest that for item B6 the highest optimism mean score belongs to the chief officer but still the master mariner had the lowest confidence level.
e) The difference in scores for item B11 (AIS improves overall safety of navigation) across the 3 groups is highly significant with a $P < 0.009$. The chief officer had the highest mean rank of 64.45 and the master mariner had the lowest mean rank of 39.77. Similar to paragraph d of this section above, the mean ranks for the groups suggest that the highest mean score belongs to the chief officer but still the master mariner had the lowest confidence level about improvement of overall safety of navigation by AIS.
f) There is a statistically significant difference in scores for item C5 (AIS responds slowly to data inputs by navigators) across the 3 groups with a $P < 0.029$. The highest mean rank was for the master mariner with 63.77 and the lowest rank was for the chief officer with 42.29. Since the scores for this item were reversed, the highest mean rank shows the lowest mean score and vice versa. Therefore, the mean ranks for the groups suggest that the chief officer had the highest

confidence level and the master mariner had the lowest confidence level about C5.

g) There is a statistically significant difference in scores for item C6 (it is easy to use AIS for anti-collision operation) across the 3 groups with a $P < 0.015$. The highest mean rank was for the second officer with 59.15 and the lowest rank was for the master mariner with 41.00. Therefore, the mean ranks for the groups suggest that the second officer had the highest confidence level and the master mariner had the lowest confidence level about ease of use of AIS for anti-collision operation.

h) There is a statistically significant difference in scores for item D6 (the way that the AIS information is presented is clear and understandable) between the 3 groups with a $P < 0.015$. The highest mean rank was for the second officer with 58.76 and the lowest rank was for the chief officer with 42.90. Therefore, the mean ranks for the groups suggest that the second officer had the highest optimism level and the chief officer had the lowest optimism level about D6.

i) The difference in scores for item D7 (some of the AIS information on the AIS display is unnecessary) across the 3 groups is also highly significant with a $P < 0.008$. The highest mean rank was 60.34, for the second officer and the lowest mean rank was 38.93, for the chief officer. Since the scores for this item were reversed, the highest mean rank shows the lowest mean score and vice versa. Therefore, the mean ranks for the groups suggest that the second officer had the lowest level of belief about D7.

j) There is a highly significant difference in scores for item D9 (getting data in and out of AIS is easy) between the 3 groups with a $P < 0.002$. The highest mean rank was for the second officer with 60.60 and the lowest mean rank was for the chief officer with 40.05. Therefore, the mean ranks for the groups suggest that the second officer had the highest level of optimism about D9.

	Certificate of Competency	N	Mean Rank	Chi-Square	Asymp. Sig.	Monte Carlo Sig.
B1	Master Mariner	26	39.83	8.071	.018	.017
	Chief Officer	21	57.88			
	Second Officer	58	57.14			
	Total	105				
B3	Master Mariner	26	41.31	7.861	.020	.021
	Chief Officer	21	48.76			
	Second Officer	58	59.78			
	Total	105				
B5	Master Mariner	26	39.17	9.274	.010	.008
	Chief Officer	21	51.81			
	Second Officer	58	59.63			
	Total	105				
B6	Master Mariner	26	40.85	6.419	.040	.037
	Chief Officer	21	60.38			
	Second Officer	58	55.78			
	Total	105				
B11	Master Mariner	26	39.77	9.362	.009	.009
	Chief Officer	21	64.45			
	Second Officer	58	54.78			
	Total	105				
C5	Master Mariner	26	63.77	7.065	.029	.027
	Chief Officer	21	42.29			
	Second Officer	58	52.05			
	Total	105				
C6	Master Mariner	26	41.00	7.491	.024	.021
	Chief Officer	21	50.88			
	Second Officer	58	59.15			
	Total	105				
D6	Master Mariner	26	48.31	8.338	.015	.015
	Chief Officer	21	42.90			
	Second Officer	58	58.76			
	Total	105				
D7	Master Mariner	26	48.00	9.768	.008	.007
	Chief Officer	21	38.93			
	Second Officer	58	60.34			
	Total	105				
D9	Master Mariner	26	46.50	12.334	.002	.001
	Chief Officer	21	40.05			
	Second Officer	58	60.60			
	Total	105				

Table 5. 3 Ranks of scores and the Kruskal-Wallis test for certificate of competency

It was expected that aspects of usefulness of the AIS for navigation is realised by senior officers more than junior officers, but the results of impact of navigators' certificate of competency on their perception did not show such optimism level. Master mariners had the lowest level belief in some aspects of the usefulness of the AIS, and on the other hand, second officers had the highest level of such belief. Nonconformity of the results with the expectation is also evident in some aspects of ease of use of the AIS technology.

5.5.4 Total Sea Service

The results of the Kruskal-Wallis H Test (table 5.4) for the impact of navigators' total sea service on their response scores across 5 groups (1 year or less, 3 years or less but more than 1 year, 5 years or less but more than 3 years, 10 years or less but more than 5 years, and above 10 years) are as follows:

a) There is a statistically significant difference in scores for item B8 (AIS increases navigator's physical workload) between the 5 groups with a $P < 0.018$. The highest mean rank was for the group with 1 year or less sea service with 85.65. Therefore, the mean ranks for the groups suggest that the navigators with 1 year or less sea experience had the lowest level of perception about increase of navigator's physical workload by AIS (scores for this item were reversed).

b) There is a statistically significant difference in scores for item B9 (AIS increases navigator's mental workload) across the 5 groups with a $P < 0.038$. The highest mean rank was 85.45, for the group with 1 year or less sea service and the lowest mean rank was 51.95, for the group with above 10 years sea service. Since the scores for this item were also reversed, the highest mean rank shows the lowest mean score and vice versa. Therefore, the mean ranks for the groups suggest that navigators with 1 year or less sea service had the lowest belief and navigators with above 10 years sea service had the highest belief in increase of navigator's mental workload by AIS.

c) There is a statistically significant difference in scores for item B10 (Navigators prefer to use AIS alone rather than radar) across the 5 groups with a $P < 0.049$. The highest mean rank was 70.47, for the group with above 10 years sea service and the lowest mean rank was 46.70, for the group with 1 year or less sea service. Therefore, the mean ranks for the groups suggest that navigators with 1 year or less sea service had the lowest optimism and navigators with above 10 years sea service had the highest optimism in their preference to use AIS alone rather than radar.

d) There is a statistically significant difference in scores for item D3 (AIS keyboard is user friendly) across the 5 groups with a $P < 0.013$. The highest mean rank was 70.15, for the group with 1 year or less sea service and the lowest mean rank was 42.36, for the group with above 10 years sea service. Therefore, the mean ranks for the groups suggest that navigators with 1 year or less sea service had the highest mean optimism and navigators with above 10 years sea service had the lowest mean optimism in user friendliness of AIS keyboard.

e) There is a statistically significant difference in scores for item D6 (the way that the AIS information is presented is clear and understandable) across the 5 groups with a $P < 0.038$. The highest mean rank was 66.31, for the group with 10 years or less but more than 5 years sea service and the lowest mean rank was 46.95, for the group with above 10 years sea service. Therefore, the mean ranks for the groups suggest that, despite inconsistency of the highest mean score with previous highest mean scores in this subsection, the navigators with above 10 years sea service had the lowest optimism level about D6.

f) There is a statistically significant difference in scores for item D9 (Getting data in and out of the AIS is easy) between 5 groups of navigators with a $P < 0.024$. The highest mean rank was 64.00, for group with 1 year or less sea service and the lowest mean rank was 43.81, for the group with above 10 years sea service. Therefore, the mean ranks for the groups suggest that navigators with 1 year or less sea service had the highest mean perception and navigators with above 10 years sea service had the lowest mean perception that getting data in and out of the AIS is easy.

g) There is a statistically significant difference in scores for item E5 (Learning to operate AIS without a proper training course is easy) across the 5 groups with a $P < 0.015$. The highest mean rank was 62.50, for the group with 3 years or less but more than 1 year sea service and the lowest mean rank was 39.28, for the group with above 10 years sea service. Therefore, despite inconsistency of the highest mean score with previous highest mean scores in this subsection, the mean ranks for the groups suggest that the navigators with above 10 years sea service had the lowest confidence level about E5.

h) There is a statistically significant difference in scores for item G1 (since AIS stations have no means of assessing the data received, the information received from target ships are not reliable due to spoofing) across the 5 groups with a $P < 0.038$. The consistency of the result for G1 with previous results in this subsection was in the lowest mean score in perception of the navigators with 1 year or less sea service.

	Total Sea service	N	Mean Rank	Chi-Square	Asymp. Sig.	Monte Carlo Sig.
B8	1 Year or less	10	85.65	11.885	.018	.015
	3 Years or less but >1 Year	27	50.04			
	5 Years or less but >3 Years	19	64.05			
	10 Years or less but >5 Years	27	59.28			
	Above 10 Years	32	51.41			
	Total	115				
B9	1 Year or less	10	85.45	10.131	.038	.037
	3 Years or less but >1 Year	27	53.89			
	5 Years or less but >3 Years	19	54.74			
	10 Years or less but >5 Years	27	61.41			
	Above 10 Years	32	51.95			
	Total	115				
B10	1 Year or less	10	46.70	9.541	.049	.043
	3 Years or less but >1 Year	27	51.72			
	5 Years or less but >3 Years	18	50.28			
	10 Years or less but >5 Years	26	54.52			
	Above 10 Years	32	70.47			
	Total	113				
D3	1 Year or less	10	70.15	12.588	.013	.010
	3 Years or less but >1 Year	27	60.72			
	5 Years or less but >3 Years	19	66.08			
	10 Years or less but >5 Years	27	63.63			
	Above 10 Years	32	42.36			
	Total	115				
D6	1 Year or less	10	64.20	10.120	.038	.035
	3 Years or less but >1 Year	27	61.33			
	5 Years or less but >3 Years	19	56.79			
	10 Years or less but >5 Years	27	66.31			
	Above 10 Years	32	46.95			
	Total	115				
D9	1 Year or less	10	64.00	11.236	.024	.020
	3 Years or less but >1 Year	27	63.67			
	5 Years or less but >3 Years	19	63.11			
	10 Years or less but >5 Years	27	63.33			
	Above 10 Years	32	43.81			
	Total	115				
E5	1 Year or less	9	53.44	12.341	.015	.011
	3 Years or less but >1 Year	27	62.50			
	5 Years or less but >3 Years	15	43.47			
	10 Years or less but >5 Years	24	57.17			
	Above 10 Years	27	39.28			
	Total	102				
G1	1 Year or less	10	42.35	10.098	.039	.023
	3 Years or less but >1 Year	27	58.06			
	5 Years or less but >3 Years	19	75.55			
	10 Years or less but >5 Years	26	56.17			
	Above 10 Years	32	52.13			
	Total	114				

Table 5. 4 Ranks of scores and Kruskal-Wallis test for total sea service

The result of this section shows some significant differences in perceptions on some aspects of AIS between navigators with lower sea service and navigators with higher sea service. There may be similar results in this section with those of the previous section for the impact of certificate of competency as navigators with higher ranks of certificate of competency may be the same as those who have higher duration of sea service.

5.5.5 Type(s) of AIS Display

The results of the Kruskal-Wallis H Test (table 5.5) for the impact of type(s) of AIS display available on board ships on navigators response scores between 5 groups of AIS display (MKD, stand-alone graphical display, integrated with radar, integrated with ECDIS, and more than one type) are as follows:

a) There is a statistically significant difference in scores for item B4 (using AIS would increase navigator's ability in anti-collision operation) across the 5 groups of AIS display type with $P < 0.018$. The highest mean rank was 66.32 for integrated with radar, and the lowest mean rank was 15.70 for integrated with ECDIS. Therefore, the mean ranks for the groups suggest that navigators optimism level on different types of AIS display was at highest level for display integrated with radar and at it lowest level for display integrated with ECDIS.

b) There is a statistically significant difference in scores for item B13 (Detection of targets in radar shadow areas is improved with AIS) across the 5 groups with $P < 0.020$. The highest mean rank was 74.38 for display integrated with radar, and the lowest mean rank was 32.50 for display integrated with ECDIS. Therefore, the mean ranks for the groups suggest that the navigators who have used AIS display integrated with radar had a higher level of optimism about improvement in detection targets in radar shadow areas with AIS, and those who have used AIS display integrated with ECDIS had the lowest level of optimism.

c) The difference in scores for item D3 (AIS keyboard is user friendly) across the 5 groups is highly significant with $P < 0.002$. The highest mean rank was 84.93 for stand-alone graphical display, and the lowest mean rank was 21.60 for display integrated with ECDIS. Therefore, the mean ranks for the groups suggest that the navigators who have used a stand-alone graphical display had a higher level of optimism about user friendliness of the AIS keyboard, and those who have used AIS display integrated with ECDIS had the lowest level of optimism.

d) There is also a statistically high significant difference in scores for item d7 (some of the information on the AIS display is unnecessary) across the 5 groups with $P < 0.001$. The highest mean rank was 67.70 for more than one type, and the lowest mean rank was 35.93 for stand-alone graphical display. The scores for this item were reversed, therefore, the mean ranks for the groups suggest that the navigators who have used more than one type of AIS display had the lowest mean score of perception about D7, and those who have a stand-alone graphical display had the highest mean score of perception.

e) There is a statistically significant difference in scores for item F2 (AIS causes increased use of VHF for anti-collision operation) across the 5 groups with $P <$ 0.018. The highest mean rank was 78.20 for display integrated with ECDIS, and the lowest mean rank was 47.70 more than one type of display. Therefore, the mean ranks for the groups suggest that the navigators who have used a display integrated with ECDIS had a higher mean score of belief about increased use of VHF for anti-collision operation by AIS, and those who have used more than one type of AIS display had the lowest level of belief about such increased use of VHF.

f) There is a statistically significant difference in scores for item F3 (the increased use of VHF for anti-collision decisions due to AIS violates International Regulations for Preventing Collisions at Sea) across the 5 groups with $P < 0.041$. The highest mean rank was 62.03 for display integrated with radar, and the lowest mean rank was 29.70 for display integrated with ECDIS. The scores for this item were reversed, therefore, the results suggest that the navigators who have used display integrated with radar had the lowest level of perception about violation of IRPCS due to increased use of VHF by AIS, and those who have used display integrated with ECDIS had the highest level of such perception.

g) The difference in scores for item G2 (AIS is vulnerable due to jamming) across the 5 groups is also highly significant with $P < 0.005$. The highest mean rank was 65.15 more than one type of display, and the lowest mean rank was 37.76 MKD. Therefore, the results suggest that the navigators who have used more than one type of display had the highest level of confidence, and those who have used MKD had the lowest level of such confidence about AIS vulnerability due to jamming.

h) There is a statistically significant difference in scores for item G4 (there is a risk of erroneous information displayed through wrong data input associated with AIS) across the 5 groups with $P < 0.035$. The highest mean rank was 73.90 for display integrated with ECDIS, and the lowest mean rank was 31.14 for stand-alone graphical display. The scores for this item were reversed; therefore, the results suggest that the navigators who have used stand-alone graphical display had the highest mean score about the risk stated in item G4, and those who have display integrated with ECDIS had the lowest mean score about such risk.

	Type(s) of AIS Display	N	Mean Rank	Chi-Square	Asymp. Sig.	Monte Carlo Sig.
B4	Minimum Keyboard and Display (MKD)	24	60.44	11.960	.018	.013
	Stand-Alone Graphical Display	7	43.43			
	Integrated with Radar	17	66.32			
	Integrated with ECDIS	5	15.70			
	More than one type	60	58.01			
	Total	113				
B13	Minimum Keyboard and Display (MKD)	24	46.48	11.628	.020	.016
	Stand-Alone Graphical Display	7	53.79			
	Integrated with Radar	17	74.38			
	Integrated with ECDIS	5	32.50			
	More than one type	60	58.70			
	Total	113				
D3	Minimum Keyboard and Display (MKD)	24	65.79	17.196	.002	.001
	Stand-Alone Graphical Display	7	84.93			
	Integrated with Radar	17	60.74			
	Integrated with ECDIS	5	21.60			
	More than one type	60	52.12			
	Total	113				
D7	Minimum Keyboard and Display (MKD)	24	46.00	17.928	.001	.001
	Stand-Alone Graphical Display	7	35.93			
	Integrated with Radar	17	44.12			
	Integrated with ECDIS	5	45.60			
	More than one type	59	67.70			
	Total	112				
F2	Minimum Keyboard and Display (MKD)	23	66.17	11.869	.018	.016
	Stand-Alone Graphical Display	7	74.07			
	Integrated with Radar	17	60.85			
	Integrated with ECDIS	5	78.20			
	More than one type	60	47.70			
	Total	112				
F3	Minimum Keyboard and Display (MKD)	22	43.84	9.943	.041	.038
	Stand-Alone Graphical Display	7	51.64			
	Integrated with Radar	17	62.03			
	Integrated with ECDIS	5	29.70			
	More than one type	60	61.45			
	Total	111				
G2	Minimum Keyboard and Display (MKD)	23	37.76	14.96	.005	.003
	Stand-Alone Graphical Display	7	51.50			
	Integrated with Radar	17	52.21			
	Integrated with ECDIS	5	60.50			
	More than one type	60	65.15			
	Total	112				
G4	Minimum Keyboard and Display (MKD)	24	67.44	10.374	.035	.031
	Stand-Alone Graphical Display	7	31.14			
	Integrated with Radar	17	56.76			
	Integrated with ECDIS	5	73.90			
	More than one type	60	54.50			
	Total	113				

Table 5. 5 Ranks of scores and Kruskal-Wallis test for type of AIS display

As observed during the literature review, in chapter 2, that MKD had raised the most debates and level of criticism among 4 types of AIS display, it was expected that this could be reflected in the navigators' feedback. However, this section did not show such results for MKD. Further it showed unexpected results for AIS display integrated with ECDIS, which could probably be, firstly, due to the small sample size (N =5) for respondent exposed to display integrated with ECDIS, and secondly, due to 5%

significance results that could be derived by chances in test. In fact, if the total sample size is small (N = 7 or less), Kruskal-Wallis test will show a probability value of greater than 0.05 (not significant) regardless of actual difference between compared groups. Further, there will be 5% possibility that significant results ($P<0.05$) are achieved by chance (GraphPad Software inc, 2007).

5.6 Discussion and conclusion

This section contains discussion and conclusions of the results of the questionnaires completed by navigators for each of the measured variables and assessment of demographic factors impacts on navigators' responses.

- The analysis results show that AIS is generally perceived to be a useful navigational aid as it can enhance situational awareness with better display of shipping traffic, and improve performance, efficiency, and the ability of navigators in anti-collision operations at sea. It would also enhance the confidence level of the navigators in situation control, ship's safety, and overall safety of navigation. The increase in the level of navigators' physical and mental workload due to the introduction of AIS is not significant, but disruption of the normal anti-collision operation by AIS seems to be of concern. It can also be inferred that AIS provides clearer and more continuous information than radar and is able to overcome most of the radar limitations in detection of targets in radar shadow areas such as round the bends and in heavy rain and sea clutters. AIS is perceived as complementary to radar technology rather than a competitor.

- It can also be concluded that most of the navigators' experience about ease of use of AIS is generally positive. The process of obtaining information from AIS is considered to be clear and understandable by most navigators. The majority of them did not see any great difficulty in self-learning and becoming skilful to operate and use AIS on board ship. They also more often believed that the use of AIS, particularly for anti-collision operation, is easy. The ease of use of AIS is reflected by the fact that most of navigators thought that AIS is slow for data input (only 36% thought that input is satisfactory).

- Importance of the display of AIS information was highlighted by a majority of the mariners. It can be concluded that most AIS keyboards are user friendly, and that symbols used in AIS graphical displays are efficient, AIS unit help and instructions are useful and clear, it is relatively easy to move from one menu to another one, and the way that the AIS information is presented is clear and understandable. Concern that some of the AIS information shown on an AIS display might be unnecessary and the possibility of overlay of radar echoes with AIS data causing confusion is low. Despite the noted AIS slow response time for data input, the way of getting data in and out of the AIS seems to be easy. Time for learning to extract AIS information is likely to be a problem in this regard.

- Only 19.1% of the navigators were reported to have completed a formal training on basic operation of AIS. Therefore, probably one of the most alarming problems in AIS application for navigation could be the training and competency of the navigators on basic operations, capabilities and limitation of the AIS equipment. Even among the navigators that have completed some type of training programme, only 40% of them believed in the adequacy of their training to safely perform their duties in anti-collision operations on the bridge using AIS. This might be a sign of unsuitability of the training programmes that has been available due to a lack of an international standard of training for AIS so far. Nearly half of the navigators were uncertain about whether a formal AIS training for navigators to safely conduct anti-collision operation is essentially needed or not. The navigators' uncertainty was also evident in their response on the degree of difficulty of learning to operate AIS without a suitable training course. These types of uncertainties could be due to the lack of understanding and insufficient use of the AIS technology by navigators for the navigation operation. The recent Model Course on AIS recommended by IMO (2006) could assist in improving navigators' training and education, if widely adopted. The IMO Model Course is intended to introduce, organise, and enhance AIS training taking into account the considerable variations in educational systems and cultural backgrounds of different trainees in maritime subjects.

- It was perceived that AIS reduces overall VHF traffic congestion, which could be due to the AIS capability to present extra precise information. Despite the apparent relief in overall VHF calls, the extent of communication that might be affected by the navigators for the specific purpose of anti-collision agreements needs further investigation. A result of the questionnaire analysis shows that 34% of navigators perceived that VHF traffic increases with AIS. The concern of violation of IRPCS by navigators, which might occur due to possible increase in VHF use for mutual anti-collision agreements, needs further investigation.

- The results of the analysis on possible disadvantages of AIS show that probably navigators did not have enough knowledge of the possibility of AIS misuse and its vulnerability due to jamming, which can affect the system reliability. It is probable that AIS increases the danger of piracy in certain areas with potential piratical activity. The possibility of transmitting erroneous information by AIS through wrong data input (see chapter 4) is probably an even higher disadvantage perceived by a large section of respondents.

- Assessment of the impact of the training on navigators' responses showed a number of statistically significant differences in navigators' responses. Navigators who had completed formal training on the basic operation of AIS had a higher mean perception score on the possibility of disruption of the anti-collision operation by AIS, the difficulty in self-learning to operate AIS, slow response of AIS to data input, ease of use of AIS for anti collision operations, the importance of AIS display in the navigator's performance, adequacy of their training to safely perform anti-collision operations, and the overall decrease of VHF traffic congestion with AIS. The higher optimism score of navigators about the above mentioned aspects of the AIS could be due to enhancement in utilisation of the operation and use of AIS technology, disclosure of covered features of the AIS, proper familiarisation with different AIS functions and information, exposure of capabilities and limitation of different types of AIS display, more efficient use of the AIS, and the need for less VHF communications by training, and the higher extent of use of the AIS by the trained navigators.

- Assessment of the impact of the type of the training showed one statistically significant difference between 4 types of training. Navigators who had completed a theoretical training programme had the highest hopefulness that their ship is safer with AIS. This could probably be due to the detailed explanation of the AIS capabilities and limitations being given in the theoretical training course.

- The evaluation of the impact of the certificate of competency of the navigators on their responses also showed some significant differences across the 3 classes of certificate. These significant differences suggested that the junior navigators (second officers) had the highest optimism level about enhancement of situational awareness with improved situational display of the traffic, increased efficiency in anti-collision operation, and feeling of being more in control of anti-collision operation with AIS, ease of use of AIS for anti-collision operation, clear and understandable way of presenting information, non-existence of unnecessary information on the AIS display, and ease of getting data in and out of AIS. In contrast, the most senior navigators (master mariners) had the lowest confidence level about enhancement of situational awareness with improved situational display of the traffic, increased efficiency in anti-collision operation, and the feeling of being more in control of the anti-collision operation, feeling of safer ship, and improvement in overall safety of navigation with AIS, and ease of use of AIS for anti-collision operation. The probable reason for these outcomes could be the higher presence of second officers on the bridge, compared with the masters, and more recent training of second officers that could have been included in AIS training.

- The assessment of the impact of the navigators' total sea service revealed some statistically significant differences across the 5 groups. The differences suggested that the group of navigators with the lowest sea service duration (1 year or less) had the lowest mean perception about the increased physical and mental workload of the navigators with AIS, their preference to use AIS alone rather than radar, and unreliability of the information from target ships due to spoofing. They also had the highest mean optimism about user friendliness of the AIS keyboard and simplicity of getting data in and out of AIS. The group of navigators with the highest sea service duration (above 10 years) had the lowest mean perception about user friendliness of the AIS keyboard, clear and understandable way of presenting information, simplicity of getting data in and out of AIS, and the simplicity of leaning to operate AIS without a training course. They also had the highest mean perception about the increased mental workload of the navigators with AIS and their preference to use AIS alone rather than radar.

- The influence of the type of AIS display available to the navigators on their responses was also significantly different for the 5 groups of display. The assessment result suggested that navigators who had the AIS display integrated with radar had the highest level of optimism about their increased ability in anti-collision operations and improved detection of targets in radar shadow areas with AIS, and those who had the AIS display integrated with ECDIS had the lowest level of optimism about these features of the AIS. Users of the display integrated with radar also perceived the lowest level of IRPCS violation due to increased use of VHF by AIS, and users of a display integrated with ECDIS perceived the highest level of such violation. The stand-alone graphical display users had the highest level of perception about user friendliness of the AIS keyboard and unnecessary information on the AIS display, but the lowest level of perception about user friendliness of the AIS keyboard was observed for the display integrated with ECDIS, and lowest level of perception about unnecessary information on the AIS display was observed for more than one type of display. The level of perception about the increased use of VHF for anti-collision operation was the highest for a display integrated with ECDIS, and the lowest for more than one type of display. The highest level of perception about AIS vulnerability due to jamming was for more than one type of display, and the lowest level was for MKD. The highest level of belief about the risk of erroneous information displayed through wrong data input observed for display integrated with ECDIS, and lowest level of such risk observed for stand-alone graphical display. It is important to mention that if the total sample size is seven or less, the Kruskal-Wallis test will always give a non-significant probability no matter how the groups in the total sample differ (GraphPad Software inc, 2007). Therefore, the accuracy of the perception measurement for display types integrated with ECDIS and stand-alone graphical display might have been suffered due to small sample sizes (N = 5 for integrated with ECDIS and N = 7 for stand-alone graphical display).

Overall, the above results show a trend in lack of knowledge and proper understanding of AIS along with insufficient use of the AIS technology for navigation operations.

5.7 Summary

This chapter has analysed the data from the AIS questionnaire, which was designed to evaluate navigators' perception about some aspects of the newly implemented AIS technology. The chapter also analysed the respondents' responses in relation to the demographic factors.

The chapter explained the methodology applied in the AIS questionnaire survey, descriptions of the study sample, and the questionnaire measurement construct, in the first section.

Then it presented results of preliminary data analysis. The preliminary analysis included descriptive statistics on demographic factors and sample size, in the second section.

The third section explained the results of data analysis for measured variables in the questionnaire.

The next section of this chapter considered results of the data analysis on the assessment of the impact of demographic factors, identified in the Personal Information section of the questionnaire, on responses of navigators. This section showed navigators' attitudes towards different aspects of AIS, according to whether they have had completed AIS training or not, the type of training they have completed (if any), certificate of competency, total sailing experience, and type of AIS display they have used.

Chapter 6

AIS User Satisfaction: A Theoretical Model

6.1 Introduction

New technology is introduced in order to enhance efficiency, safety, and work quality. The introduction of new technology has resulted in much improvement in work efficiency and effectiveness. Nevertheless, sometimes, the introduction of new technology is associated with unpredicted side effects and problems. Lack of training and practical experience in the use, capabilities, and weaknesses of the new equipment could further intensify the problems. To make effective use of new technology, it should be implemented with consideration of the contributory factors such as human factors, organisational factors, working practices, and social and physical environmental factors.

Acceptance of the new technology by the user and his/her adjustment with the changes brought about by such technology is very important for technology application to be successful. User perceptions and feelings are playing major roles in his/her acceptance of new technology. Proper implementation planning should take into account such factors, since proper implementation of technology can encourage the user to accept it. Different measures taken by any industry or organisation prior to implementation can be very influential in its mission success. Technology designers must properly understand the needs of front-line operators and the environment in which the operator uses the new technology during developmental stages. The degree of efficiency improvement and ease of use offered by new technology in the workplace will affect the user's tendency towards new system acceptance and speed of its implementation.

Implementation strategy that is being selected for deployment of a new system in any industry often has some advantages and disadvantages. To reduce the number of disadvantages, the applied implementation strategy should be selected with adequate prior study. For example, an implementation programme, which might be suitable for deployment of simple systems, may have unfavourable effects and be unsuitable for complex systems with higher degrees of integration. Proper investigation using research techniques such as interview, observation, pilot testing, etc. on human-machine systems could be helpful in understanding the user's needs and requirements in system design. Ergonomic design options are an essential element of the technical system development process that should be considered by designers and manufactures. Otherwise it leads to development of systems that are not comprehensible and that are difficult to use, sometimes leading to tragic events. Needs and performance of the front-line operators in the real workplace, along with basic knowledge of the man/machine interface and environment, should be considered in manufacturing stages of any new technology in order to reduce chances for failure. Knowing the changes in cognitive demands of front-line operators, along with changes in working practices, is useful for more precise planning of the design and implementation of new technology (Jones and Smith, 2001; Cheatham and Douglass, 2006).

The reliable operation of new systems in the early stages of its introduction, along with a correct implementation strategy, is very important. Such matters can influence the development of the users' impressions and attitudes towards the system's acceptance and future use. Regular monitoring of feedback and responses from the users will be useful in determining the use and efficacy of new technologies. Complex systems might be best implemented after the users are familiar and more comfortable with the basic operations, abilities, and limitations of the systems through early training and education. This could affect the user's satisfaction and their acceptance of new systems.

Evaluating navigators' perceptions about AIS through the questionnaire considered in the previous chapter. This chapter is going to select a suitable theoretical model for assessing the satisfaction of the navigators with AIS. This model may be used for measuring the user satisfaction with other similar technologies on the ship's bridge. This will be carried out through evaluation of some of the common theories and models of human behaviour and attitude. Firstly, this chapter covers the subject of technology implementation in section 6.2. Secondly, it covers new technology usage behaviour in section 6.3. AIS user satisfaction model, and conclusion of this chapter are covered in section 6.4 and 6.5, respectively.

6.2 Technology Implementation

Klein and Knight (2005) refer to new technology implementation as the switching period during which technology users becoming competent, consistent, and committed in their use of new technology. Implementation is the crucial access point between adoption and actual practical use of new systems. Often new technologies are being adopted by organisations and/or individuals but the problem will be failure in implementation success.

Adoption of new technology is the introductory step in the process of technology application but using it regularly in a professionally accepted manner is an important point that should be properly planned for in implementation stages. New systems may be useable in a workshop or in a laboratory but in real situations and workplaces, with varying environmental conditions, things may be different. Operation of a single new system alone may not be difficult but when it is being used simultaneously with many other types of equipment in a complex system within a limited time gap it may not be quite so simple. This is where the implementation process will be negatively affected and it may crate some problems. Success of any new system to achieve certain aims and objectives will depend on both the effectiveness of the technology itself for such a purpose and on the effectiveness of the implementation strategy. New technology in marine navigation, when properly implemented, has the potential to improve the safety, reliability, and quality of marine navigation. Perhaps one of the most important elements in new technology success is the human. Therefore, identification and analysis of the human issues in implementation of technology is one of the major challenges affecting actual technology use.

6.2.1 Human Issues in Technology Implementation

The implementation framework of any new technology will consist of different stages. Some human issues may influence implementation success in a specific stage, which must be analysed during its relevant period. Kenneth (1990) mentioned that, in order to successfully deal with the psychological aspects of implementing new technology, three distinctive stages must be considered. Three stages are the pre-implementation phase, the implementation phase, and the post implementation phase.

Implementation framework for new technology, introduced by Chung (1996), appear to be a more comprehensive structure that consists of the following 4 stages, each with associated human issues:

Conceptual Phase – this is the stage in which the decisions on the reason and place of application of technology will be taken. It consists of utilisation of design processes and level of complexity. The expected critical human issues that may affect implementation in this phase are: a) considerations for human-centred technology, and b) users involvement in planning.

Planning Phase – the stage in which decisions on the technology acquisition and how it is going to be implemented in the workplace will be taken. The expected critical human issues that may affect implementation in this phase are: a) considerations for human-centred technology, b) users involvement in planning, and c) use of more skill, knowledgeable, and competent operators.

Installation Phase – this stage is the execution of planning for initial operation of new technology, which includes physical installation of the technology and functional supporting systems. The expected critical human issues that may affect implementation in this phase are: a) considerations for human-centred technology, b) use of more skill, knowledgeable, and competent operators, and c) use of pilot studies.

Start-up Phase – this is the stage that execution of planning for large-scale operation of new technology begins and most of the planning, design, and installation have already been done. The expected critical human issues that may affect implementation in this phase are: a) use of more skill, knowledgeable, and competent operators, b) reorganisation of the resources, and c) training and education of the operators.

6.2.2 Implementation Problems

The implementation of new technology in real workplaces is not straightforward and sometimes it is associated with problems. According to Klein and Knight (2005) there are six interrelated reasons that might create difficulties in new technology implementation and its usage. These reasons are highly likely to affect the users' satisfaction in technology usage. The reasons are:

Unreliability and imperfect design of new technology - new technology may be associated with failure and embarrassment in use.

User's requirement of new technological knowledge and skills - this may increase level of stress and boredom in the users. It also might affect the user satisfaction.

Decision for adoption and implementation not taken by targeted user – little or no user input in decision regarding adoption and implementation produces uncertainty on the value and advantages of the technology.

Change in tasks and practices requirement by individuals – this may affect independency of individuals' activities and hierarchical status.

Time consuming, expensive, and reduced initial performance – large investment in time, and money is required for technology implementation that sometimes may be doubtful and long-term potential.

Organisations failures in their role as a stabilising power - this is where organisations fail to do the things that would improve performance and confidence.

A proper utilisation of newly installed systems could positively influence usage of such technologies and it can improve organisational efficiencies. Therefore, correct understanding of situations under which new technologies are adopted is important in the implementation process and needs to be properly investigated.

6.3 New Technology Usage Behaviour

Successful use of new technology by the target users requires identifying factors affecting the actual usage. It is important to study different issues for predicting and explaining the users behaviour in actual situations and different conditions in which such new technologies are to be used. According to Fishbein and Ajzen (1975), a person's attitude toward any object is a function of his beliefs and the implicit evaluative responses associated with those beliefs.

Significant progress has been made recently in explaining and predicting the user acceptance of technology at work, especially in information technology (Venkatesh, 2000). According to Rawstorne, Jayasuriya, and Caputi (2000) a number of socio-cognitive models has been presented by different researchers. These models can be helpful in studying the adoption and acceptance of new systems by front-line users. Most of these theories are based on behavioural intention models and they are suggesting that human attitude and behaviour will be best predicted by their intentions. These models are mainly used to predict and explain the user behaviour in computer and information technologies. In this section some of the most prevalent models will be discussed. A suitable model will be selected and later applied to AIS technology in subsequent chapters. Some of the widely applied theories of the user behaviour predictions, which are discussed in the following sections, are the Theory of Reasoned Action (TRA), the

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Theory of Planned Behaviour (TPB), the Technology Acceptance Model (TAM), and the Extended Technology Acceptance Model (TAM2).

6.3.1 Theory of Reasoned Action (TRA)

TRA is a very general intention model for predicting and explaining human behaviour and has successfully been used in a broad range of fields. The Theory of Reasoned Action (TRA) proposes that a person's behaviour is determined by his intention to perform the behaviour and that this intention is, in turn, a function of his attitude toward the behaviour and his subjective norm that is his belief about how other people would view him if he performed the behaviour (Ajzen and Fishbein, 1980). This means that intention for action will form according to a person's positive or negative feelings about the action and subjective norms surrounding the action. Intention for action, in turn, makes up the person's action. One of the limitations of this model is that it does not take into account the limited freedom to act due to restrictions in ability, time, environmental and organisational limitations, and unaware practices. Another limitation is the significant risk of confusing between attitudes and norms due to the possibility that attitudes can often be remodelled as norms and vice versa (Ajzen and Fishbein, 1980; Tailor, 2001).

In the theory of reasoned action, the person's intention to perform the behaviour is the primary determinant of human behaviour. The intention, in turn, is a function of two determinants, namely the attitude towards performing the behaviour based on the person's beliefs about the outcome of performing such behaviour, and the perception of the normative pressure on the person for performing such behaviour (Alcalay and Bell, 2000). Therefore, individual's beliefs about themselves and the environment surrounding them are determining factors related to attitude and subjective norms, which influence behaviour. Figure 6.1 shows the theory of reasoned action model.

Figure 6. 1 Theory of Reasoned Action Model (source: Fishbein and Ajzen, 1975)

The TRA consists of four variables, which are defined in the following sections (Fishbein & Ajzen, 1975 and 1980; Ajzen, 1991; Ellis and Arieli, 1999; Alcalay and Bell, 2000; Taylor, 2001):

6.3.1.1 Attitude (A)

Attitude is defined as the person's feeling (positive or negative) about performing the behaviour. Attitudes are based on assessment of the individual's beliefs (person's knowledge and information about an objects and environment) regarding the outcomes of and consequences arising from a defined behaviour and individual's evaluation of the desirability of the outcomes and consequences of such behaviour. Beliefs are formed over a person's lifetime from direct experience, outside information, and self generated. It is a set of *salient beliefs* (a small number of beliefs that a person can attend to at a given time) that determine attitude towards behaviour. Attitudes are determined by salient beliefs about advantages and disadvantages of performing behaviour, which are called *behavioural beliefs*. The positive or negative perception of the believed outcome of behaviour can be assessed using a Likert scale. The overall attitude is the sum of the individual consequence multiplied by desirability assessment for all expected consequences of the behaviour.

6.3.1.2 Subjective Norm (SN)

Subjective Norm (SN) is an individual's perception about opinions of other important people regarding the behaviour to be performed. The contribution of other people's opinions is weighted by the motivation or willingness of an individual to comply with those people's wishes. Subjective norms are determined by salient beliefs relating to social pressure, which are called *normative beliefs*. The overall subjective norm is the sum of the individual perception multiplied by motivation assessments for all other important people.

6.3.1.3 Intention (I)

Intention (I) is the motivational factor that influence person's behaviour and it shows the degree of willingness and amount of effort of the individual to perform behaviour. Intentions are the predictors of occurrence of a desired behaviour. Both attitude and subjective norm influence individual's intention to perform behaviour.

6.3.1.4 Behaviour (B)

Behaviour is the transmission of intention into action. Behavioural intention is a linear regression function of attitude toward the behaviour and subjective norm. Attitude toward behaviour itself is a function of the individual's behavioural beliefs about consequences of the behaviour and the value of those consequences according to the individual's opinion.

The TRA is presented algebraically as follows:

$B \approx B_I = w_1 A_B + w_2 SN$

where B is behaviour, B_I is behavioural intention, A_B is the person's attitude toward behaviour, SN is subjective norm, and w_1 and w_2 are weights representing the importance of each term.

The relations between attitude toward the behaviour and behavioural beliefs can be expressed algebraically as follows:

$$A_B = \sum_{i=1}^{n} b_i e_i$$

where b_i is the behavioural belief that performing the behaviour leads to some consequences, e_i is the evaluation of consequence i, and n is the number of salient beliefs.

The relation between the subjective norm and normative beliefs can be expressed algebraically as follows:

$$SN = \sum_{j=1}^{r} b_j m_j$$

where b_j is the normative beliefs (i.e., subjective probability) that some referent j thinks one should perform the behaviour, m_j is the motivation to comply with referent j, and r is the number of referents.

6.3.2 Theory of Planned Behaviour (TPB)

The theory of planned behaviour is an extension of the theory of reasoned action, a theory designed to predict and explain human behaviour in specific contexts. This theory was introduced to improve the TRA by adding a general predictor of perceived behavioural control (PBC) in predicting human behaviour (Ajzen, 1991). In this model, the same as the theory of reasoned action, the individual's intention to perform a specified behaviour is a central factor. Intentions are impressions of motivational factors that influence the behaviour. Individual's intentions indicate people's degree of willingness and amount of

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effort they apply, to carry out a given behaviour. This behavioural intention can only influence the behaviour if the given behaviour is under volitional control, i.e., the person is free to perform or not perform the behaviour (Ajzen, 1991). Motivational factors correspond to people's actual control over the behaviour. PBC as a factor directly linked to a particular behaviour plays an important role in the TPB. PBC refers to people's beliefs about his/her ability and the ease or difficulty of performing the behaviour in question. In conditions when a person does not have enough information about the behaviour, requirement or available resources have changed, or new and unfamiliar elements have entered into the situation a measure of PBC may not be a realistic behavioural prediction and accurate. TPB refers to three factors of attitude toward the behaviour, subjective norms, and perceived behavioural control. Figure 6.2 represents the theory of planned behaviour model. People may have many beliefs about a particular behaviour, but only some of them that are more relevant to the behaviour and time can be attended to - these are called salient beliefs. The TPB hypothesises that salient beliefs are the main determinants of a person's intentions and actions. Salient beliefs are of three categories: behavioural beliefs, which influence attitude toward the behaviour, normative beliefs that represent the control of subjective norms, and control beliefs, which are based on perceived behavioural control. This model highlights the significance of assessing the level of the information required for an action; the skill, resources and opportunities to act; and others support (Ajzen, 1991).

Figure 6. 2 Theory of Planned Behaviour Model (source: Ajzen, 1991)

A person's attitude toward behaviour (A) is directly proportional to the sum of the products of the strength of each behavioural belief multiplied by subjective evaluation of the belief, shown in the following equation.

$$A \propto \sum_{i=1}^{n} b_i e_i$$

where b_i is the behavioural belief, e_i is the subjective evaluation of the belief, and n is the number of salient beliefs.

Subjective norm (SN) is directly proportional to the sum of products of the strength of each normative belief multiplied by the person's motivation to comply with referent in question, shown in the following equation.

$$SN \propto \sum_{j=1}^{n} n_i m_i$$

where n_i is the normative belief, m is the person's motivation to comply, and n is the number of referents.

The relation between the perceived behavioural control and control beliefs is shown in equation below. PBC is the sum of the products of each control belief multiplied by the perceived power of the particular control factor influencing performance of the behaviour.

$$PBC = \sum_{j=1}^{n} p_i c_i$$

where c_i is control beliefs, p is perceived power of the particular control factor, and n is the number of control beliefs.

6.3.3 Technology Acceptance Model (TAM)

Technology acceptance model (TAM) was initially developed in the mid-1980s and is one of the models widely used for assessing individual acceptance and use of technologies (Davis, 1986, 1989). TAM, like TPB, is adapted from the TRA (Fishbein & Ajzen, 1975). TAM (figure 6.3) was designed to explore underlying factors linking external variables to technology acceptance and its actual use. In TAM, it is theorised that usage behaviour (*B*) is a direct function of behavioural intention (*BI*) to use technology. *BI* is, in turn, influenced by perceived usefulness (PU) and perceived ease of use (PEOU), which, in turn, are influenced via external factors.

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Figure 6. 3 Technology Acceptance Model (TAM) (source: Davis, 1986)

Therefore, the TAM model consists of four variables of behaviour, behavioural intention, perceived usefulness, and perceived ease of use. Behaviour and intention are already defined in earlier models and perceived usefulness and perceived ease of use are defined as follows:

6.3.3.1 Perceived Usefulness (PU)

Perceived usefulness (PU) is the degree to which an individual believes that using a particular system will enhance his/her job performance and productivity (Davis, 1986). This measure reflects the probability that applying the new technology will be beneficial to the job performance and final outcome. Final outcome benefits may consist of improvement in work productivity, enhancement of quality and cost saving.

6.3.3.2 Perceived Ease of Use (PEOU)

Perceived ease of use is the degree to which an individual believes that using a particular system will be free of effort (Davis, 1986). This measure reflects the potential difficulty to use the technology. It can also reflect the potential difficulty to learn to use such technology for frontline operators. Ease of use of new technology can considerably reduce the time and effort required by frontline operators and probably can increase the chance of technology success.

It is the combination of these two factors that will influence the individual's behaviour on technology acceptance and actual use in the workplace. It is important to highlight that the influence of these two factors on behaviour may be very different. A person may still use a new technology even when his/her perception on the ease of use is not very positive if he/she believes that it is advantageous and useful, and will help to perform his/her job better. The perceived usefulness of the new technology is, to some extent, influenced by perceived ease of use.

6.3.4 Technology Usage Behaviour in a Mandatory Environment

Various theories and models discussed different determinants of the acceptance and use of new technology based on volitional choices and voluntarily adoption and explain only volitional behaviour, but in some cases behaviours related to technology or system might be mandatory. Mandatory adoption is a situation where adoption and use of a system by the operators is directed from higher levels such as top management. In mandatory adoption, the users have to perform a specific behaviour even they might not like to do so. Therefore, their beliefs and attitude as determinant of such behaviour will be less significant. A mandatory use environment is a situation in which the users are obliged to perform a particular behaviour (usage) in relation to a specific technology or system in order to perform their job (Brown et al, 2002). According to Goodhue (1995), in cases of mandatory use of new technology, social norms to use a system are very influential and overpower other considerations such as beliefs about expected consequences and outcome. It is unlikely that the above-mentioned models can effectively explain the determinants of acceptance and usage in mandatory adoption (Ram and Jung, 1991; Gallivan, 2001). It was noted (Wynekoop, 1992) that in traditional frameworks for implementation of technology innovations the centre of attention is on individual adoption and therefore, in mandatory environment, where new technologies are implemented in organisations after authoritarian decisions are incomplete and limited.

However, it is not the technology investment alone that is important in improvement of work processes, quality, and productivity in a firm. Other factors like acceptance, adoption, and appropriate use are also very important and essential (Sircar et al, 2000). Even in mandatory system use, some users may choose not to comply with such a mandate if they believe that the new system is not satisfactory in supporting their work mission and therefore, such mandatory system implementation may not achieve its proposed aims and objectives (Adamson and Shine, 2003). Further, the users may use the mandated technology as their only available choice but their job satisfaction can be negatively affected. This may further result in unconventional behaviours such as resistance to use or lack of use that could lead to reduction in job performance, efficiency, and/or quality (Karsh, 2004). Identifying the appropriate functions and characteristics of any new system is important in delivering the right system to the end-users. Evaluating the acceptability of a system in the design and implementation process will help in understanding people's responses and satisfaction levels in using such systems and in improving the user acceptance by modifications made to the systems and their implementation plan.

According to Gallivan (2001), traditional theories and models for innovation adoption have been very useful in scenarios where individuals voluntarily decide to use a technology for personal use or not, especially in information technology, such as personal computers or different computer software. However, they have limitations in their application to technologies adopted as a result of authority decisions. Results of traditional innovation adoption frameworks may be associated with inconsistent findings, particularly in circumstances when (Fichman, 1992):

- Adoption occurs within an organisation setting where the users are mandated to use the innovation.
- Adoption is subject to heavy coordination requirements or strong interdependencies across multiple adopters.
- Adoption requires extensive, specialised training to learn the principles underlying the innovation, in order, to overcome knowledge barriers to use.
- Adoption and use occurs within an organisational setting, but only a single respondent is available to vouch for the innovation use of many other employees in the organisation.

6.3.5 Extended Technology Acceptance Model (TAM2)

Venkatesh and Davis (2000) extended the TAM to measure the user acceptance of mandated technologies after it was found out (Hartwick and Barki, 1994) that subjective norm has a significant effect on the user intention to use certain technology in a mandatory environment. The extended Technology Acceptance Model is referred to as TAM2. Venkatesh and Davis (2000) argued, "This model explained perceived usefulness and usage intentions in terms of social influence and cognitive instrumental processes". It was tested for 4 different systems in different organisations and strongly supported. It was noticed that both social influence and cognitive instrumental processes significantly influence the user acceptance (Venkatesh and Davis, 2000).

Figure 6.4 shows the proposed TAM2 (Venkatesh and Davis, 2000). In this model, impacts of two additional theoretical constructs of *social influence processes* and *cognitive instrumental processes* are added to the original TAM. Social influence processes consist of three interrelated social forces including *subjective norm, voluntariness, and image*, and cognitive instrumental processes include *job relevance, output quality,* and *result demonstrability*, which influence the users' decision to adopt or reject a new system (Venkatesh and Davis, 2000).

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Figure 6. 4 Proposed Extension of Technology Acceptance Model - TAM2 (adapted from Venkatesh and Davis, 2000)

The definition of each of these additional constructs is given below according to Venkatesh and Davis (2000).

6.3.5.1 Social Influence Processes

Social Influence Processes are described as follow:

a) Subjective Norm

Subjective norm is the user's perception that important people to him believe he should or should not perform a particular behaviour in question, as it was defined earlier in this chapter (Fishbein and Ajzen, 1975).

b) Voluntariness

Voluntariness is the user's perception on compliance with a social feature in performing a particular behaviour.

c) Image

Image is the user's perception on the degree to which his/her status is enhanced in any social system by acceptance and use of a new technology.

d) Experience

Experience is the user's increase of knowledge and expertise through involvement in activities with the use of new technology.

6.3.5.2 Cognitive Instrumental Processes

Cognitive Instrumental Processes are described as follows:

a) Job Relevance

Job relevance is the user's perception concerning the new technology's applicability to his/her duty and its capabilities in a user's set of tasks.

b) Output Quality

Output quality is the user's perception regarding the quality (how well) the tasks are performed by new technology.

c) Result Demonstrability

Result demonstrability is the user's perception concerning tangible results of using new technology.

Venkatesh and Davis (2000) conducted four case studies regarding different systems, two in voluntary, and two in a mandatory environment, to test TAM2. They demonstrated the following results in their test:

Intention and usage

- *Subjective norm* did have direct effects on *intention and usage* only when usage was mandatory. These effects were stronger at pre-implementation stage and early stages of post-implementation but its effects weakened to the point of non-significance by the passage of post-implementation time.
- *Perceived usefulness (PU) and perceived ease of use (PEOU)*, unlike subjective norm, remained reliable important deciding factors of intention at all stages of implementation.

Perceived usefulness

- Subjective norm had a positive direct effect on perceived usefulness at the pre-implementation stage and early stages of post-implementation but its effect reduced with increased experience.

Image

- Subjective norm had a positive effect on image and image significantly influenced perceived usefulness at all stages of implementation.

Job relevance and output quality

- Effects of job relevance and output quality on the perceived usefulness were positive and significant in all stages of implementation. The effects of these two constructs were combined multiplicatively and not additively, due to their two-way interaction.

Result demonstrability and perceived ease of use

- Result demonstrability and perceived ease of use had positive effects on perceived usefulness and were significant at all stages of implementation.

6.3.6 Simplified Technology Usage Model

In TAM2, a widely used model for a diverse group of technologies and the users, subjective norm was added to the original TAM, as an additional determinant of technology acceptance behaviour in mandated environments (Venkatesh and Davis, 2000).

It was found (Venkatesh et al, 2003) that the role of social influence appears to be important only in the initial stage of introduction of new technology when the user experience with the technology is at low levels, but it is eroded over time and finally becomes not significant with continued usage. They further, pointed out that increasing experience over time provides a more instrumental basis, rather than social, for the user behaviour in using the technology. Therefore, the influential effect of social processes as an additional construct in TAM2 can be ignored over time, conversely, influence of cognitive instrumental processes increases over time.

Additionally, when technology use is mandatory in an organisation, it is the usage behaviour that is variable since the users can vary their extent of use of such technology, and there will be a little variance in technology use (Hartwick and Barki, 1994). This usage variability is a function of the degree to which technology is integrated into one's job function (Melone, 1990).

6.3.7 End User Satisfaction Model (EUS)

The End User Satisfaction model (EUS) was introduced by Adamson and Shine (2003) to measure systems satisfaction in mandatory environment. In the next section, the EUS model will be reviewed and modified to find out if and how it can be applied to measure navigators' satisfaction with AIS technology, which is mandatory implemented by the IMO to be used as a navigational aid on ships bridges of SOLAS Convention vessels.

The user satisfaction is widely recognised to measure a system's success and effectiveness, especially success of a computer information system because it is believed that satisfied users will be more productive (Gatian, 1994; Gelderman, 1998; Downing, 1999). The End User Satisfaction Model (EUS) was developed (Adamson and Shine, 2003) to measure end user satisfaction, since it is likely the satisfaction of the actual users of mandated new technology that leads to acceptance, and consequently to increased usage. According to Adamson and Shine (2003), the EUS Model, shown in figure 6.5, consists of the following three aspects that are sequentially related:

6.3.7.1 Attitudinal Aspect

Attitudinal aspect measures formation of the users' attitudes towards new technology. It consists of subjective norms (SN), system self- efficacy (SS-E), and system quality (SQ) constructs.

6.3.7.2 Perceptual Aspect

Perceptual aspect measures the users' perception of the new technology. It consists of perceived usefulness (PU), and perceived ease of use (PEOU) constructs.

6.3.7.3 Behavioural Aspect

Behavioural aspect measures the user's satisfaction with new technology, expectedly, leading to technology usage. The related construct of this aspect is end user satisfaction (EUS).

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Figure 6. 5 End User Satisfaction Model (source: Adamson and Shine, 2003)

6.4 AIS User Satisfaction Model

AIS can play an important role in the safety of marine navigation by improving performance of anti-collision activities, provided that it is successfully implemented, and used by navigators. The role of navigators as end users of the AIS technology appears to be an imperative influence on factors affecting successful application of AIS in navigation activities. It is the extent of satisfaction of navigators that can decide on the acceptance and use or the rejection of this technology.

It was found by Venkatesh et al (2003) that the role of social influence such as subjective norm appears to be important only in the initial stage of introduction of new technology when the user experience with the technology is at low levels but it is eroded over time, and finally becomes non-significant with continued usage. They further, pointed out that increasing experience over time provides a more instrumental basis, rather than social, for the user behaviour to use the technology. Therefore, the influential effect of social processes as an additional construct in TAM2 can be ignored over time, conversely, influence of cognitive instrumental processes increases over time.

The AIS Satisfaction Model, shown in figure 6.6, is a model adapted from EUS model (Adamson and Shine, 2003); which is based on TAM2 (Venkatesh and Davis, 2003). In this model subjective norm has not been taken into account and is dropped from the model. This is because AIS is mandatory and has been used on SOLAS Convention ships for more than 2 years. It is assumed that, with more than 2 years of experiences' use, the effect of social influence is non-significant in this research. The aim of this model is to measure navigators' satisfaction with AIS.

Figure 6. 6 AIS User Satisfaction Model (adapted from Adamson and Shine, 2003)

In order to assess validity of the AIS user satisfaction model, the model will be applied to analyse the AIS questionnaire (previously discussed in chapter 5). This is demonstrated in chapter 7.

6.5 Conclusion

Implementation stages of new technology is considered as an important and crucial phase during which the users adapt themselves with the technology by becoming competent, consistent, and committed in their use of such technology. Regular use of technology in a professional manner should be planned for in implementation stages. Therefore, proper identification of human factors implications during implementation processes, consisting of different phases, could have a major impact on achievement of objectives for new technology application. Satisfactory use of new technology by the frontline operators may be affected due to many reasons but the correct understanding of situations in which new technology is used are very important and need to be properly investigated.

It can be concluded that professionally accepted use of technology is a function of the users' perceptions about the technology and satisfaction of the users with technology. There are a number of commonly used theories and models for prediction of the user behaviour on new technology. Voluntarily or mandatory adoption of new technology is an important issue in technology implementations that should be taken into account in predicting the user behaviour on new technology. However, most of these commonly used theories and models are appropriate in predicting the user behaviour in a voluntarily base, and therefore, are not suitable for measuring AIS user satisfaction. AIS adoption is mandatory, and therefore, the users have to use it even if they do not like it. However, even in the case of mandatory use of AIS, some users may not fully comply with such mandates if they believe that the AIS will not satisfactorily support their tasks in the navigation operation.

In view of mandatory adoption of AIS technology for navigation, the AIS user satisfaction model was adopted, which is a modified representation of the End User Satisfaction Model introduced by Adamson and Shine (2003). In this model, social influence of subjective norm has been ignored because of mandatory use AIS for more than 2 years. This model is going to be used, in chapter 7, for reliability and validity assessment of the AIS survey questionnaire.

6.6 Summary

This chapter discussed various models for measuring navigators' satisfaction with AIS technology. The models took into account mandatory basis of AIS adoption and amount of navigators' experience with AIS.

The first section of this chapter discussed technology implementation, human issues associated with different phases of such implementation, problems in implementation that are likely to affect the users' satisfaction in technology usage.

The next section discussed the new technology usage behaviour and commonly used theories and models for predicting the users' behaviour. This section also discussed differences in technology usage behaviour between voluntary and mandatory environment of technology adoptions.

The third section considered adoption of the End User Satisfaction model, which is thought to be appropriate for evaluation of AIS user satisfaction.

Chapter 7

Extending AIS User Satisfaction Model to Evaluate the AIS Questionnaire

7.1 Introduction

The reliability and the construct validity of a research tool are very important in assessing the efficiency of a research methodology. Reliability shows if a research tool is consistent and stable, and validity shows the extent of its ability to measure what it is designed to measure (Kumar, 1999).

A number of the generic models for measuring acceptance of new technology and their suitability for this study were discussed in chapter 6. A theoretical model was also adopted for measuring satisfaction of the navigators with AIS technology. In this chapter the AIS user satisfaction model will be used to assess reliability and validity of the AIS questionnaire scale. This chapter will further intend to select a suitable measurement construct to improve reliability and accuracy of the results in a future survey of the AIS user satisfaction and the user satisfaction with other similar technology implementation in a seagoing context. Firstly, the methodology of grouping the questionnaire's items is covered in section 7.2, and then preliminary analysis is discussed in section 7.3. Selection of the suitable statistical technique for data analysis, and final analysis are covered in sections 7.4 and 7.5 respectively. Finally, discussion and conclusion are covered in section 7.6.

7.2 Methodology

Items included in the original survey questionnaire were not initially designed according to the AIS user satisfaction model. Therefore, the items in the original questionnaire are shown grouped to fit into the AIS user satisfaction model in table 7.1. They are clustered to match the model's groupings as close as possible. The relevant groups are:

- **System Quality (SQ).**
- **Self-Efficacy (S-E).**
- **Perceived Usefulness (PU).**
- **Perceived Ease of Use (PEOU).**
- **AIS User Satisfaction (AISUS).**

The suitability of the questionnaire for measuring the AIS user satisfaction will be analysed using the computer software SPSS version 14. The internal consistency of the measurement scale will be examined through Cronbach's alpha coefficient (α). Pallant (2004) and Field (2005) stated that the alpha coefficient is one of the most commonly used indicators of the scale reliability and ranges in value from 0 to 1. They also mentioned that values of above 0.7 are acceptable values of alpha, but the higher the score, the more reliable the generated scale is. The validity of the measurement scale (relationship among variables) will be explored through the statistical technique of multiple regression. According to Tabachnick and Fidell (2000); Pallant (2004); and Field (2005) multiple regression is a popular technique that could be used to deal with variety of questions, especially in predicting a dependent variable (DV) from several continuous independent variables (IV), in many disciplines.

Rank
Certificate of competency held
Total time at sea (year)
Total sailing experience with AIS (month)
Type(s) of AIS display available
Have you completed any formal training on basic operation of AIS?
If you have completed an AIS training, what kind of training was it?
System Quality (SQ) SQ1- AIS display is valuable in navigator's performance. SQ2- Symbols used in AIS display are efficient. SQ3- AIS keyboard is user friendly. SQ4- The AIS unit help and instructions are useful and clear. SQ5- It takes a long time to learn to extract AIS information. SQ6- The way that AIS information is presented is clear and understandable. SQ7- Some of the information on the AIS display is unnecessary. SQ8- It is relatively easy to move from one menu to another menu. SQ9- Getting data in and out of AIS is easy. SQ10- Overlay of radar echoes with AIS data causes confusion. SQ11- Since AIS stations have no means of assessing the data received, the information received from target ships is not reliable due to spoofing. SQ12- AIS is vulnerable due to jamming. SQ13- There is a risk of erroneous information displayed, through wrong data input associated with AIS.

Self-Efficacy (SE)
SE1- I think that my training on the use of AIS (if any) is adequate to safely perform anti-collision operation on the bridge using AIS.
SE2- Formal training for AIS is essential for safe operation in collision situation.
SE3- It is easy to use AIS for anti-collision operation.
Perceived Usefulness (PU)
PU1- AIS enhances navigator's situational awareness with a better situation display of the traffic.
PU2- Using AIS would increase navigator's efficiency in anti-collision operation.
PU3- Using AIS would let the navigator feel more in control of anti-collision operation.
PU4- AIS will disrupt the normal anti-collision operation.
PU5- AIS increases navigator's physical workload.
PU6- AIS increases navigator's mental workload.
PU7- AIS provides clearer and continuous information in comparison with radar.
PU8- Detection of targets in radar shadow areas is improved with AIS.
PU9- AIS decreases overall VHF traffic congestion.
PU10- The increased use of VHF for anti-collision decisions due to AIS violates International Regulation for Preventing Collisions at Sea (ColRegs).
Perceived Ease of Use (PEOU)
PEOU1- Self-learning to operate AIS is hard for navigators.
PEOU2- It is easy to become skilful at using AIS.
PEOU3- The process of obtaining information from AIS is clear and understandable.
PEOU4- AIS is easy to use.
AIS User Satisfaction (AISUS)
AISUS1- Using AIS would improve navigator's performance in anti-collision operation.
AISUS2- Using AIS would increase navigator's ability in anti-collision operation.
AISUS3- Navigators feel their ship is safer with AIS.
AISUS4- AIS improves overall safety of navigation.

Table 7. 1 Questionnaire Grouped According to AIS User Satisfaction Model

Five of the items with low reliability figures (Cronbach's alpha less than 0.7) were dropped from the analysis. These items are shown in table 7.2.

Navigators prefer to use AIS alone rather than radar.
AIS responds slowly to data inputs by navigators.
Learning to operate AIS without a proper training course is easy.
AIS causes increased use of VHF for anti-collision operation.
AIS will increase the danger of piracy in areas of piratical activity.

Table 7. 2 Questions dropped from AIS User Satisfaction Model

7.2.1 Questionnaire Codebook

The questionnaire codebook, which was prepared in chapter 5, will be also used in this chapter to convert required data into the SPSS format.

7.3 Preliminary Analysis

Preliminary analysis of data is carried out to prepare the data for final statistical analysis.

7.3.1 Manipulating the Data

Before performing statistical analyses of the data, missing values were defined. Further, scores for negatively worded items (high scores indicate low optimism) were reversed. The negatively worded items are: SQ7, AQ10, SQ13, PU5, PU6, PU10, and PEOU1.

Total scale scores were calculated by adding together scores from all the items that comprise each of the five constructs in the model. The total scores are shown as a new variable at the end of survey's data set. They are named TSQ, TSE, TPU, TPEOU, and TAISUS. The manipulated data table is shown in appendix C.1.

7.3.2 Distribution of Scores

Figures 7.3 to 7.7 show histograms of total scores with normal curve for the five variables in our adopted AIS User Satisfaction Model. The corresponding statistic and frequency tables are shown in appendix C.2. These histograms show that the scores are normally distributed. The distributions of the scores were further examined by calculation of z-scores, which showed normal distributions. Field (2005) pointed out that distribution of the scores could be further ascertained by the skewness and kurtosis values in descriptive table. He further mentioned that these values should be first converted to z-scores in order to obtain standardised units for comparison. The table of calculated absolute z-scores is shown in appendix C.3.

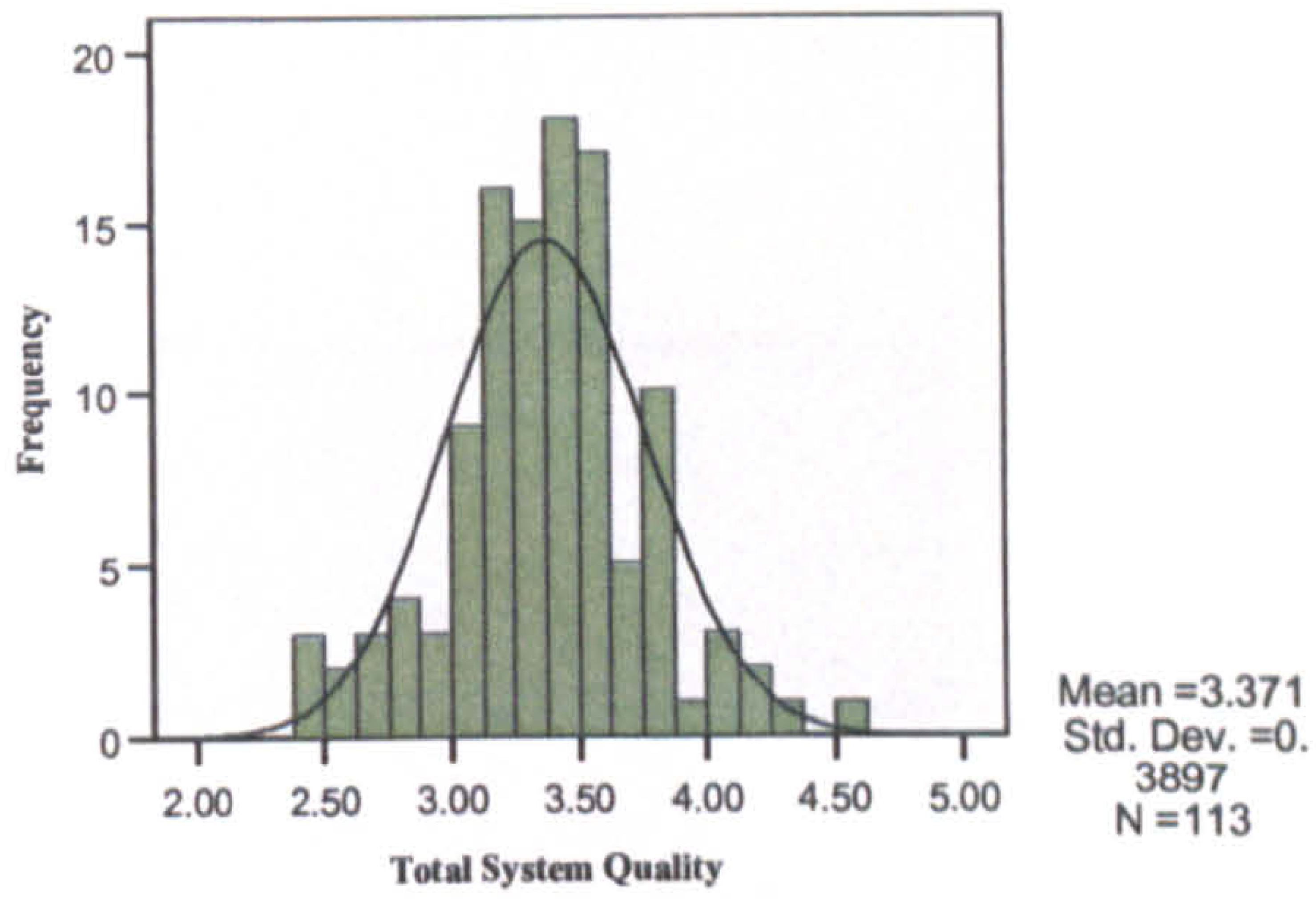

Figure 7. 1 Histogram of total system quality scores with normal curve

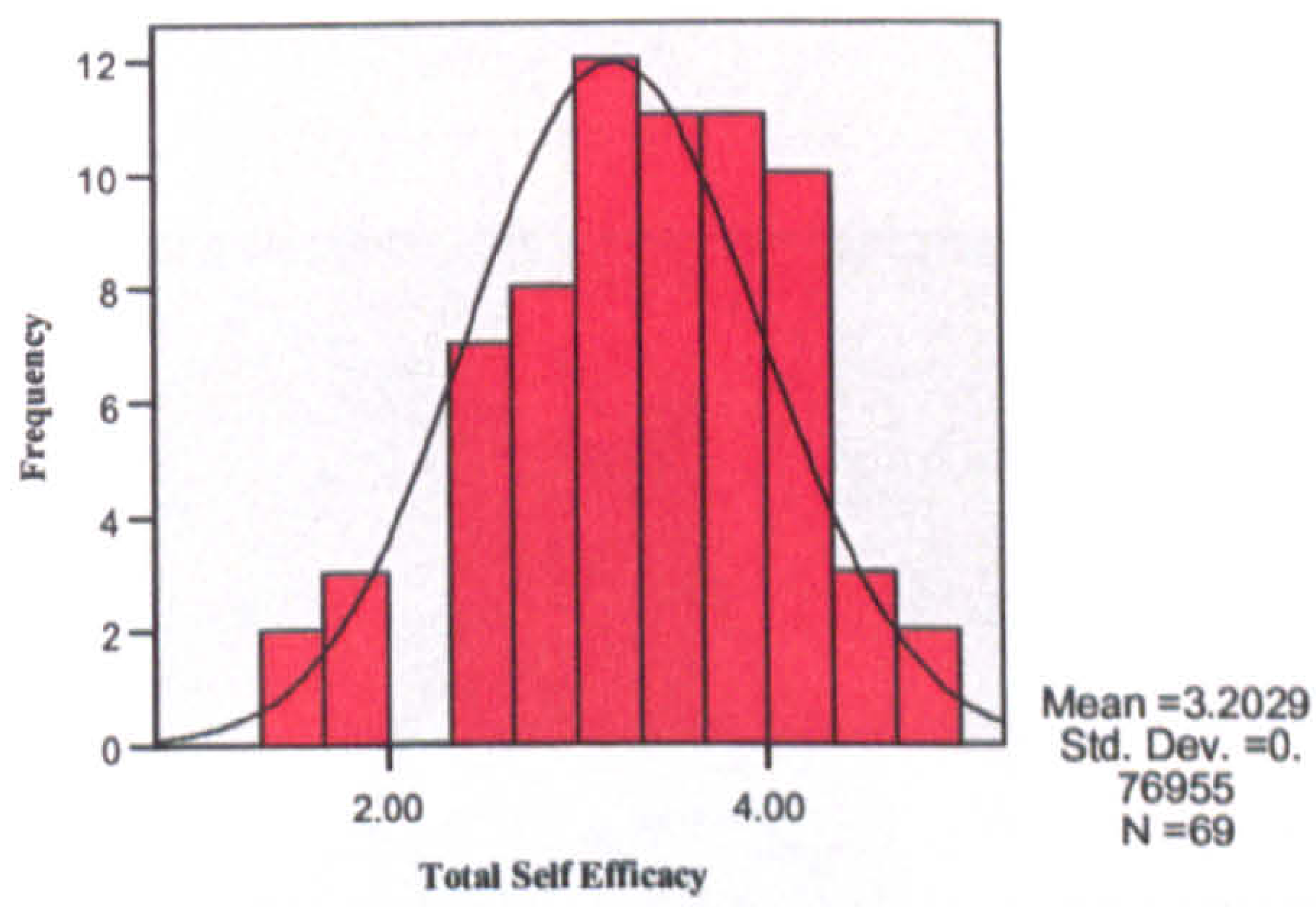

Figure 7. 2 Histogram of total self-efficacy scores with normal curve

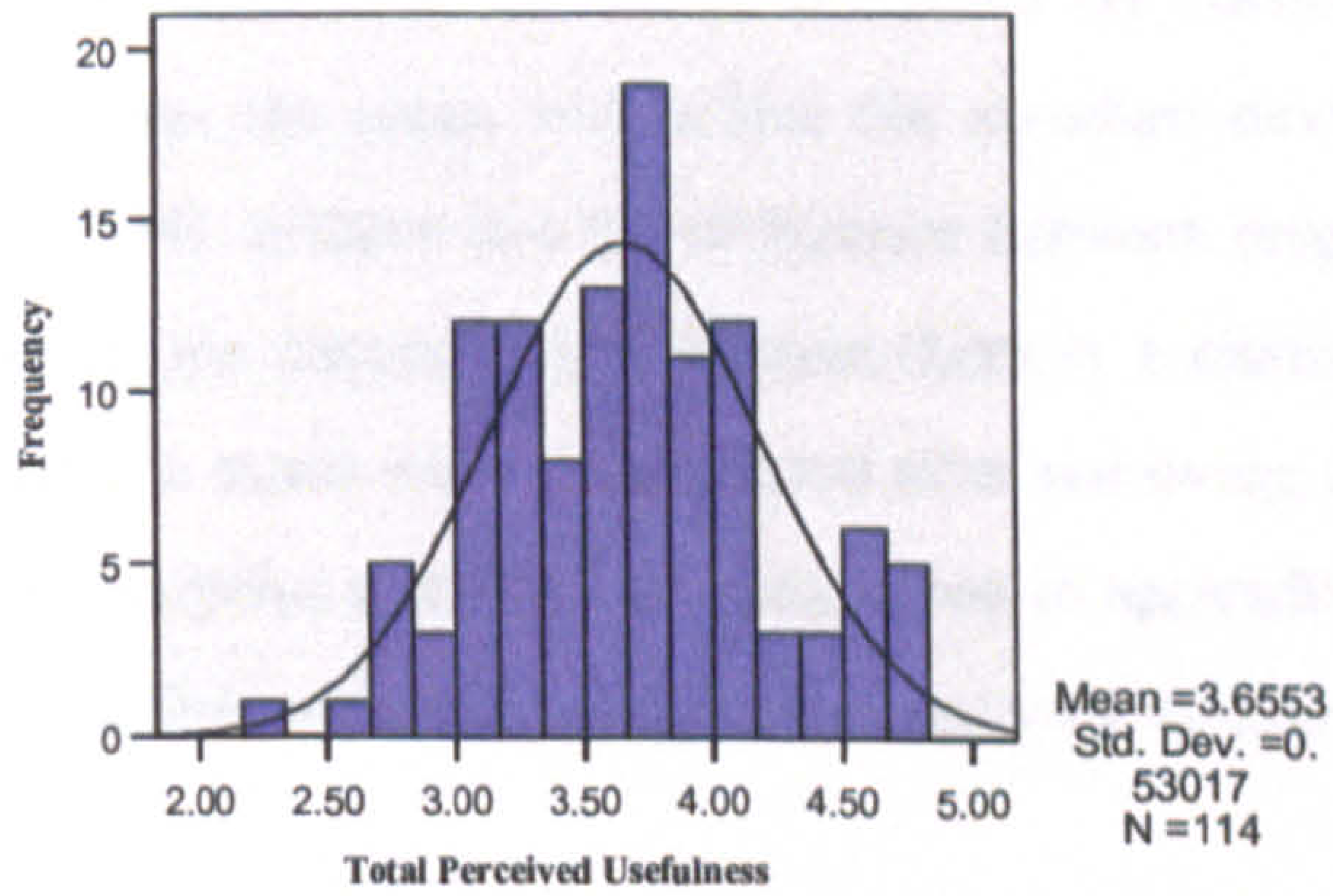

Figure 7. 3 Histogram of total perceived usefulness scores with normal curve

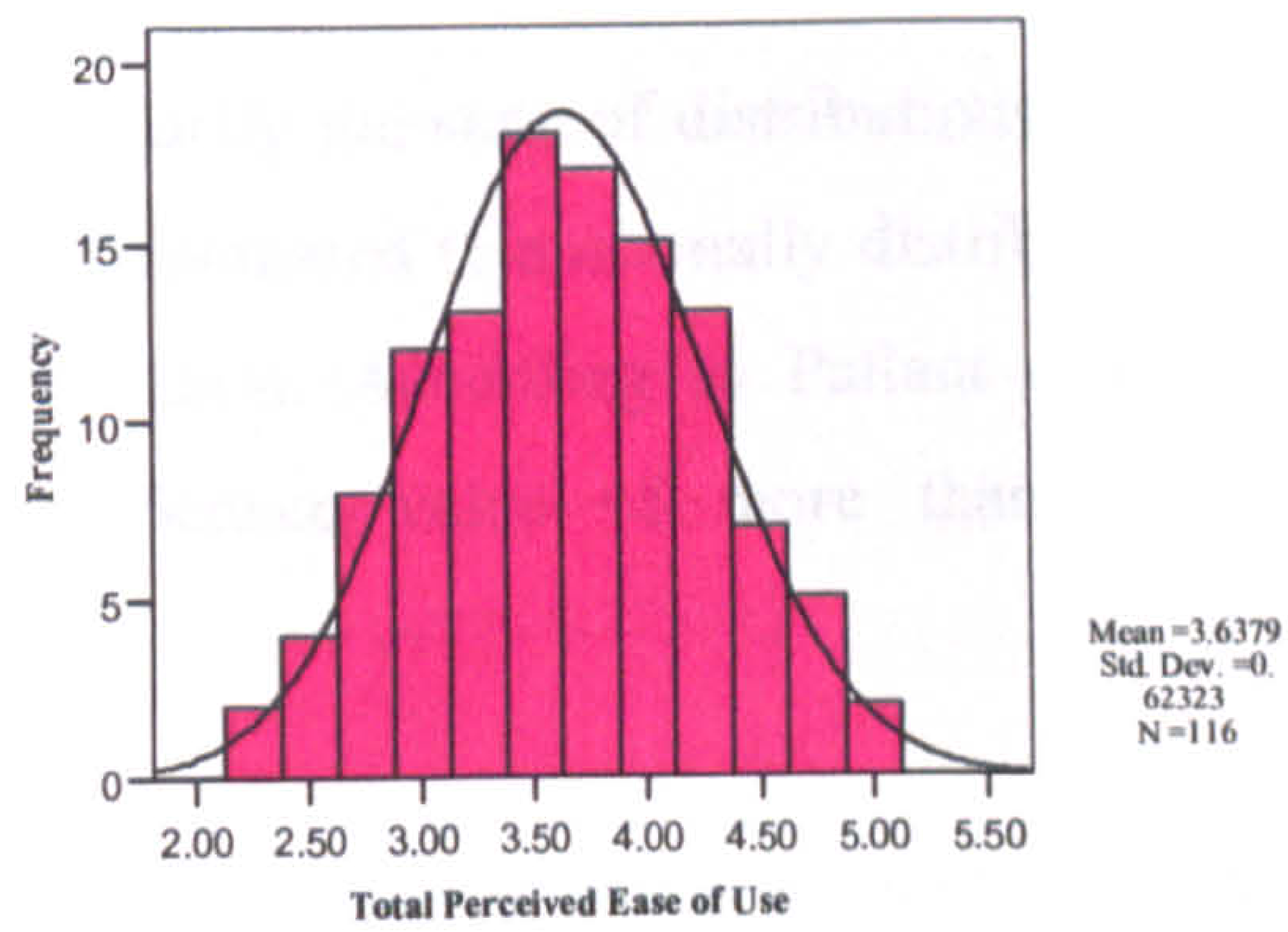

Figure 7. 4 Histogram of total perceived ease of use scores with normal curve

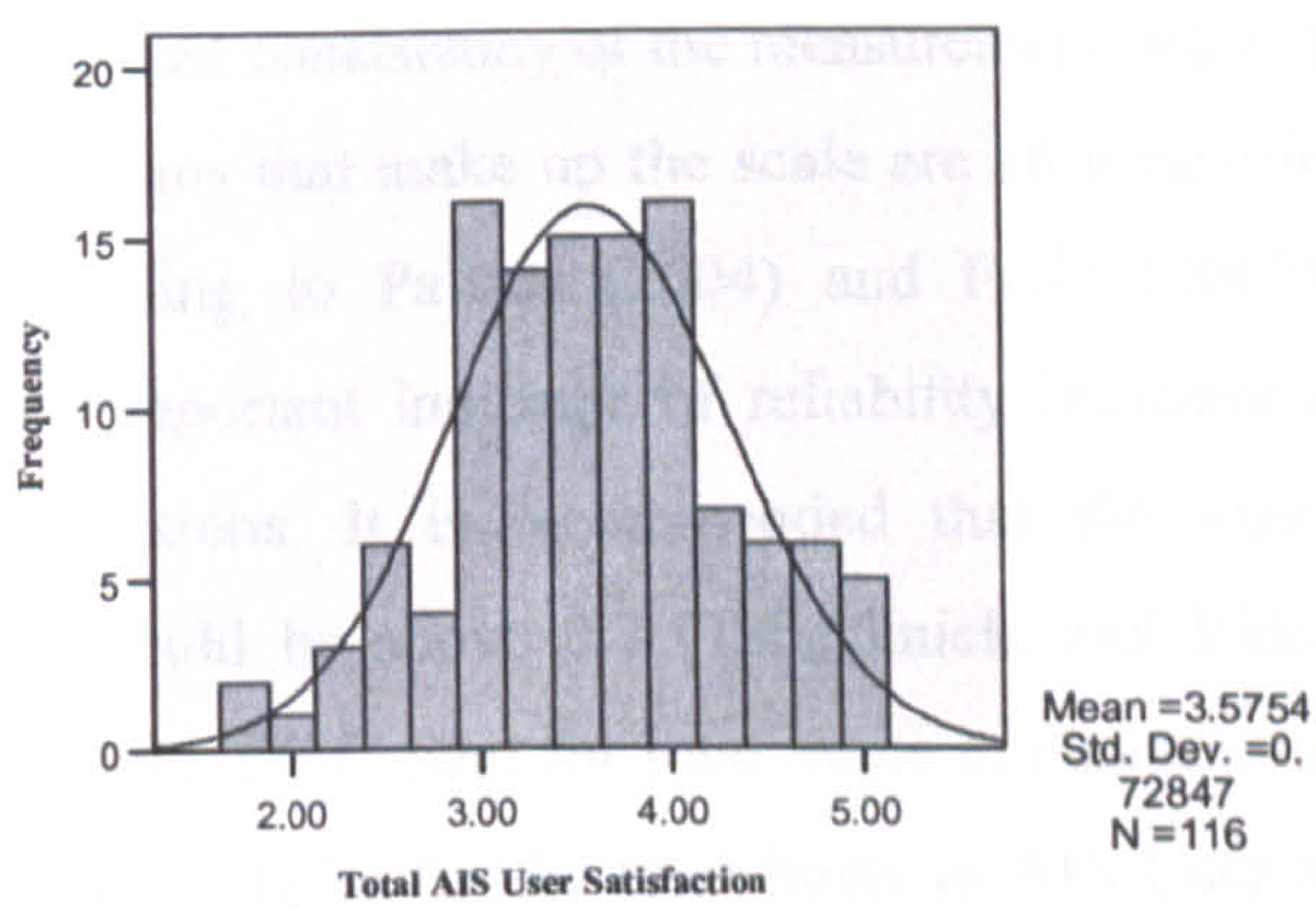

Figure 7. 5 Histogram of total AIS user satisfaction scores with normal curve

Outliers in data were also looked for. An outlier is a score very different from the rest of the data, and they can bias the mean and inflate the standard deviation (Field, 2005). According to Pallant (2004), if there is a big difference between original mean score and the 5% trimmed mean in the descriptive table then there is a chance of outlying cases. The 5% trimmed mean is a mean score recalculated after removing the top and bottom 5 percent of the cases. Descriptive table for our data, given in appendix C.4, shows that the original means and 5% Trimmed means of the cases are very similar. Therefore, extreme scores did not have a strong influence on the mean values. Absence of significant outliers in the scores was also revealed by the result of absolute z-scores, given in appendix C.5.

Field (2005) argued that the skewness and kurtosis, and histograms do not give sufficient information about normality of a distribution, but Kolmogorov-Smirnov (K-S) tests of normality could further clarify the state of distributions more appropriately. In K-S test scores in the sample are compared to a normally distributed set of scores with the same mean and standard deviation. According to Pallant (2004) and Field 2005, a non-significant result (significance value of more than 0.05) indicates normality of distribution.

To crosscheck the distribution of the scores Kolmogorov-Smirnov test is carried out. The test showed non-significant results for all variables (TSQ, TSE, TPU, TPEOU, and TAISUS), which confirm normality of the distribution of the scores.

7.3.3 Reliability of Measurement Scales

It is important for the measurement scale used in the study to be reliable. This reliability is concerned with the internal consistency of the measurement scale. The Reliability scale is showing whether the items that make up the scale are all measuring the same original construct or not. According to Pallant (2004) and Field (2005) Cronbach's alpha coefficient is the most important indicator of reliability indicator commonly used for internal consistency decisions. It is recommended that the ideal Cronbach's alpha coefficient of a scale should be above 0.7 (Tabachnick, and Fidell, 2001). Table 7.3 shows the Cronbach's alpha coefficient for total items in measurement scale. According to table 7.3, the Cronbach's alpha for the total items in AIS User satisfaction Model is 0.804, which is above 0.7. Therefore, the scale of our sample is considered to be reliable.

Cronbach's Alpha	N of Items
.804	34

Table 7. 3 Reliability Statistics for Total Scale's Items

Table 7.3 shows the Cronbach's alpha coefficients for five variables with the entire make up items in their underlying constructs in AIS User Satisfaction Model. The Cronbach's alphas for TSQ, TSE, TPU, TPEOU, and TAISUS are 0.739, 0.711, 0.769, 0.737, and

0.704, respectively. These alpha figures also show that the reliability of scales used to measure each of the five variables in the study sample is above 0.7 and within acceptable limit.

Pallant (2004) pointed out that Corrected Item-Total Correlation gives an indication of the degree to which each item correlates with the total score. She also mentioned that values of less than 0.3 indicate that the item is measuring something different from the overall scale, and if the scale's overall Cronbach's alpha is less than 0.7 the items with low item-total correlation may need to be removed (Pallant, 2004). This correlation is shown as a column marked Corrected Item-Total Correlation, in table 7.4.

The table shows that some items such as SQ1, SQ7, SQ10, SQ11, and SQ13 in TSQ, and PU7 and PU10 in TPU have Corrected Item-Total Correlation figures of less than 0.3. We may need to remove such items if overall Cronbach's alpha is less than 0.7 in order to increase the overall reliability and validity of scales. However, since our overall Cronbach's alpha value is 0.804, there is no need for removing them.

	Cronbach's Alpha	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
TSQ	.739		
SQ1		.252	.736
SQ2		.326	.727
SQ3		.612	.692
SQ4		.583	.696
SQ5		.319	.728
SQ6		.569	.711
SQ7		.276	.734
SQ8		.365	.723
SQ9		.506	.706
SQ10		.257	.739
SQ11		.267	.734
SQ12		.413	.718
SQ13		.141	.753
TSE	.711		
SE1		.689	.395
SE2		.518	.635
SE3		.423	.739
TPU	.769		
PU1		.445	.750
PU2		.670	.717
PU3		.594	.729
PU4		.401	.754
PU5		.502	.740
PU6		.482	.743
PU7		.155	.790
PU8		.529	.738
PU9		.426	.751
PU10		.233	.778
TPEOU	.737		
PEOU1		.466	.719
PEOU2		.480	.711
PEOU3		.575	.657
PEOU4		.631	.628
TAISUS	.704		
AISUS1		.530	.614
AISUS2		.553	.599
AISUS3		.359	.718
AISUS4		.528	.620

Table 7. 4 Statistics for Reliability of Scales

7.4 Statistical Technique for Data Analysis

Choosing the correct statistical technique to analyse the data is an important aspect of any research. Statistical technique is dealing with the suitability of the approach, which could enable a researcher to address particular research questions. The type of statistical technique depends upon the addressed research question and nature of the available data (Field, 2005; Pallant, 2004).

The purpose of this analysis is to explore relationships and the amount of variance in AIS user satisfaction scores that can be explained by perceived usefulness and perceived ease of use. It will also look at the amount of variance in perceived usefulness and perceived ease of use scores that can be explained by AIS system quality and self-efficacy of the AIS operators. According to Pallant (2004) and Field (2005) with multiple regression analysis the relationships between one DV and several IVs could appropriately be predicted. The goal of regression in this research is to arrive at a set of regression coefficients (β values) for the IVs. Tabachnick and Fidell (2000) also pointed out "regression analysis would only reveal the relationships among variables but do not indicate causality of the relationships". Therefore, since our data (one sample) are normally distributed (normality of the data was already checked in this chapter) multiple regression is considered to be the most suitable technique for our analysis. In the AIS User Satisfaction Model adapted in chapter 6, system quality and self-efficacy are the two continuous independent variables (IV) for continuous dependent variable (DV) of perceived usefulness. They are also IVs for total perceived ease of use. Perceived usefulness and perceived ease of use are, in turn, IVs for DV of AIS user satisfaction.

7.5 Final Analysis

The final data analysis is undertaken in relation to individual sub scales, and the results are explained accordingly.

7.5.1 Perceived Usefulness

7.5.1.1 Correlations

Pearson correlation coefficient (R) shows the strength of the relationship between two variables. According to Pallant (2004), a positive correlation is an indication of an increase in the second variable due to the increase in the first one, and a negative correlation is showing opposite relation. Preferably a correlation coefficient should be above 0.3 to show some relation of independent variable with dependent variable (Pallant, 2004). A correlation coefficient of more than 0.9 is a substantial coefficient that shows multicollinearity in the data (Field, 2005). Multicollinearity will be discussed later in this chapter.

According to the value of Pearson correlation coefficient in correlation matrix (table 7.5), both of the TSQ and TSE scales correlate positively with TPU ($R = 0.504, p < 0.001$ and $R = 0.380, p < 0.001$, respectively). However, TSQ has a larger positive correlation with TPU, than TSE. Thus it is likely that TSQ will best predict TPU. Apparently, there is not any correlation between TSQ and TSE (R= -0.049). One-tailed significance values in table 7.5, shows that both the positive correlations of TSQ with TPU and TSE with TPU are significant as $p < 0.001$.

		Total Perceived Usefulness	Total System Quality	Total Self Efficacy
Pearson Correlation	Total Perceived Usefulness	1.000	.504	.380
	Total System Quality	.504	1.000	-.049
	Total Self Efficacy	.380	-.049	1.000
Sig. (1-tailed)	Total Perceived Usefulness	.	.000	.001
	Total System Quality	.000	.	.348
	Total Self Efficacy	.001	.348	.
N	Total Perceived Usefulness	114	112	69
	Total System Quality	112	113	67
	Total Self Efficacy	69	67	69

Table 7. 5 Correlation Matrix for Regression Analysis (TPU)

7.5.1.2 Evaluation

The model summary indicates the degree of successfulness of the model in predicting the dependent variable. The model summary provides some very important information about the model, such as R (value of multiple correlation coefficient between the predictors and outcome), R^2 (amount of variability in the outcome explained by the predictors), and adjusted R^2 (indicates amount of model generalisation) (Field, 2005). Table 7.6 is the model summary for Total Perceived Usefulness of the AIS. It shows that 41.8% (R^2 = 0.418) of the variance in TPU (DV) is explained by the model, which includes the TSQ (R^2 = 0.254) and TSE (R^2 = 0.164). Adjusted R^2 is 0.399 and the shrinkage is equal to $1.9\% = (0.418 - 0.399) \times 100$. The Shrinkage is the reduction of variance in the outcome if the model were derived from the population rather than a sample (Field, 2005). Therefore, the percentage of the variance explained by the model for TPU is very close to that of the corrected estimate of the true population.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.504(a)	.254	.242	.46151
2	.646(b)	.418	.399	.41089

(a) Predictors: (Constant), Total System Quality
(b) Predictors: (Constant), Total System Quality, Total Self Efficacy
Dependent Variable: Total Perceived Usefulness

Table 7. 6 Regression Model Summary (TPU)

According to Field (2005), to assess the goodness-of-fit of the model (improvement in prediction of outcome due to the model) it is important to evaluate the *F*-ratio. The *F*-ratio measures the amount of the improvement in prediction of the outcome by the model compared to the level of inaccuracy of the model. He further added that an *F*-ratio of greater than 1 shows that the model is reasonable and the improvement due to the regression model is greater than the inaccuracy within the model. The result of analysis of variance (ANOVA), in table 7.7, shows that the *F*-ratio for model 1 is 22.099, and *F*-ratio for model 2 is 22.939, and therefore, the improvement due to the regression models is much grater than inaccuracy within the models. Both of the *F*-ratios are significant as $p < 0.001$ for both the cases, and therefore, it is unlikely to have happened by chance. These results show that the model is a significant fit of the data overall and it significantly improves our ability to predict the outcome variable because the *F*-ratio is significant (probability less than 0.05).

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.707	1	4.707	22.099	.000(a)
	Residual	13.844	65	.213		
	Total	18.551	66			
2	Regression	7.746	2	3.873	22.939	.000(b)
	Residual	10.805	64	.169		
	Total	18.551	66			

(a) Predictors: (Constant), Total System Quality
(b) Predictors: (Constant), Total System Quality, Total Self Efficacy
Dependent Variable: Total Perceived Usefulness

Table 7. 7 ANOVA (TPU)

7.5.1.3 *Model Parameters*

Parameters of the regression model are shown in the coefficients table of SPSS output. The *b*-values show the relationship between a dependent variable and each independent variable (correspond to the change in dependant variable by a unit change in independent variable). Positive or negative values show a positive or negative relationship between IV and DV, respectively. The degree of affect of each IV on DV given by *b*-value is when the effects of all other predictors are held constant. Standard error associated with each *b*-value shows the extent of difference in that *b*-value from sample to sample. The amount of contribution of the predictor and its significance to the model will be shown by the value of t and p, respectively. The greater contribution of a predictor is shown by the larger value of t, and the smaller value of p (Field, 2005). From the summary of the regression model, in table 7.8, it could be inferred that:

- The *b*-value of 0.712 for TSQ indicates that as the TSQ increases by one unit, TPU increases by 0.712 units provided that the effect of the TSE is held constant. This value would vary across different samples by 0.130 (associated standard error with TSQ).
- The *b*-value of 0.279 for TSE indicates that as the TSE increases by one unit, TPU increases by 0.279 units provided that the effect of the TSQ is held constant. This value would vary across different samples by 0.066 (associated standard error with TSE).
- The t-test results for this model indicate that the TSQ ($t = 5.48$, $p < .001$), and TSE ($t = 4.24$, $p < .001$) are both significant predictors of TPU, but the TSQ has a greater impact than the TSE.

More appropriate interpretation of a variable's importance in the model is possible by standardised beta (β) coefficients that are not dependent on the units of measurement of variables. They are measured in standard deviation units and are directly comparable. Confidence intervals of beta-values show the limits of true *b*-values for 95% of these samples. A good model is the one with small confidence intervals, which do not cross zero (Pallant, 2004; Field, 2005). According to table 7.8, the TSQ, with standardised beta of 52.3%, makes a stronger unique contribution to explaining TPU, when the variance explained by the TSE is controlled. The standardised beta value for TSE is showing a less contribution with 40.5%. Further, TSQ and TSE both with significance value of 0.001 are making a unique, and statistically significant, contribution to the prediction of the TPU scores. This also means no overlap between TSQ and TSE. Pallant (2004) pointed out that a significance value of less than 0.05 for an IV shows a significant unique contribution of that IV to the prediction of the DV, and a significance value of greater than 0.05 shows no such contribution that may be due to overlap with other IVs in the model.

The confidence interval for TSQ is between 0.452 and 0.972, and for TSE is between 0.148 and 0.411, which both are relatively narrow, and do not cross Zero. This indicates that the parameters for these variables are significant and they have positive relationships.

The zero-order correlations are the Pearson correlation coefficients that correspond to the same values in correlation table 7.5, and the part correlations indicate the relationship between each predictor and the outcome variable, when the effects of the other predictors on the outcome are controlled. Square of the value of part correlations shows the unique contribution of the variable to the total variance in dependent variable (R^2) in the model (Field, 2005; and Pallant, 2004). According to table 7.8, the zero-order correlations are 0.504 for TSQ and 0.380 for TSE. The part correlation coefficients are 0.523 for TSQ and 0.405 for TSE, indicating that TSQ uniquely explains 27% (0.523^2) and TSE uniquely explains 16% (0.405^2) of the variance in TPU scores. It should be noted that sum of all the squared part correlations does not equal the total R^2 value, because part correlations values do not include overlaps or shared variance but total R^2 does (Pallant, 2004).

Model		Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B		Correlations		Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Part	Tolerance	VIF
1	(Constant)	1.345	.495		2.720	.008	.357	2.333				
	Total System Quality	.685	.146	.504	4.701	.000	.394	.976	.504	.504	1.000	1.000
2	(Constant)	.361	.498		.725	.471	-.633	1.355				
	Total System Quality	.712	.130	.523	5.480	.000	.452	.972	.504	.523	.998	1.002
	Total Self Efficacy	.279	.066	.405	4.243	.000	.148	.411	.380	.405	.998	1.002

Dependent Variable: Total Perceived Usefulness

Table 7. 8 Coefficients of the regression model (TPU)

7.5.1.4 Multicollinearity Assessment

Multicollinearity refers to a strong correlation between independent variables. The problem of multicollinearity occurs when at least one of the independent variables is highly correlated with other independent variables (correlation coefficient = 0.80 0r 0.99). This perfect correlation prevents unique estimation of the regression coefficients in the model. Collinearity diagonistics are carried out in SPSS by giving two values of variance inflation factor (VIF) and tolerance (Pallant, 2004; Field, 2005). Tabachnick and Fidell (2000) mentioned that if Tolerance ($1 - R^2$) is less than 0.10 and VIF (just inverse of Tolerance) is more than 10, the possibility of multicollinearity exists. According to table 7.8, the lowest tolerance value is 0.998, which is not less than 0.10. The highest VIF value is 1.002, which is well below the critical value of 10. The tolerance and VIF values confirm that collinearity is not a problem for this model, and therefore, the variability of TPU is properly explained by the TSQ and TSE.

Further examination of multicollinearity is possible through eigenvalues given in collinearity diagnostics output of SPSS. Eigenvalues shows the distribution of variances of the matrix for variables. Large variance proportions on the same small eigenvalues are to be checked. The range of variance proportions is between 0 and 1. The variance proportions for variables that both have high-variance proportions for the small eigenvalues in the bottom few rows of the collinearity diagnostics table should be distributed across different dimensions. These values show the accuracy of the regression model. The condition indices represent the square root of the largest eigenvalue to the eigenvalue of interest. There are not hard and fast rules about the highest limits of condition index to indicate collinearity problem, but the final dimention should not have a very large condition index (Field, 2005). Table 7.9 shows that the eigenvalues of the scales are between 2.95 and 0.006, which are fairly close, and condition index of the final dimension is 22.32, which is not very large compared to other dimensions. The variance proportions show that for TSQ highest percentage of its variance proportion (92% of the variance of the regression coefficient) is associated with eigenvalue number 3, and for TSE highest percentage of its variance proportion (89% of the variance of the regression coefficient) is associated with eigenvalue number 2. These results indicate that multicollinearity is not a problem in this model.

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	Total System Quality	Total Self Efficacy
1	1	1.993	1.000	.00	.00	
	2	.007	17.488	1.00	1.00	
2	1	2.954	1.000	.00	.00	.01
	2	.040	8.614	.02	.08	.89
	3	.006	22.320	.97	.92	.11

Dependent Variable: Total Perceived Usefulness

Table 7. 9 Collinearity Diagnostics (TPU)

7.5.1.5 Casewise Diagnostics

The error in the regression model will be represented by residuals. It shows the differences in the values of the outcomes between the model and that observed in the sample. In order to define a universal scale for measuring a large residual, the residuals are divided by their standard deviation and they are called standardised residuals. In an ordinary sample 95% of the cases should have standardised residuals within about ± 2 (Field, 2005). Thus, it is reasonable to expect about 6 cases (5%) to have standardised residuals outside of the limits (± 2). Table 7.10 shows that out of 116 cases only 3 cases (about 3%) are with standardised residuals outside the limits. Therefore, there is not a big difference between the outcome of the sample and the outcome of the model, and the model is reasonably accurate.

Case Number	Std. Residual	Total Perceived Usefulness	Predicted Value	Residual
30	2.111	4.70	3.8327	.86729
67	-2.130	3.10	3.9752	-.87522
68	-2.154	2.80	3.6849	-.88489

Dependent Variable: Total Perceived Usefulness

Table 7. 10 Casewise Diagnostics (TPU)

7.5.2 Perceived Ease of Use

7.5.2.1 Correlations

Pearson correlation coefficient in correlation matrix (table 7.11) shows that TSQ correlates substantially with TPEOU (R = 0.360, $p < 0.001$), but TSE has a smaller positive correlation with TPEOU (R = 0.132, $p < 0.14$) than TSQ. TSE had a lower positive correlation with TPEOU, which is not significant in predicting TPEOU. Bivariate correlation between TSQ and TSE is -0.049. One-tailed significance values indicates that the correlations between TSQ and TPEOU is positive and significant, $p<0$ .001, but the correlation between TSE and TPEOU is not significant, $P>0.05$ (table 7.11).

		Total Perceived Ease of Use	Total System Quality	Total Self Efficacy
Pearson Correlation	Total Perceived Ease of Use	1.000	.360	.132
	Total System Quality	.360	1.000	-.049
	Total Self Efficacy	.132	-.049	1.000
Sig. (1-tailed)	Total Perceived Ease of Use	.	.000	.140
	Total System Quality	.000	.	.348
	Total Self Efficacy	.140	.348	.
N	Total Perceived Ease of Use	116	113	69
	Total System Quality	113	113	67
	Total Self Efficacy	69	67	69

Table 7. 11 Correlation Matrix for Regression Analysis (TPEOU)

7.5.2.2 Evaluation

According to model summary in table 7.12, 15.2% (R^2 = 0.152) of the variance in TPEOU is explained by the model, which includes the TSQ (R^2 = 0.129) and TSE (R^2 = 0.023). Adjusted R^2 is 0.125 and the shrinkage is equal to 2.7% $=(0.152-0.125)\times 100$. This shows that the percentage of the variance explained by the model is very close to that of the corrected estimate of the true population.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.360(a)	.129	.116	.58595
2	.390(b)	.152	.125	.58286

(a) Predictors: (Constant), Total System Quality
(b) Predictors: (Constant), Total System Quality, Total Self Efficacy
Dependent Variable: Total Perceived Ease of Use

Table 7. 12 Regression Model Summary (TPEOU)

According to ANOVA (table 7.13) both the *F*-ratio values for model 1 (F = 9.667, $p <$ 0.003), and for model 2 (F = 5.729, p < 0.005) are significant and unlikely to have happened by chance. The values of *F* are greater than 1 in both the models. This means that the improvement due to the regression model is greater than inaccuracy within the model. Therefore, the ability to predict the outcome variable will be significantly improved by the model, and the model is a significant fit of the data overall due to the significant F-ratio (significance value is less than 0.05).

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.319	1	3.319	9.667	.003(a)
	Residual	22.317	65	.343		
	Total	25.636	66			
2	Regression	3.893	2	1.946	5.729	.005(b)
	Residual	21.743	64	.340		
	Total	25.636	66			

(a) Predictors: (Constant), Total System Quality
(b) Predictors: (Constant), Total System Quality, Total Self Efficacy
Dependent Variable: Total Perceived Ease of Use

Table 7. 13 ANOVA (TPEOU)

7.5.2.3 Model Parameters

According to table 7.14:

- The b-value for TSQ (0.587) indicates that as TSQ increases by one unit, TPEOU increases by 0.587 units provided that the effect of TSE is held constant. The associated standard error with TSQ shows that this value would vary across different samples by 0.184.
- The b-value for TSE (0.121) indicates that as TSE increases by one unit, TPEOU increases by 0.121 units provided that the effect of TSQ is held constant. The associated standard error with TSE shows that this value would vary across different samples by 0.093.
- The t-test results for this model indicate that the TSQ ($t = 3.185, p < 0.002$) is a significant predictor of TPEOU, while TSE ($t = 1.300, p < 0.198$) is not a significant predictor of TPEOU. Therefore, TSE has no impact on the TPEOU.

Table 7.14 shows that the TSQ, with β value of 0.367, has 36.7% unique contribution in explaining TPEOU, when the variance explained by the TSE is controlled. The TSE with β value of 0.150 has less contribution with 15.0%. Table 7.14 also reveals that TSQ with a significance value of 0.002 making a unique, and statistically significant, contribution to the prediction of the TPEOU scores, but the contribution of TSE with significance value of 0.198 is not significant. This may be due to some degrees of overlap between TSQ and TSE.

The confidence interval for TSQ is between 0.219 and 0.955, which is relatively narrow and does not cross zero. Confidence interval for TSE is between -0.065 and 0.308, which is narrow but it does cross zero. This indicates that only the parameters for TSQ are significant, and it has a positive relationship, but the parameters for TSE are not significant and it has a negative relationship.

The zero-order correlation for TSQ is 0.360 and for TSE is 0.132. These values correspond to the same values of the Pearson correlation coefficients in table 7.11. Table 7.14 indicates that TSQ (with part correlation coefficients of 0.367), and TSE (with part correlation coefficients of 0.150) each uniquely explain 13.5% (0.367^2), and 2.3% (0.150^2) of the variance in TPEOU scores, respectively, when the effects of the other predictors on the outcome are controlled.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Part	Tolerance	VIF
1	(Constant)	1.698	.628		2.704	.009	.444	2.952				
	Total System Quality	.575	.185	.360	3.109	.003	.206	.945	.360	.360	1.000	1.000
2	(Constant)	1.270	.706		1.799	.077	-.140	2.681				
	Total System Quality	.587	.184	.367	3.185	.002	.219	.955	.360	.367	.998	1.002
	Total Self Efficacy	.121	.093	.150	1.300	.198	-.065	.308	.132	.150	.998	1.002

Dependent Variable: Total Perceived Ease of Use

Table 7. 14 Coefficients of the regression model (TPEOU)

7.5.2.4 Multicollinearity Assessment

According to table 7.14, the lowest tolerance value is 0.998, which is more than 0.10. The highest VIF value is 1.002, which is well below 10. These values of tolerance and VIF confirm that the problem of multicollinearity is not an issue for this model, and therefore, the variability of TPEOU is properly explained by the TSQ and TSE.

In addition, the collinearity diagnostics data, in table 7.15, shows that the eigenvalues of the scales are between 2.95 and 0.006, which are fairly close. Condition index of the final dimension is 22.32, which is not very large compared to other dimensions. The variance proportions show that for TSQ 92% of the variance of the regression coefficient is associated with eigenvalue number 3, and for TSE 89% of the variance of the regression coefficient is associated with eigenvalue number 2, which is a sign of no multicollinearity.

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	Total System Quality	Total Self Efficacy
1	1	1.993	1.000	.00	.00	
	2	.007	17.488	1.00	1.00	
2	1	2.954	1.000	.00	.00	.01
	2	.040	8.614	.02	.08	.89
	3	.006	22.320	.97	.92	.11

Dependent Variable: Total Perceived Ease of Use

Table 7. 15 Collinearity Diagnostics (TPEOU)

7.5.2.5 Casewise Diagnostics

Table 7.16 indicates that out of 116 cases only 2 cases (less than 2%) are with the standardised residuals outside the limits of ± 2. Therefore, our sample appears to conform to the expectation of a reasonably accurate model.

Case Number	Std. Residual	Total Perceived Ease of Use	Predicted Value	Residual
49	-2.364	2.50	3.8781	-1.37812
67	-2.809	2.25	3.8875	-1.63754

Dependent Variable: Total Perceived Ease of Use

Table 7. 16 Casewise Diagnostics (TPEOU)

7.5.3 AIS User Satisfaction

7.5.3.1 Correlations

The Pearson correlation coefficients in the correlation matrix (table 7.17) for both the scales of TPU and TPEOU are above 0.3, ($R = 0.543$, $p < 0.001$, and $R = 0.311$, $p < 0.001$, respectively) which show important correlations with TAISUS. However, TPU has a larger positive correlation with TAISUS, than TPEOU. Bivariate correlation between TPU and TPEOU is 0.407 and bellow maximum limit of 0.9. One-tailed significance values indicate that positive correlations are significant ($p < 0.001$) in both the cases, between TPU and TAISUS, and between TPEOU and TAISUS (see table 7.17). The number of cases is also given in the same table.

		Total AIS User Satisfaction	Total Perceived Usefulness	Total Perceived Ease of Use
Pearson Correlation	Total AIS User Satisfaction	1.000	.543	.311
	Total Perceived Usefulness	.543	1.000	.407
	Total Perceived Ease of Use	.311	.407	1.000
Sig. (1-tailed)	Total AIS User Satisfaction	.	.000	.000
	Total Perceived Usefulness	.000	.	.000
	Total Perceived Ease of Use	.000	.000	.
N	Total AIS User Satisfaction	116	114	116
	Total Perceived Usefulness	114	114	114
	Total Perceived Ease of Use	116	114	116

Table 7. 17 Correlation Matrix for Regression Analysis (TAISUS)

7.5.3.2 Evaluation

Table 7.18 shows that 30.4% ($R^2 = 0.304$) of the variance in TAISUS is explained by the model. This includes the TPU ($R^2 = 0.294$), and TPEOU ($R^2 = 0.010$). Adjusted R^2 is 0.292, which shows shrinkage of 1.2% (shrinkage = $(.304-.292)\times 100$). This means that the percentage of the variance explained by the model is not much away from the corrected estimate of the true population. TPU causes R^2 to change from zero to 0.294. This change in the amount of variance explained gives rise to a significant *F*-ratio of 46.751 with a probability of less than 0.001. Addition of TPEOU causes R^2 to increase by 0.010. This change in the amount of variance that it can explain gives rise to an *F*-ratio of 1.5430, which is not significant with a probability of less than 0.217.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.543(a)	.294	.288	.61460
2	.552(b)	.304	.292	.61312

(a) Predictors: (Constant), Total Perceived Usefulness
(b) Predictors: (Constant), Total Perceived Usefulness, Total Perceived Ease of Use
Dependent Variable: Total AIS User Satisfaction

Table 7. 18 Regression Model Summary (TAISUS)

According to ANOVA (table 7.19), both the *F*-ratio for model 1 ($F = 46.751$), and *F*-ratio for model 2 ($F = 24.261$) are significant ($p < 0.001$ for both the cases), and therefore, it is unlikely to have happened by chance. These results show that both models 1 (with TPU as the IV) and 2 (with addition of TPEOU) are significant fit of the data overall, and they significantly improve our ability to predict the outcome variable, because the *F*-ratios are significant (probability less than 0.05).

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	17.660	1	17.660	46.751	.000(a)
	Residual	42.307	112	.378		
	Total	59.966	113			
2	Regression	18.240	2	9.120	24.261	.000(b)
	Residual	41.726	111	.376		
	Total	59.966	113			

(a) Predictors: (Constant), Total Perceived Usefulness
(b) Predictors: (Constant), Total Perceived Usefulness, Total Perceived Ease of Use
Dependent Variable: Total AIS User Satisfaction

Table 7. 19 ANOVA (TAISUS)

7.5.3.3 Model Parameters

According to table 7.20:

- The *b*-value for TPU (0.685) indicates that as TPU increases by one unit, TAISUS increases by 0.685 units provided that the effect of TPEOU is held constant. This value would vary across different samples by 0.119 (associated standard error with TPU).
- The *b*-value for TPEOU (0.126) indicates that as TPEOU increases by one unit, TPU increases by only 0.126 units provided that the effect of TPU is held constant. This value would vary across different samples by 0.101 (associated standard error with TSE).
- The t-test results for this model indicate that the TPU ($t = 5.754, p < 0.001$), is a significant predictor of TAISUS, but TPEOU ($t = 1.242, p < 0.217$) is not a significant predictors of TAISUS.

The TPU with β value of 49.9% makes a stronger unique contribution to explaining TAISUS, when the variance explained by the TPEOU is controlled. The standardised beta value for TPEOU is only showing a contribution of 10.8%. According to table 7.20, TPU with a significance value of 0.001 is making a unique significant contribution to predict TAISUS scores, but TPEOU with significance value of 0.217 does not make such a unique and statistically significant contribution to TAISUS scores prediction. This may be due to some overlap between TPU and TPEOU.

The confidence interval for TPU is between 0.449 and 0.921, which is relatively narrow and does not cross zero. The range of confidence interval for TPEOU is between -0.75 and 0.325, which despite being narrow, crosses zero. These confidence intervals indicate that the parameters for TPU are significant, but the parameters for TPEOU are not significant and they do not have positive relationships.

The zero-order correlations (TPU = 0.543, and TPEOU = 0.311) are again the Pearson correlation coefficients that correspond to the same values in correlation table 7.17. The part correlation coefficients for TPU (0.456) and for TPEOU (0.098), in table 7.20, indicate that TPU uniquely explains about 21% (0.456^2) and TPEOU could only uniquely explain less than 1% (0.098^2) of the variance in TAISUS scores, when the effect from the other variable on the outcome is controlled.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Part	Tolerance	VIF
1	(Constant)	.850	.403		2.110	.037	.052	1.648				
	Total Perceived Usefulness	.746	.109	.543	6.837	.000	.530	.962	.543	.543	1.000	1.000
2	(Constant)	.612	.445		1.376	.172	-.270	1.494				
	Total Perceived Usefulness	.685	.119	.499	5.754	.000	.449	.921	.543	.456	.834	1.199
	Total Perceived Ease of Use	.126	.101	.108	1.242	.217	-.075	.327	.311	.098	.834	1.199

Dependent Variable: Total AIS User Satisfaction

Table 7. 20 Coefficients of the regression model (TAISUS)

7.5.3.4 Multicollinearity Assessment

The lowest tolerance value in table 7.20 is 0.834 (more than 0.10), and the highest VIF value is 1.199 (well below 10). These show that multicollinearity is not a problem for this model.

In addition, table 7.21 shows that the eigenvalues of the scales are between 2.974 and 0.010, which are reasonably close. Condition index of the final dimension is 17.026, which in comparison to other dimensions is not very large. The variance proportions show that the highest percentage (80%) of TPU variance proportion is associated with eigenvalue number 3, and the highest percentage (100%) of TPEOU variance proportion is associated with eigenvalue number 2. These data indicate no multicollinearity.

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	Total Perceived Usefulness	Total Perceived Ease of Use
1	1	1.990	1.000	.01	.01	
	2	.010	13.922	.99	.99	
2	1	2.974	1.000	.00	.00	.00
	2	.016	13.726	.15	.20	1.00
	3	.010	17.026	.84	.80	.00

Dependent Variable: Total AIS User Satisfaction

Table 7. 21 Collinearity Diagnostics (TAISUS)

7.5.3.5 Casewise Diagnostics

Table 7.22 indicates that out of 116 cases only 3 cases (less than 3%) are with standardised residuals outside the limits of (± 2). This means that about 97% of the cases are with standardised residuals within the limits, and therefore, our sample is reasonably accurate.

Case Number	Std. Residual	Total AIS User Satisfaction	Predicted Value	Residual
41	-2.501	2.25	3.7832	-1.53315
54	2.250	5.00	3.6202	1.37980
97	-2.691	2.75	4.4000	-1.64999

Dependent Variable: Total AIS User Satisfaction

Table 7. 22 Casewise Diagnostics (TAISUS)

7.6 Discussion and Conclusion

7.6.1 Internal Consistency

Preliminary data analysis showed that scores of the grouped questionnaire items were normally distributed. Five items with low reliability dropped from the analysis. The remaining 34 items included in the questionnaire, for the final analysis according to AIS user satisfaction model, had a reliable total scale with an overall Cronbach's alpha of 0.804. Reliability figures for total score for the items included in model variables were 0.739 for system quality, 0.711 for system self-efficacy, 0.769 for perceived usefulness, 0.737 for perceived ease of use, and 0.704 for AIS user satisfaction, which are within an acceptable limit.

7.6.2 Implications of the Model

Pearson correlation coefficients (R) are used to test the relationship between the attitudinal forming IVs of system quality and self-efficacy, and the sample's perceived usefulness and ease of use of AIS. The results are as follows:

SQ: PU (R = 0.504, $P < 0.001$, 1-tailed)
SE: PU (R = 0.380, $P < 0.001$, 1-tailed)
SQ: PEOU (R = 0.360, $P < 0.001$, 1-tailed)
SE: PEOU (R = 0.132, $P < 0.140$, 1-tailed)

Results show that both the system quality and self-efficacy have a statistically significant and positive relationship with perceived usefulness. About perceived ease of use, only system quality has a significantly positive relationship with perceived ease of use, but the positive relationship of self-efficacy with perceived ease of use is not statistically significant ($P > 0.05$). The strongest relationship is between SQ and PU with R = 0.504, and the weakest relationship is between SE and PEOU with R = 0.132. The relationships show that the system quality is strongly related with AIS perceived usefulness and its perceived ease of use.

The results of Pearson correlation coefficients (R) for perceptual variables of perceived usefulness, perceived ease of use, and AIS user satisfaction are as follows:

PEOU: PU (R = 0.407, $P < 0.001$, 1-tailed)
PU: AISUS (R = 0.543, $P < 0.001$, 1-tailed)
PEOU: AISUS (R = 0.311, $P < 0.001$, 1-tailed)

The above correlation coefficients show positive and statistically significant relationships between the PU, PEOU and AISUS. It also can be seen that there is a relatively strong bivariate relationship between PU and PEOU. The relationship between PU and AISUS is stronger than the relationship between PEOU and AISUS. This means that if the AIS users perceive that the implemented AIS technology is useful and easy to use then they are likely to be satisfied with the system, and therefore, they would prefer to use the AIS for navigational activities.

Path analysis of the model is drawn in figure 7.6 to show the importance of different variables in predicting dependent variable in AIS User Satisfaction Model. The diagram includes standardised beta coefficients (β), which shows the strength of influence of each predictor variable on the criterion variable according to the measurement constructs of the model.

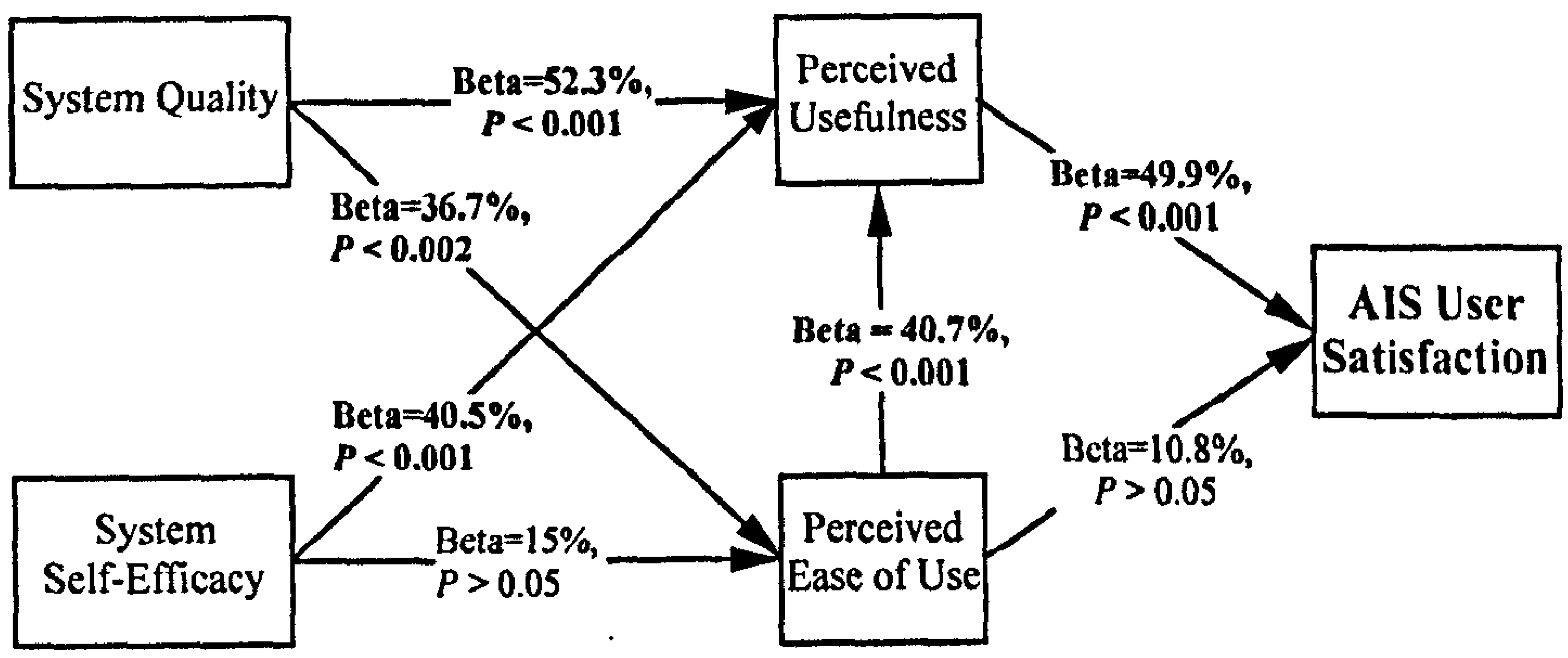

Figure 7. 6 Path Analysis of the AIS Satisfaction Model

The diagram demonstrates that:

- Unique influence of each one of the independent variables on predicting perceived usefulness, when variance explained by the other is controlled, was 52.3% for AIS system quality and 40.5% for navigators' self-efficacy. This unique importance of the variables in predicting AIS perceived usefulness were both significant with a probability of 0.001 and without any overlap between them.
- Unique influence of the each one of the independent variables on predicting perceived ease of use, when variance explained by other is controlled, was 36.7% for AIS system quality and 15.0% for navigators' self-efficacy. The unique importance of the system quality in predicting AIS perceived ease of use was significant with a probability of 0.002, but this unique importance was not significant for navigators' self-efficacy (P = 0.195, which is more than 0.05). There is a possibility of overlap between system quality and self-efficacy.
- Unique influence of each one of the independent variables on predicting perceived AIS user satisfaction, when variance explained by other is controlled, was 49.9% for AIS perceived usefulness and 10.8% for AIS perceived ease of use. The unique importance of the perceived usefulness in predicting AIS user satisfaction was significant with a probability of 0.001, but the unique importance of perceived ease of use was not significant (P = 0.217, which is

more than 0.05). Some degrees of overlap might exist between perceived usefulness and perceived ease of use.

Confidence intervals show that the parameters for AIS system quality and navigators' self-efficacy in predicting perceived usefulness were significant with positive relationships. According to part correlation values, AIS system quality uniquely explained 27%, and navigators' self-efficacy 16% of the variance in perceived usefulness of the AIS for navigation. A shrinkage of 1.9% shows that difference in percentage of the variance in AIS perceived usefulness explained by the model and the corrected estimate of the true population was very low. The result showed that the model was a good fit and it significantly improves prediction of perceived usefulness.

Parameters for AIS system quality in predicting perceived ease of use was significant with positive relationships but parameters for self-efficacy in predicting perceived ease of use was not significant and with negative relationships. AIS system quality uniquely explained 13.5%, and navigators' self-efficacy 2.3% of the variance in perceived ease of use of the AIS for navigation. The difference in percentage of the variance in AIS perceived ease of use explained by the model and the corrected estimate of the true population was 2.7%. The result also showed that the model was a significant fit of the data overall for perceived ease of use.

Parameters for AIS perceived usefulness in predicting AIS user satisfaction was significant with positive relationships but parameters for perceived ease of use in predicting AIS user satisfaction was not significant and with negative relationships. AIS perceived usefulness uniquely explained 21%, and AIS perceived ease of use uniquely explained less than 1% of the variance in perceived AIS user satisfaction for marine navigation. The difference in percentage of the variance in AIS perceived AIS user satisfaction explained by the model and the corrected estimate of the true population was 1.2%. The result also showed that the model was a significant fit of the data overall for perceived ease of use. The model showed significant goodness-of-fit in predicting the perceived AIS user satisfaction.

It was also observed that the problem of multicollinearity due to the fact that perfect or strong correlation between independent variables did not exist in the model. Therefore, the regression coefficients were uniquely estimated in the model. Casewise diagnostics showed that the regression models were reasonably accurate as the maximum percentage of the cases with standardised residuals outside the limits was 3%. Therefore, there was not a big difference between the outcome of the sample and the outcome of the model.

The path analysis (figure 7.6) showed that the there is not a significant unique influence of the navigators' AIS self-efficacy on predicting perceived ease of use. It is also revealed that the unique influence of perceived ease of use is not significant on the AIS user satisfaction. However, a unique influence from navigators' self-efficacy on the perceived usefulness was observed in the model, which was not considered in the original model. Therefore, the AIS user satisfaction could be modified as shown in figure 7.7.

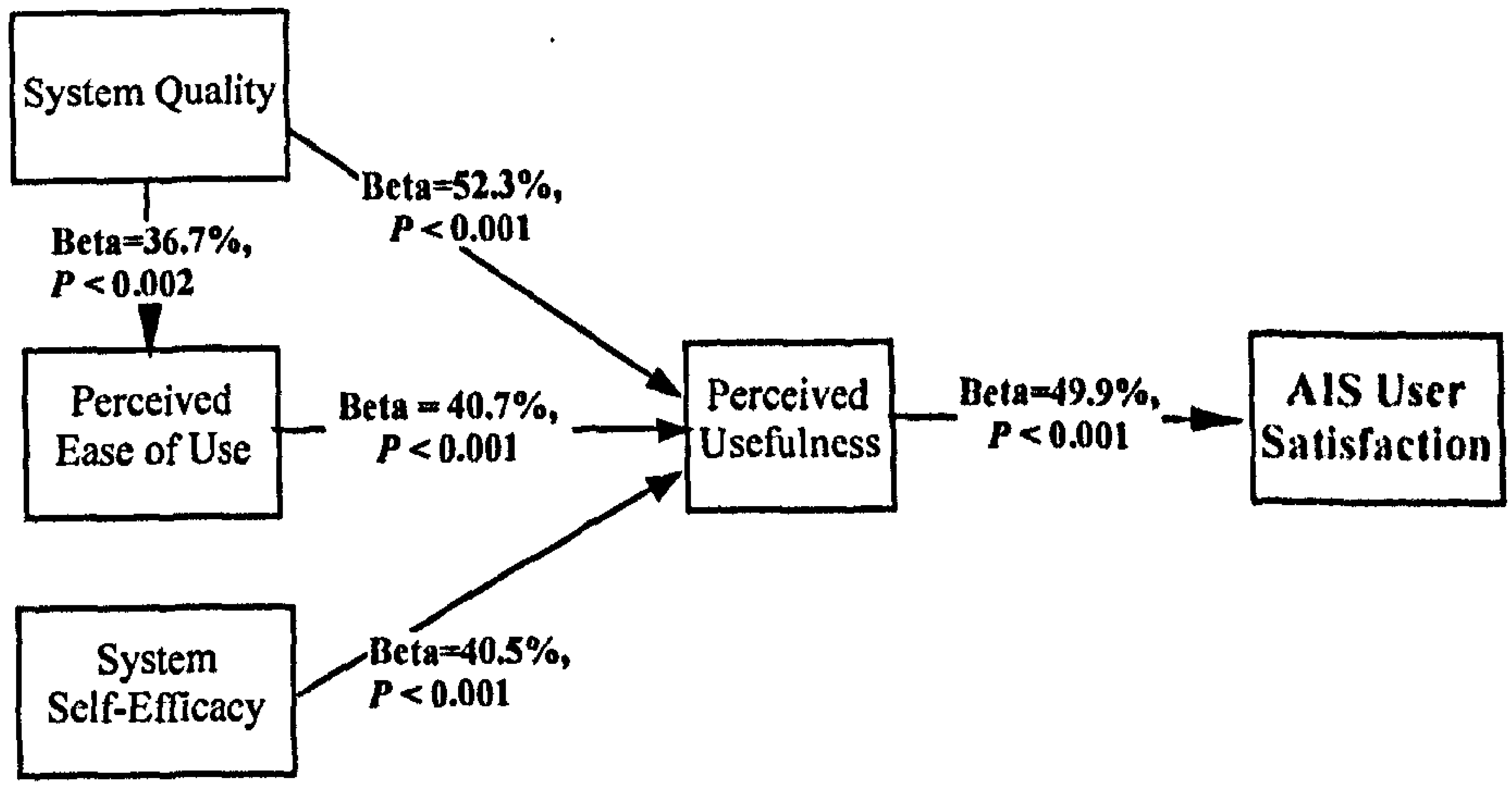

Figure 7. 7 Modified AIS User Satisfaction Model

The findings of the AIS data studies, in chapter 4, showed a number of cases for unreliability of AIS data. Therefore, it could not be wholly trusted by navigators, which consequently could lead to further deterioration in AIS usage and data quality. The improved model for measuring AIS User Satisfaction (figure 7.7) derived in this chapter is of benefit in understanding the user perception of AIS technology. This model will help the construction of future surveys of AIS User Satisfaction and usage, as it will improve reliability and accuracy of the results.

The research has demonstrated that such models can be implemented in a seagoing context. Such research is best carried out before or at an early stage of implementation and it is suggested that it is not too late for AIS implementation to benefit from the use of such models. This User Satisfaction model may also be of benefit for measuring user satisfaction in the implementation of similar technologies in a mandatory environment.

Similar models have been successfully used to design implementation plans and strategies in other industries, particularly those relating to IT.

7.7 Summary

AIS user satisfaction model was used to find out reliability and validity of the AIS questionnaire measurement scale. The questionnaire items were clustered to match the AIS user satisfaction model. SPSS version 14 was used to carry out data analysis. Internal consistency of the measurement scale was examined through Cronbach's alpha coefficient. As the scores were normally distributed, Multiple Regression was used to explore the relationships between different constructed variables. After dropping five items with low Cronbach's alpha from the AIS questionnaire, the reliability coefficients for the remaining items showed that the measurement scale for items in total questionnaire and measurement for five variables were reliable.

The results for the variables' relationship and amount of variance in scores for AIS users satisfaction that can be explained by the measurement constructs showed that each of the AIS system quality and navigator's self efficacy had a significantly unique influence on predicting perceived usefulness of AIS, when variance explained by other one is controlled. However, in predicting perceived ease of use of AIS there was possibility of overlap between predictors as it was only AIS system quality that had such a significantly unique influence, and unique influence of navigator's self-efficacy was not significant. The results also showed that only the unique influence of perceived usefulness of the AIS on predicting AIS user satisfaction was significant, but not the influence of perceived ease of use of the AIS.

Importantly, it was found that there was a significantly unique influence of 40.5%, ($P<0.001$) from navigators' self-efficacy on predicting perceived usefulness, which was not included in the original model. Therefore, a modified AIS user satisfaction model was suggested.

Chapter 8

Discussion

8.1 Introduction

This thesis has evaluated the impact of AIS technology on the safety of marine navigation. The main objectives of this research were to examine the accuracy of AIS data fields that are inputted manually, and to measure the extent of use of AIS by navigators. The objectives were addressed by summarising failures at different levels of the AIS structure, and suggesting remedial actions in order to reduce the likelihood of errors and thus minimise accident opportunities. Further, the objectives were addressed by adopting a theoretical model of human behaviour for measuring AIS user satisfaction and modification of the model for evaluation of the AIS questionnaire survey.

A system's approach of human error qualitative analysis, based on an application of Reason's (1990, 1997) "Swiss Cheese" model, showed a number of problems and human errors associated with AIS information. These problems are indications of failures (active or latent) at different system levels. Further, the results of the questionnaire survey showed that some aspects of the AIS and competency level of its users require more attention and improvement. These issues have major implications for the success of AIS in improving and enhancing the safety of marine navigation. The modified AIS user satisfaction model demonstrates how it could be used to measure the satisfaction of navigators using AIS technology for anti-collision and other navigation operations, in a mandatory environment.

This chapter considers the contribution of this research to the application and use of AIS technology and improvement of safety of marine navigation. It reviews the research objectives stated in chapter 1, and the way in which these objectives have been addressed in section 8.2. The main conclusions of this research will be discussed in section 8.3. Section 8.4 discusses limitations and areas for further research. Section 8.5 will state final remarks of this research.

8.2 Reviewing the Objectives

This research has examined how AIS technology as a navigational aid has affected the safety of marine navigation. It has identified ways in which such safety can be enhanced. The research included the following stages:

- *Overview of AIS technology.*

The current situation of AIS, satisfaction of navigators with AIS and thus the actual extent of use of the technology in the navigation operation was examined. A detailed overview of AIS technology and its application in marine navigation. to further expand reader's practical understanding of the AIS technology and what it does, was also presented.

- *Accuracy of AIS information.*

Examination of the performance and accuracy of the information transmitted by AIS to identify the major issues associated with its application in navigation operations especially for anti-collision activities was carried out. This was done following an extensive literature review, which identified the safety issues involved in AIS implementation for marine navigation. The literature review examined the reasons underlying the use of new technology in the marine industry with a particular consideration given to the application of AIS as an anti-collision aid. The review also identified many issues regarding important aspects of AIS application for its intended purposes, and included findings of some of the pre-implementation pilot studies. The safety of marine navigation and human aspects of new technology were also investigated during the review in order to examine their possible constitution to marine accidents. The review adopted a systems approach to the issues of human performance and error in regard to the AIS that can have an impact on safety of marine navigation. The extent of such failures was explored and examined through the AIS data studies in chapter 4.

- *Navigator's views and satisfaction with AIS.*

Evaluation of navigators' performance in AIS usage for anti-collision operation on-board ships was carried out to identify and validate end user problems and required improvement actions. This was addressed through the analysis of questionnaire data concerning navigators' views about different features and aspects of AIS. The impact of demographic factors between subsets of population, including navigator's training, type of training, certificate of competency, total sea experience, and type of AIS display available, was considered in chapter 5.

- *A model of user satisfaction with AIS.*

Adapting a suitable model for identifying a reliable and valid scale for measurement of satisfaction that can be used as a framework for examining end user performance and usage of AIS, and possibly other similar technologies in future. This was carried out through discussing a number of commonly used theories and models of human attitude and behaviour, and adopting the AIS User Satisfaction Model as the basis for assessing navigators' satisfaction with AIS, in chapter 6 of this thesis. Reliability and validity of the measurement scale of the questionnaire survey along with application of the model for the study of human usage behaviour in relation to AIS are shown in chapter 7 of this research. Chapter 7 also suggested some modification to the model and showed that the modified model has implications for studying human acceptance of similar new technologies in mandatory environments.

8.3 Discussion of the Main Conclusions

The conclusions of this research have been broken down into the following 4 subsections.

- *Navigation Safety and risk management.*
- *AIS and levels of human failures.*
- *Navigators' views of the AIS as an anti-collision aid.*
- *Reliability and validity of the AIS survey.*

8.3.1 Navigation Safety and Risk Management

Accident investigation results have indicated that the contribution of human error to maritime accidents has increased over a ten-year period from 1991 to 2001 (Baker and Seah, 2004). Most of these accidents resulted from avoidable human errors. Safety is an important aspect of a navigation system with many persons involved, individually or jointly as an organisation, at different levels. Official control and management of marine safety is carried out by different actions of these stakeholders. The actions include navigation activities performed by frontline operators, rules and regulations, and procedures and instructions. The socio-technical system of safety and risk management in marine navigation, adapted from Rasmussen (1997, 2000), is a hierarchical framework showing various elements at different levels that can contribute to safety of the system and risk management in marine navigation. The framework comprises at least 8 layers, depicting the involvement of individuals and organisations in marine navigation. They include the following:

1. *At the lowest level- behaviours associated with the navigation process.*

2. *At second level- activities of the individual mariners directly engaged in the navigation operation.*
3. *At third level- activities of senior officers that supervise junior officers.*
4. *At forth level- activities of shipping companies.*
5. *At fifth level- activities of designers in designing equipment, interfaces, and operational procedures.*
6. *At sixth level- activities of maritime associations and organisations (i.e., classification societies, etc.) responsible for setting up industrial and professional rules and regulations.*
7. *At seventh level- national regulators responsible for setting up local regulations, supervision and enforcement of rules and regulations.*
8. *At the highest level- International regulators (i.e., IMO, ILO, etc.) setting up regulations, and monitoring of navigation at international levels.*

Many challenges from dynamic, technical, socio-political, financial and physical environment, technological changes, organisational structures and communications, and public opinion imposed upon the above constituents to influence the safety of the system. Such forces may impose additional pressure on the mariner's responsibilities and workloads (physically and/or mentally). They may lead to a deterioration of system defences at different levels due to errors and violations of regulations and procedures. The proper interaction of the system elements with each other and with forces external to the system will play an important role in safety and risk management in marine navigation. Proper human factors research could improve detection and control of undesirable variability in human performance and, consequently, reduce chances of errors that could lead to unexpected and unwanted disasters.

8.3.2 AIS and Levels of Human Failures

Using a system's approach, possible failures (active or latent) at different levels of the AIS utilisation system were explored in this thesis. The failures are based on application of the "Swiss Cheese" model (Reason, 1990, 1997) of human error. The original model was adopted to indicate how failures at various stages of the AIS utilisation system might allow a problem to pass through the weaknesses in the system's various defence layers that jeopardise safety of navigation with potentially serious consequences. The model highlighted human failures that can happen at different levels. The main defence layers that are considered important in the AIS system include the following:

- *Correct data input and updating data by AIS operators.*
- *AIS operator's competency and management of operation.*
- *Worldwide defined standards for AIS design.*
- *Sufficient regulations on supervision of AIS information and training.*

Problems identified in the AIS data studies, in the course of this research, showed human failures at different levels. The failures include:

- *Frontline operator failures.*
- *Installation failures.*
- *Training and management failures.*
- *Regulatory failures.*
- *Violations.*

The findings of the AIS data studies show that the data provided by AIS are not reliable in many cases due to inaccuracies highlighted in this thesis. Therefore, navigators cannot wholly trust the AIS equipment. Such distrust could lead to further deterioration of AIS use.

Currently, there are some differences in the format and terminology expected for data options in AIS equipment made by different manufacturers. The list of options available should be standardised according to different types and navigational status of the ships (as defined in the IRPCS).

Some peculiarities were found for some categories of vessels, similar to some of those for use of lights and shapes. AIS training similar to those for understanding the use of lights and shapes needs to be introduced. This training, in addition to reducing confusion in AIS use, would encourage the use of the narrow definition of the expression of 'sailing' in the context of the AIS message and in the IRPSC.

There is a need for clarification of the regulations about the use of safety text messaging, available in AIS equipment, for anti-collision by IMO. At present, there is not a clear guideline about whether such a facility in AIS equipment could, or should be used for anti-collision communication between vessels. In the case of endorsement of this method of collision avoidance, inclusion of an effective audio-visual warning signal to notify the receipt of safety text messages would be helpful. There is a need for further training for navigators on these subjects.

Many of the input errors in the field of ship's navigational status, observed during this research, were due to memory slips or omissions in the execution of actions by navigators. Self-checking mechanisms and links to other navigational equipment could easily be added to the AIS equipment to detect such obvious inconsistencies. For example, an interlink mechanism between speed and navigational status of the ship. Errors of this type could be prevented or minimised by alerting navigators to erroneous conditions in the early stages of their development. Extension of the use of warning signals is also suggested to include a link with the ship's navigational light system. Such a link could initiate a signal to warn the navigator in case of any conflict between the actual navigational status of the ship and status shown in AIS data.

The integrity of the AIS autonomous data transmission and reception depends upon many manual inputs, and the current critical unreliability of the AIS data could mitigate use of the AIS as a trustworthy navigational aid in anti-collision operation. Therefore, proper supervision, surveillance of information accuracy, and regulations enforcing such activities by competent authorities are needed to improve AIS effectiveness in navigation operation, and thus enhance the safety of navigation.

There is lack of knowledge and skill on the use, and appreciation of capabilities and limitations of AIS by navigators and AIS operators ashore. This is expected to reduce the level of confidence of the navigators in use of AIS equipment in normal anti-collision performance. Therefore, an international mandatory regime for immediate application of viable training course, such as the Model Course 1.34, recommended by IMO in 2006, is suggested.

The failure to update some optional fields of AIS information, such as destination and ETA in most cases, shows that they are not considered important by the mariners. Therefore, more encouragement of the mariners to maintain the data showing on their equipment will improve the data accuracy and also give them more confidence in data broadcasted from other ships.

8.3.3 Navigators Views of the AIS as an Anti-Collision Aid

This section discusses some points of interest identified through the evaluation of navigators' perception during this research.

The AIS is generally perceived to be a useful navigational aid in improving overall safety of navigation by enhancing the navigators' capability and confidence in navigation operations. It also provides clearer and more continuous information than radar, which could overcome most of the radar limitations in shadow areas when used as a navigational aid in addition to radar technology. However, a possibility of disruption of the normal anti-collision operation that was perceived by navigators should be removed through appropriate bridge team training and management.

In general, the AIS equipment was considered to be easy to use for navigation operation, particularly for anti-collision purposes. The process of obtaining information from the equipment was considered to be clear and understandable. One observed difficulty in ease of use of AIS was the slow response of the equipment in data input, which should be solved through design improvement.

The display of AIS information is considered to be an important issue for AIS to achieve its implementation objectives. Most of the features and characteristics of the ways of displaying AIS information were felt to be satisfactory, except the required time for familiarisation with the way of extracting AIS information. This problem could be resolved by implementation of a proper training programme. A higher level of navigators' confidence was shown for the AIS display integrated with radar, in most of the cases, and a lower level of such confidence was shown for the display integrated with ECDIS.

One of the most worrying problems in AIS implementation that could have an adverse effect of the impact of AIS on safety of marine navigation is the level of training of navigators in the basic operation of the equipment. Only 19.1% of the navigators have completed such formal training. The problem of navigators' competency is even evident in perception of those who have had some training, since, 40% of them believed that they are sufficiently competent to safely use AIS in anti-collision operation. In addition, high uncertainty of the navigators about the need for AIS training, degree of difficulty of learning to operate AIS without such training, and uncertainty about many other aspects of AIS are worrying signs in use of AIS. This lack of confidence may be a symptom of insufficient use of the technology by navigators for navigation. A widely adopted training and education programme could improve navigators' competency and confidence levels in the use of AIS for navigation, and therefore, it would enhance the safety of navigation. Some anomalies in AIS use may still be seen in coming years, until universal execution of such recommended trainings.

The statistically significant differences between the mean response scores for navigators who had AIS training and those who did not have AIS training indicate the importance of training in success of AIS implementation. Those who experienced AIS training have a higher belief about the possibility of disruption of their responsibilities in anti-collision operation by AIS, and about difficulty in self-learning to operate AIS. This higher degree of belief was also significant in the perceived ease of use of AIS for anti-collision operation, the value of the AIS display in the navigators' performance, sufficiency of their AIS training for safe conduct of anti-collision tasks, and the perceived overall decrease in VHF traffic congestion. These significant differences between the trained and the untrained navigators show the impact of AIS training on enhanced utilisation of the technology. They further indicate disclosure of some hidden features of the technology, appropriate familiarisation with different information, functions and features of the equipment and different types of display, and higher efficiency and extent of use by navigators as a result of training.

Theoretical training was shown to have the highest, and practical on the job training the lowest, potential for improving safety of navigation by AIS.

Significant differences were observed in the attitude of navigators dependent upon the certificate of competency held by them. These differences suggest that, in most cases, the second officer (as the most junior officer) had the highest, and master mariner (as the most senior officer) had the lowest optimism level about many aspects of the use of AIS for navigation. For example, junior officers had the highest level of belief about enhancement of situational awareness, increased efficiency, extent of control, ease of use, clarity and understandable presentation of information, lack of unnecessary information on display, and ease of getting data in and out of the AIS. On the contrary, senior officers had the lowest level of such belief about enhancement of situational awareness, increased efficiency, extent of control, ease of use, improvement of safety of ship and overall safety of navigation by AIS. This could be due to the more recent training of the second officer, which could have included AIS training and a higher extent of use of AIS due to his more frequent presence on the bridge than the master mariner.

AIS seems to reduce overall VHF calls at sea, but the extent of such calls for anti-collision agreements between ships and possible violation of IRPCS that may arise as a result of such agreements needs further investigation.

The possibility of misuse of AIS and its vulnerability due to jamming was argued to be security disadvantages that could affect the reliability of AIS use. The results of the questionnaire survey showed a lack of navigators' knowledge in this respect, which could be due to inadequate training of navigators. In addition, increased risk of piracy in certain areas, and transmitting erroneous information by AIS, are observed to be fundamental disadvantages.

8.3.4 Reliability and Validity of the AIS Survey

The adapted AIS user satisfaction model was used to evaluate reliability and validity of the measurement scale. Apart from five items with low reliability, which were dropped from the analysis, the remaining 34 items included in the questionnaire survey were reliable in their total scale and their grouped items scale.

The test of relationship between variables in the AIS User Satisfaction Model showed that both the system quality and self-efficacy are significantly correlated with AIS perceived usefulness. The system quality has a stronger correlation than the self-efficacy. However, in the case of AIS perceived ease of use, only the system quality is positively correlated, and not the self-efficacy. In other words, System quality is strongly correlated with both the perceived usefulness and ease of use of AIS technology, while self-efficacy is only correlated with perceived usefulness of the AIS technology and not with its perceived ease of use.

The results also showed that both the perceived usefulness and ease of use are correlated with AIS user satisfaction. However, the correlation of perceived usefulness with AIS user satisfaction is higher than perceived ease of use. There is also a significant positive correlation between perceived ease of use and perceived usefulness of the AIS.

It was observed that system quality uniquely predicts 52.3% of the variance in predicting perceived usefulness of AIS, when variance explained by self-efficacy is controlled. Self-efficacy alone will predicts 40.5% of perceived usefulness, when variance explained by system quality is controlled (this relation was not shown in the original model). These predicting abilities are both significant and without overlaps between them. Therefore, both the system quality and self-efficacy are influencing factors and should be considered in predicting the perceived usefulness of AIS.

In predicting the perceived ease of use of AIS, system quality uniquely predicts 36.7% of its variance, when variance explained by self-efficacy is controlled. Self-efficacy predicts 15% of such variance, when variance explained by system quality is controlled. The unique prediction of perceived ease of use of AIS by system quality is statistically significance but such unique predicting ability of self-efficacy is not significant. This insignificance predicting ability of self-efficacy suggests some degree of overlap between the two predictors. Therefore, only system quality is the influencing factor and should be considered in prediction of perceived ease of use of AIS.

In measurement of AIS user satisfaction, perceived usefulness uniquely predicts 49.9% of its variance, when variance by perceived ease of use is controlled. Perceived ease of use predicts only 10.8% of such variance, when variance explained by perceived usefulness is controlled. This unique predicting ability of perceived usefulness in measuring AIS user satisfaction is statistically significant but such predicting ability by perceived ease of use is not statistically significant. Despite the non-significant ability of perceived ease of use in predicting AIS user satisfaction, it significantly predicts 40.7% of the variance in perceived usefulness. Therefore, perceived usefulness of AIS is considered as the direct influencing factor, but perceived ease of use of AIS is considered as the indirect influencing factor in predicting AIS user satisfaction.

Parameters considered for both the system quality and the self-efficacy, in prediction of perceived usefulness, were significant with positive relationships. The variance in AIS perceived usefulness measured by the model has a small difference of 1.9% with the variance that could be explained by the corrected estimate of the true population. Therefore, the model is a significantly good fit and improves prediction of perceived usefulness of the AIS.

Parameters considered for system quality in prediction of perceived ease of use were significant with a positive relationship, but parameters selected for self-efficacy in such prediction were not significant. The small difference of 2.7% in measuring variance in ease of use between the model and the corrected estimate of the true population indicates that the model is also a significantly good fit for improved prediction of perceived ease of use of the AIS.

Parameters for perceived usefulness in prediction of AIS user satisfaction were also significant with a positive relationship, but parameters selected for perceived ease of use in such prediction were not significant. The difference in measurement of variance of AIS user satisfaction by perceived usefulness and perceived ease of use between the model and the corrected estimate of the true population is small (1.2%), therefore, it indicates that the model is also a significantly good fit for improved prediction of AIS user satisfaction.

The study also confirms that the outcome of the sample and outcome of the model are very close to each other, as the maximum percentage of the cases with standardised residuals outside the limits was 3%.

8.3.5 Modification to AIS User Satisfaction Model

According to the results from this research (shown in figure 8.1), the initial AIS user satisfaction model should be modified as follows:

1. System quality is considered as a predictor of both the perceived usefulness and perceived ease of use. ***This is same as the relationships that were considered in the original model.***
2. Self-efficacy is considered only as a predictor of the perceived usefulness and not as a predictor of the perceived ease of use. ***This is different from the relationship that was considered in the original model.*** In the original model, self-efficacy has been considered as a predictor of perceived ease of use but not as a predictor of perceived usefulness.
3. Perceived ease of use is considered only as an influencing factor in prediction of perceived usefulness and not as a predictor of AIS user satisfaction. ***This is different from the relationships that were considered in the original model.*** In the original model, not only perceived ease of use was considered as an influencing factor in prediction of perceived usefulness but also it has been considered as a predictor of AIS user satisfaction.
4. Perceived usefulness is alone to be considered as the main predictor of the AIS user satisfaction. ***This is different with the relationships that were considered in the original model.*** In the original model, both the perceived usefulness and ease of use were considered as main predictors of the AIS user satisfaction.

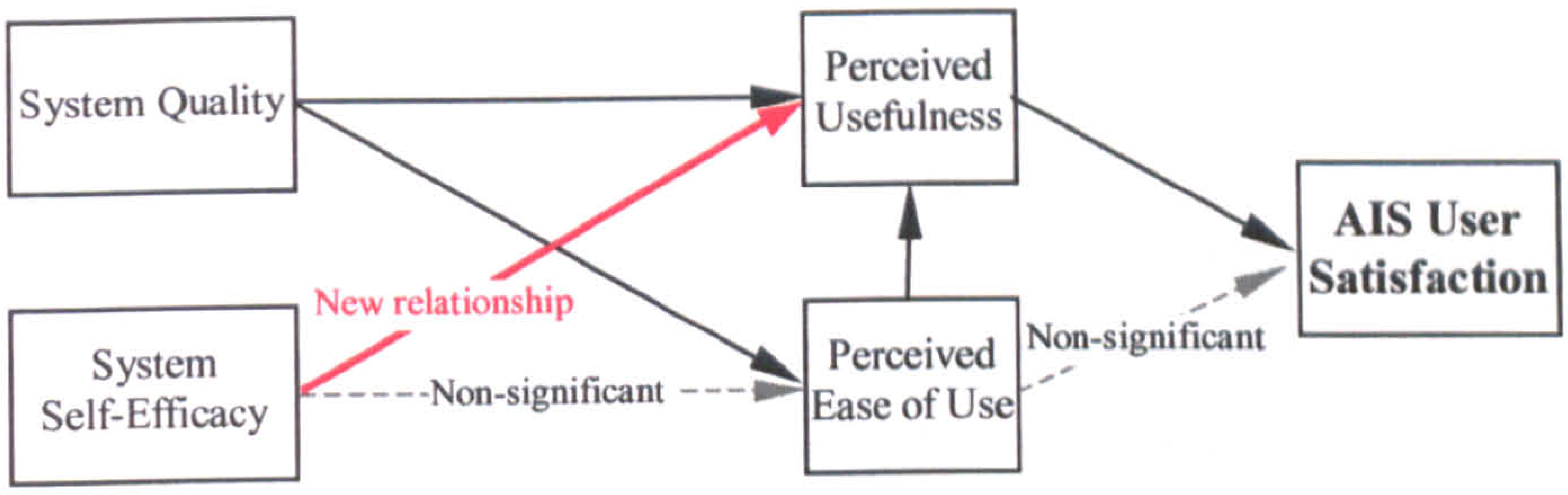

Figure 8. 1 Final relationships between variables in the AIS User Satisfaction Model

8.3.6 Recommendations for Improving AIS Success

The findings of both the AIS data studies and questionnaire analysis revealed that some improvements should be made to AIS equipment as well as the navigators training. An international mandatory training requirement for navigators is required to improve their level of knowledge and competency. This could enhance the safety of marine navigation by improving the quality of the navigators to perform in anti-collision operation and emergencies.

Moreover, the AIS could not be wholly trusted by navigators, because of unreliability of the AIS data, in many cases shown in this research, which consequently could lead to further deterioration in AIS reliance and usage. The improved model for measuring AIS User Satisfaction (figure 7.7) derived in chapter 7 is of benefit in understanding the user perception of AIS technology. This model will help the construction of future surveys of AIS User Satisfaction and usage, as it will improve reliability and accuracy of the results.

The research has demonstrated that such models can be implemented in a seagoing context. Such research is best carried out before or at an early stage of implementation and it is suggested that it is not too late for AIS implementation to benefit from the use of such models. This User Satisfaction model may also be of benefit for measuring user satisfaction in the implementation of similar technologies in a mandatory environment. Similar models have been successfully used to design implementation plans and strategies in other industries, particularly those relating to information technology.

8.4 Final Remarks

This thesis demonstrated a human factors approach to the mandatory implementation of AIS technology in marine navigation. The thesis mainly focused on the application of AIS to the ship's bridge, and studied the accuracy of the AIS information to detect the extent and level of human failures with suggestions made for remedial actions. It further examined navigators' perception about some of the main and important aspects of AIS in order to assess the extent of use of the technology on board. The thesis also evaluated the reliability and validity of the questionnaire items, clustered according to the adopted AIS user satisfaction model, in order to propose a suitable framework for measuring end user satisfaction with AIS and other similar navigation technologies. The human factors aspects of new technology, and in particular the AIS technology is an area that is relatively under-explored but it is becoming more important.

Advancement and innovation in electronics and computer technologies have resulted in a higher pace of technological change and advances in marine operations such as ships' navigation. The introduction of AIS, integrated bridge system, voyage data recorder, new generation of marine radars, ECDIS, etc. are examples of new technologies facilitating marine navigation. A probable impact of such technological changes and advances is that the scope for vigilance and information management by humans increases as a result of the complexity of the technologies and changes to working practices on the bridge. The safety of shipping and marine navigation relies on correct understanding and successful use of such new technologies by navigators. Therefore, human factors aspects of new technology are increasingly important and remain a pressing area for research.

Chapter 9

Conclusions

The aims of this research were to assess the impact of AIS in terms of how the technology has been accepted by navigators, and suggest further development in the use of AIS in order to improve the safety of marine navigation. The main conclusions are summarised in this chapter.

- AIS technology was introduced onto the ships' bridges with little prior consideration of the navigator's needs, especially human factors issues. This research has incorporated a variety of models to identify some of the key concerns.
- The project has derived an AIS User Satisfaction Model, which shows an understanding of the navigators' perception about different aspects of AIS. This model has been refined for AIS at sea from existing IT based models in the literature. The understanding of the navigator's perception of the AIS will aid improvements to design, training needs and future regulation amendments.
- The AIS User Satisfaction Model has potential for adaptation to other bridge technologies.
- In the questionnaires completed by navigators, AIS is generally perceived to be a useful technology by the navigators. It is beneficial in enhancing the safety of marine navigation by improvement of navigators' ability, performance, quality and safety of anti-collision operations.
- Generally navigators had a high level of confidence in AIS as a navigational aid. It has improved situational awareness, decision-making, and ship's safety in navigational operations as a result of its potential to provide extra precise information to the ship's bridge.
- Knowledgeable navigators also perceived that AIS complemented the radar technology by its abilities to detect other targets in radar shadow areas and in heavy rain and sea. They were confident in the AIS ability to provide fast, clear and continuous information. This improves understanding of targets' intensions and actions in anti-collision operations. Navigators also believed in the ability of AIS to reduce the overall VHF traffic congestion as a result of its automatic transmission of ship's information, thus relieving the OOW from some verbal reporting on VHF.

- The training of navigators on the use of AIS is at a very low level, and should be improved. The project has shown that navigators with theoretical as well as practical training on AIS have a higher level of confidence in the system. A standardised and mandatory training programme on the use, capabilities, and limitations of AIS should ideally be implemented in order to enable navigators to use the equipment in a professionally accepted manner for anti-collision and other navigational operations.
- The data provided by AIS are not reliable, in many cases, due to inaccuracies on part of the user. This should be an obvious area for improvement.
    1. Training would improve accuracy of the manual data input as it will remove misunderstandings and increase the confidence level and motivation of the navigators in the use of AIS in navigational operations.
    2. There are currently some peculiarities in the AIS field of ship status and some differences in system design between different manufacturers. This has resulted in slightly different lists of options available for different ship's types and navigational status. This can be addressed by incorporating into navigator training and/or a standardised design of the AIS according to the International Regulations for Preventing Collisions at Sea.
    3. Currently there is no self-checking mechanism of data from links with other equipment on board to detect inconsistencies in AIS information. For example, a link with the ship's navigational light system would be very useful in improving accuracy of AIS messages.
- Users with AIS displays integrated with radar had the highest level of confidence and satisfaction with the AIS data. Such integration will be compulsory for new radar equipment on SOLAS ships from 2008. The phasing out of existing non-AIS radar equipment should be encouraged.

Chapter 10

Recommendations for Further AIS Research

This research has shown many aspects of AIS technology for future research, not only to further develop the impact of AIS on the safety of marine navigation by its implementation to the ship's bridge but also to evaluate its impact on marine safety by its application in other areas related to marine navigation.

The limitations of this research and areas for further research, highlighted during the project are:

- ***New AIS questionnaire survey with variables' constructs based on AIS User Satisfaction Model.*** Following the development of the AIS User Satisfaction model in this project, it is now possible to develop an improved questionnaire survey based on this model. This will expand understanding of the perceptions and changes to perceptions of navigators about AIS and the usage of AIS for navigation. A new questionnaire based on the AIS User Satisfaction Model will also monitor changes of navigators' perceptions about AIS with time.

- ***Assessment of AIS information, which are relayed automatically from other shipboard navigational equipment, particularly position, course and speed over ground, heading etc.*** This project did not assess the accuracy of the information automatically inputted from other navigational equipment on board due to the unavailability of research facilities. Therefore, proper assessment of the information automatically inputted into AIS will reveal the degree of reliability and accuracy and how navigators use the AIS information.

- ***Investigation into the degree of conformity of actions within anti-collision regulations as a result of the implementation of AIS.*** There was some indication in our survey that the more precise identification of ships available by AIS technology has resulted in anti-collision action agreements between vessels over the VHF. These agreements are sometimes contravene the International Regulations for Preventing Collisions at Sea. This project did not examine this issue in detail. Further investigations on anti-collision agreements over the VHF could be beneficial for safety of marine navigation. Firstly, such investigations should assess the extent of use of VHF for such agreements as a result of introduction of AIS. Secondly, since use of VHF communication for anti-collision agreements between vessels is not authorised by the organisations in charge, this will help the authorities to decide on the regulation/advice for use of VHF for anti-collision agreements due to the AIS precise identification of ships. Thirdly, it may assist the debate of future changes to regulations.

- *Assessment of the integration of the AIS information with information from radar and ECDIS.* Integration of AIS with other navigational aids such as radar or ECDIS can reduce the chances of navigator's information overload by reducing the number of stand-alone pieces of equipment on the bridge. However, the association of the AIS and radar, or ECDIS information is an important issue, which has not been examined by this project. For example, the possibility of duplication of target information such as course, speed, bearing, CPA, and TCPA, due to difference in measurement accuracies between AIS and radar, could negatively affect performance of the navigators in anti-collision operations. Duplication of information could result in information overload, with increased chances of confusion and error in assessment, for the navigators. Combination of the AIS and radar data into one target is a better option for displaying navigational information, which can reduce the clutter on the display and provides a common track of radar and AIS data. The radar and AIS signals are based on two different principles with different accuracy and timing. Therefore, study of the combination of AIS and other information is an important issue, which can improve the data integration system between AIS and radar. Further, research on AIS data integration assists in developing suitable filtering strategies required, could resolve target discrimination errors associated with AIS display integrated with radar, and can improve target tracking ability.

- ***Investigation into the impacts of AIS application ashore on monitoring and management of marine navigation, and its overall impact on maritime security.*** Shore-based application of AIS such as in VTS operations, apart from traffic monitoring and management, could be helpful in proper enforcement of regulations regarding acceptable use of the AIS technology and maintenance of its information at sea. Therefore, further investigations on the impacts of AIS ashore will be helpful in discovering AIS associated issues and could further improve the use for AIS ashore as a complementary to the overall safety of marine navigation. This includes issues such as remote pilotage as well as the management of traffic, security and environment.

- ***Investigation into the application of the AIS user satisfaction model for evaluation of navigators' perceptions about other navigational equipment, such as ECDIS, integrated bridge system, etc.*** The research has developed a user satisfaction model for AIS, which is a starting point for consideration in the way in which other navigational technologies are currently applied on the ship's bridge. Further, research on the application of AIS User Satisfaction model for other navigational equipment would highlight system issues associated with such equipment. It would further assist in improving the usefulness of such equipment for navigation by resolving problems related to the quality of systems and their users.

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Appendix A

List of Publications Arising from this Research

Harati-Mokhtari A, Wall A, Brooks P & Wang J (2007) Evaluating the AIS Contribution in Efficiency and Safety of Marine Navigation Using AIS User Satisfaction Model. Accepted for 7th International Symposium on Marine Navigation (Trans-Nav), 20-22 June 2007, Gdynia, Poland.

Harati-Mokhtari A, Wall A, Brooks P & Wang J (2007) AIS: Data reliability and human error implications., ***In Press,*** Accepted 21 December 2006, for publication in the Journal of Navigation, September 2007, Vol. 60, No. 3.

Harati-Mokhtari A, Wall A, Brooks P & Wang J (2006) AIS and Human Error. Seaways, November, pages 12-14 (ISSN 0144-1019).

Harati-Mokhtari A, Wall A, Brooks P & Wang J (2006) Automatic Identification System (AIS): A Human Factors Approach. In: The Nautical Institute Website - AIS Forum - Technical Feedback. Available at: http://www.nautinst.org/ais/techFeedback.htm (accessed 8 November 2006).

Harati-Mokhtari A, Wall A, Brooks P & Wang J (2006) AIS: A Training Outlook. EUROSHIP Magazine, August, Pages 62-68.

Harati-Mokhtari A, Brooks P, Wall A, & Wang J (2005) Human Factors Aspects of Automatic Identification System (AIS) on the Ship's Bridge. In Proceedings of the 6th International Symposium on Navigation, Held at Gdynia Maritime University, Faculty of Navigation, Gdynia, Poland, 30 June – 1 July.

Harati-Mokhtari A, Kiani-Moghadam M, Brooks P, Wall A & Wang J (2005) Accuracy of Automatic Identification System (AIS) Information on the Ship's Bridge. Presented at: 13th Multi-disciplinary Iranian Researchers Conference in Europe, Leeds, 2 July.

Appendix B

B.1 AIS Survey Questionnaire

AIS Questionnaire

Impact of Automatic Identification System (AIS) on the Safety of Navigation

Automatic Identification System (AIS) has been on the ships bridges for up to 2 years. This survey questionnaire is part of a research project looking at the practical experience with AIS operation and its use for navigational purposes.

The research is being carried out at the Marine Technology Group, School of Engineering, Liverpool John Moores University, UK. If you have any other comments on AIS, or questions regarding this questionnaire please contact Mr Abbas Harati-Mokhtari, the researcher, Tel: +44(0)1512312359, ENRAHARA@livjm.ac.uk or Dr. Alan Wall, director of study for this research, Tel: +44(0)1512312493, A.D.Wall@livjm.ac.uk .

The allocation of some of your precious time in filling in this questionnaire will add to the accuracy of this research and is intended to contribute to safety at sea. Your responses will be greatly appreciated.

Please answer questions in respect to the type of AIS used on board vessels you have sailed on.

NOTE: YOUR INFORMATION WILL REMAIN STRICTLY CONFIDENTIAL AND WILL NOT BE INDIVIDUIALLY PASSED ON TO THIRD PARTIES.

Please return completed questionnaires:

1) By email attachment to ENRAHARA@livjm.ac.uk or
2) By post to Abbas Harati-Mokhtari, Room 1.28, School of Engineering, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, England

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Section A: Personal Information

1. Name (optional) --
2. Rank --
3. Certificate of Competency held --
4. Total time at sea --Years
5. Total sailing experience with AIS -----------------Years ----------------- Months

6. What type(s) of AIS system display was available on board ships you have sailed with **(If you have used more than 1 type, please tick more than 1 choices)**

1. Minimum keyboard and Display (MKD) ☐
2. Stand-alone Graphical Display ☐
3. Integrated with Radar ☐
4. Integrated with ECDIS ☐

For the following sections, please tick your choice in the relevant option box provided.

Strongly Disagree [1] Disagree [2] Neutral [3] Agree [4] Strongly Agree [5]

Section B: Perceived Usefulness of AIS

1. AIS enhances navigator's situational awareness with a better situation display of the traffic.

1	2	3	4	5
☐	☐	☐	☐	☐

2. Using AIS would improve navigator's performance in anti-collision operation.

1	2	3	4	5
☐	☐	☐	☐	☐

3. Using AIS would increase navigator's efficiency in anti-collision operation.

1	2	3	4	5
☐	☐	☐	☐	☐

4. Using AIS would increase navigator's ability in anti-collision operation.

1	2	3	4	5
☐	☐	☐	☐	☐

5. Using AIS would let the navigator feel more in control of anti-collision operation.

1	2	3	4	5
☐	☐	☐	☐	☐

6. Navigators feel their ship is safer with AIS.

1	2	3	4	5
☐	☐	☐	☐	☐

7. AIS will disrupt the normal anti-collision operation.

1	2	3	4	5
☐	☐	☐	☐	☐

8. AIS increases navigator's physical workload.

9. AIS increases navigator's mental workload. 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

10. Navigators prefer to use AIS alone rather than radar.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

11. AIS improves overall safety of navigation.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

12. AIS provides clearer and continuous information in comparison with radar.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

13. Detection of targets in radar shadow areas is improved with AIS.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Section C: Perceived Ease of Use of AIS

1. Self-learning to operate AIS is hard for navigators.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

2. It is easy to become skilful at using AIS.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

3. The process of obtaining information from AIS is clear and understandable.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

4. AIS is easy to use.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

5. AIS responds slowly to data inputs by navigators.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

6. It is easy to use AIS for anti-collision operation.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Section D: Perception of AIS Information Display

1. AIS display is valuable in navigator's performance.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

2. Symbols used in AIS display are efficient.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

3. AIS keyboard is user friendly.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

4. The AIS unit help and instructions are useful and clear.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

5. It takes a long time to learn to extract AIS information.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

6. The way that the AIS information is presented is clear and understandable.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

7. Some of the information on the AIS display is unnecessary.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

8. It is relatively easy to move from one menu to another menu.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

9. Getting data in and out of the AIS is easy.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

10. Overlay of radar echoes with AIS data causes confusion.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Section E: AIS Training

1. Have you completed any formal training on basic operation of AIS?

   a. Yes ☐

   b. No ☐

2. If you have completed an AIS training, what kind of training was it?

a. Theoretical training ☐
b. Practical on the job training ☐
c. Simulation training ☐
d. Theoretical and practical ☐

3. I think that my training on the use of AIS (if any) is adequate to safely perform anti-collision operation on the bridge using AIS.

1	2	3	4	5
☐	☐	☐	☐	☐

4. Formal training for AIS is essential for safe operation in collision situation.

1	2	3	4	5
☐	☐	☐	☐	☐

5. Learning to operate AIS without a proper training course is easy.

1	2	3	4	5
☐	☐	☐	☐	☐

Section F: AIS and Use of VHF

1. AIS decreases overall VHF traffic congestion.

1	2	3	4	5
☐	☐	☐	☐	☐

2. AIS causes increased use of VHF for anti-collision operation.

1	2	3	4	5
☐	☐	☐	☐	☐

3. The increased use of VHF for anti-collision decisions due to AIS violates International Regulations for Preventing Collisions at Sea (ColRegs).

1	2	3	4	5
☐	☐	☐	☐	☐

Section G: Disadvantages of AIS

1. Since AIS stations have no means of assessing the data received, the information received from target ships is not reliable due to spoofing.

1	2	3	4	5
☐	☐	☐	☐	☐

2. AIS is vulnerable due to jamming.

1	2	3	4	5
☐	☐	☐	☐	☐

3. AIS will increase the danger of piracy in areas of piratical activity.

1	2	3	4	5
☐	☐	☐	☐	☐

4. There is a risk of erroneous information displayed, through wrong data input associated with AIS.

1	2	3	4	5
☐	☐	☐	☐	☐

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B.2 Questionnaire Codebook (Initial Questionnaire)

Variable	SPSS variable name	Coding instructions
ID	IdentificationNumber	Subject identification number
Rank	A2 - Rank	1=Master Mariner, 2=Chief Officer, 3=Second Officer, 4=Third Officer
Certificate of competency held	A3 - CertificateOfCompetency	1=Master Mariner, 2=Chief Officer, 3=Second Officer, 4=Third Officer
Total time at sea (year)	A4 - TotalSeatime	In years
Total sailing experience with AIS (month)	A5 - TotalSailingWithAIS	In months
Type(s) of AIS display available	A6 - TypesOfAISdisplay	1=Minimum Keyboard & Display (MKD), 2=Stand-Alone Graphical Display, 3=Integrated with Radar, 4=Integrated with ECDIS, 5=More than one type
AIS enhances navigator's situational awareness with a better situation display of the traffic.	B1 - SituationalAwareness	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Using AIS would improve navigator's performance in anti-collision operation.	B2 - AnticollisionPerformance	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Using AIS would increase navigator's efficiency in anti-collision operation.	B3 - AnticollisionEfficiency	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Using AIS would increase navigator's ability in anti-collision operation.	B4 - AnticollisionAbility	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Using AIS would let the navigator feel more in control of anti-collision operation.	B5 - MoreInControl	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Navigators feel their ship is safer with AIS.	B6 - FeelingSafership	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS will disrupt the normal anti-collision operation.	B7 - DisruptAnticollision	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS increases navigator's physical workload.	B8 - PhysicalWorkload	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS increases navigator's mental workload.	B9 - MentalWorkload	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Navigators prefer to use AIS alone rather than radar.	B10 - PreferAISalone	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS improves overall safety of navigation.	B11 - ImproveOverallSafety	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS provides clearer and continuous information in comparison with radar.	B12 - ProvideClearInformation	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree

Variable	SPSS variable name	Coding instructions
Detection of targets in radar shadow areas is improved with AIS.	B13 - ImprovedDetectionInRadarShadow	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Self-learning to operate AIS is hard for navigators.	C1 - HardSelfLearningOperation	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
It is easy to become skilful at using AIS.	C2 - EasyToBecomeSkillful	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
The process of obtaining information from AIS is clear and understandable.	C3 - ProcOfObtainingInfoIsClearAndUnderstandable	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS is easy to use.	C4 - EasyToUse	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS responds slowly to data inputs by navigators.	C5 - SlowResponceToDataInput	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
It is easy to use AIS for anti-collision operation.	C6 - EasyToUseForAnticollision	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS display is valuable in navigator's performance.	D1 - DisplayIsValuableInPerformance	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Symbols used in AIS display are efficient.	D2 - EfficientSymbol	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS keyboard is user friendly.	D3 - UseFriendlyKeyboard	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
The AIS unit help and instructions are useful and clear.	D4 - UsefulUnitHelpAndInstruction	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
It takes a long time to learn to extract AIS information.	D5 - LongTimeToLearnToExtractInfo	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
The way that AIS information is presented is clear and understandable.	D6 - PresentingInfoClearAndUnderstandable	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Some of the information on the AIS display is unnecessary.	D7 - SomeUnnecessaryInformation	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
It is relatively easy to move from one menu to another menu.	D8 - EasyMoveMenuToMenu	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Getting data in and out of AIS is easy.	D9 - EasyDataInAndOut	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Overlay of radar echoes with AIS data causes confusion.	D10 - ConfusionDueToRadarOverlay	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Have you completed any formal training on basic operation of AIS?	E1 - Training	1=Yes, 2=No

Variable	SPSS variable name	Coding Instructions
If you have completed an AIS training, what kind of training it was.	E2 - Traintype	1=Theoretical training, 2=Practical on the job training, 3=Simulation training, 4=Theoretical and practical
I think that my training on the use of AIS (if any) is adequate to safely perform anti-collision operation on the bridge using AIS.	E3 - AdequateTraining	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Formal training for AIS is essential for safe operation in collision situation.	E4 - TrainEssentialForSafeOperation	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Learning to operate AIS without a proper training course is easy.	E5 - LearingToOperateWithoutTraining	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS decreases overall VHF traffic congestion.	F1 - DecreaseOverallVHFTraffic	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS causes increased use of VHF for anti-collision operation.	F2 - IncreaseVHFUseForAnticollision	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
The increased use of VHF for anti-collision decisions due to AIS violates International Regulation for Preventing Collisions at Sea (ColRegs).	F3 - RegViolationDueToVHFUse	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
Since AIS stations have no means of assessing the data received, the information received from target ships are not reliable due to spoofing.	G1 - NoReliableDataDueToSpoofing	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS is vulnerable due to jamming.	G2 - VulnerableDueToJamming	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
AIS will increase the danger of piracy in areas of piratical activity.	G3 - IncreasePiracy	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
There is a risk of erroneous information displayed, through wrong data input associated with AIS.	G4 - ErroneousInfoDueToWrongDataInput	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree
		99=Missing, 999=Not Applicable

B.3 AIS Survey Data (Initial Questionnaire)

ID	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	C1	C2	C3	C4	C5
1	2	1	12.0	27	2	4	3	4	4	4	2	3	2	2	3	3	4	4	2	2	1	2	1
2	1	1	14.0	12	5	5	3	4	3	3	2	4	2	2	3	4	2	4	3	4	2	1	1
3	4	3	5.5	24	5	4	4	3	2	4	3	3	3	4	4	5	4	3	2	2	3	4	3
4	3	99	6.0	30	5	4	4	3	2	2	3	3	3	4	4	5	4	3	2	2	4	3	99
5	4	3	3.0	3	3	5	4	5	4	5	2	3	3	3	1	2	2	5	1	4	5	4	3
6	2	2	12.0	28	5	4	4	3	3	4	4	2	2	2	2	4	4	4	3	4	6	2	2
7	4	3	.3	4	3	5	4	4	4	4	3	4	2	2	2	4	4	2	3	3	7	4	3
8	4	3	7.0	7	3	3	3	5	5	4	2	4	2	2	2	3	2	3	3	3	8	4	3
9	3	3	3.5	16	5	4	3	4	3	4	2	4	3	3	1	4	2	5	2	3	9	3	3
10	2	1	27.0	27	5	4	3	5	4	4	3	4	2	2	2	3	4	4	2	4	10	2	1
11	4	3	2.0	11	5	4	3	4	2	4	4	4	2	2	1	4	3	4	2	3	11	4	3
12	2	99	99.0	36	5	4	4	3	3	4	4	4	2	2	1	4	3	3	3	2	12	2	99
13	4	99	1.0	12	5	3	2	2	2	3	4	4	2	2	1	4	2	4	3	2	13	4	99
14	4	99	1.0	12	5	3	2	2	2	3	4	4	1	1	1	2	2	4	2	2	14	4	99
15	4	3	.4	5	5	5	5	5	5	5	5	5	1	1	1	5	2	4	3	4	15	4	3
16	1	1	33.0	24	5	4	3	4	3	4	3	4	2	2	2	3	3	4	3	4	16	1	1
17	4	3	.7	8	5	4	3	4	4	4	2	2	2	2	2	3	4	4	3	3	17	4	3
18	2	2	12.0	16	5	4	4	3	3	4	4	2	2	2	2	4	4	4	3	4	18	2	2
19	3	3	13.0	11	1	5	5	5	5	5	5	5	1	1	1	5	3	3	3	4	19	3	3
20	1	1	19.0	15	5	4	4	3	2	3	3	4	2	2	2	4	4	3	3	4	20	1	1
21	4	3	2.0	12	5	4	5	5	4	5	4	4	3	4	2	4	4	5	2	4	21	4	3
22	4	3	3.0	31	1	5	2	5	2	4	2	2	5	5	3	2	3	4	4	3	22	4	3
23	3	3	4.5	12	5	4	5	5	5	5	4	2	5	5	3	4	3	4	2	4	23	3	3
24	4	3	7.0	18	5	4	2	4	4	4	2	5	2	2	2	4	4	4	3	3	24	4	3
25	2	1	18.0	14	5	3	4	3	3	2	1	4	2	1	3	4	4	4	3	2	25	2	1
26	3	3	4.5	13	2	4	4	3	2	3	3	4	2	2	2	4	4	3	2	4	26	3	3
27	4	3	3.0	13	2	4	4	3	2	3	3	4	2	2	2	4	4	3	3	3	27	4	3
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37	3	99	8.0	12	5	4	4	4	2	4	3	4	2	2	2	3	4	5	2	4	37	3	99
38	1	1	37.0	24	1	3	3	3	3	3	5	3	3	3	5	3	5	5	4	2	38	1	1
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41	4	3	2.0	20	4	5	4	4	1	2	2	4	2	2	1	2	5	3	1	5	41	4	3
42	99	2	1.2	6	3	4	3	2	2	2	2	3	3	3	1	3	4	4	2	4	42	99	2
43	1	1	26.0	7	1	4	3	3	3	4	4	3	3	2	1	2	1	3	2	4	43	1	1

ID	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	C1	C2	C3	C4	C5
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46	3	3	2.5	14	1	4	3	3	4	4	4	4	1	2	2	3	4	4	3	4	46	3	3
47	1	1	15.0	18	99	3	4	3	4	3	3	4	4	3	2	4	3	3	2	3	47	1	1
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66	2	1	30.0	1	4	3	2	2	2	2	1	2	3	3	1	2	2	2	5	3	66	2	1
67	1	1	22.0	18	4	4	4	4	2	2	2	3	2	2	1	2	2	4	4	2	67	1	1
68	2	2	22.0	15	4	4	3	3	3	3	4	2	4	4	5	4	4	3	1	4	68	2	2
69	1	1	33.0	36	5	2	2	2	2	2	1	3	3	4	2	2	2	2	4	3	69	1	1
70	1	1	15.0	6	5	4	2	2	2	2	4	3	2	2	1	2	2	2	2	4	70	1	1
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72	3	3	7.0	24	5	3	4	3	3	4	2	4	2	4	1	1	4	3	2	4	72	3	3
73	4	3	6.0	24	1	5	4	4	4	4	4	3	2	2	2	4	4	4	4	3	73	4	3
74	99	99	5.0	6	1	5	3	3	4	4	4	4	2	2	2	4	3	3	3	2	74	99	99
75	2	1	20.0	12	3	5	5	4	4	4	3	4	3	3	2	4	4	5	4	2	75	2	1
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78	3	3	8.0	12	3	5	5	4	4	4	3	4	3	3	2	4	4	5	3	3	78	3	3
79	1	1	25.0	12	5	5	5	4	4	4	3	4	2	3	2	4	4	5	2	5	79	1	1
80	3	3	4.0	36	5	5	4	4	4	4	5	3	2	2	1	4	2	3	3	3	80	3	3
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82	4	3	1.5	12	5	4	4	4	4	3	5	3	5	2	1	4	2	3	4	4	82	4	3
83	4	3	2.0	7	5	5	4	3	4	3	5	3	2	2	1	3	2	3	3	3	83	4	3
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85	4	3	1.0	5	5	5	5	5	5	5	4	5	1	1	2	5	5	5	2	5	85	4	3
86	4	3	1.0	12	5	5	5	5	5	5	4	5	1	1	2	5	5	5	2	5	86	4	3
87	3	3	10.0	24	5	4	4	4	4	4	4	2	4	4	4	4	2	4	3	2	87	3	3
88	1	1	20.0	36	5	4	5	5	4	4	4	4	2	2	2	4	4	4	2	2	88	1	1
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ID	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	C1	C2	C3	C4	C5
90	3	3	6.0	30	3	4	4	4	4	3	4	4	2	2	1	4	4	5	2	4	90	3	3
91	4	3	2.0	5	3	4	4	4	3	2	2	5	1	1	2	4	2	5	2	5	91	4	3
92	4	3	5.0	30	3	4	4	4	3	4	4	4	2	2	1	3	4	4	2	4	92	4	3
93	1	1	21.0	60	5	4	5	5	4	4	4	4	2	2	2	4	4	4	2	2	93	1	1
94	3	3	12.0	24	5	4	4	4	4	4	4	2	4	4	4	4	2	4	3	2	94	3	3
95	3	3	8.0	32	1	4	4	4	4	5	4	4	2	2	1	4	3	4	3	4	95	3	3
96	3	3	6.0	24	3	4	2	4	4	5	5	4	2	1	1	5	3	5	2	4	96	3	3
97	4	3	1.0	11	2	5	2	5	4	5	3	5	1	1	1	2	3	5	2	5	97	4	3
98	3	3	6.0	24	3	5	4	5	4	5	5	4	2	1	1	5	3	5	1	5	98	3	3
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107	3	3	4.0	36	5	5	4	4	4	4	5	3	2	2	1	4	2	3	2	4	107	3	3
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111	3	3	6.0	33	3	4	3	3	3	3	3	5	1	2	2	3	3	4	2	3	111	3	3
112	4	99	1.5	11	5	4	4	4	4	4	3	3	1	2	1	3	4	5	2	5	112	4	99
113	4	99	5.5	20	5	4	4	4	3	4	3	4	2	2	1	4	4	4	2	4	113	4	99
114	4	99	2.0	13	5	4	4	4	4	4	2	3	2	2	1	4	4	5	2	5	114	4	99
115	4	99	5.0	24	5	4	5	4	4	4	5	2	1	1	1	5	4	5	4	4	115	4	99
116	3	99	8.0	24	5	4	4	5	4	4	2	2	2	2	2	4	4	5	4	4	116	3	99

ID	C6	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	E1	E2	E3	E4	E5	F1	F2	F3	G1	G2	G3	G4
1	12.0	27	2	4	3	4	4	4	2	3	2	2	3	3	4	4	2	2	1	2	1	12.0	27
2	14.0	12	5	5	3	4	3	3	2	4	2	2	3	4	2	4	3	4	2	1	1	14.0	12
3	5.5	24	5	4	4	3	2	4	3	3	3	4	4	5	4	3	2	2	3	4	3	5.5	24
4	6.0	30	5	4	4	3	2	2	3	3	3	4	4	5	4	3	2	2	4	3	99	6.0	30
5	3.0	3	3	5	4	5	4	5	2	3	3	3	1	2	2	5	1	4	5	4	3	3.0	3
6	12.0	28	5	4	4	3	3	4	4	2	2	2	2	4	4	4	3	4	6	2	2	12.0	28
7	.3	4	3	5	4	4	4	4	3	4	2	2	2	4	4	2	3	3	7	4	3	.3	4
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9	3.5	16	5	4	3	4	3	4	2	4	3	3	1	4	2	5	2	3	9	3	3	3.5	16
10	27.0	27	5	4	3	5	4	4	3	4	2	2	2	3	4	4	2	4	10	2	1	27.0	27
11	2.0	11	5	4	3	4	2	4	4	4	2	2	1	4	3	4	2	3	11	4	3	2.0	11
12	99.0	36	5	4	4	3	3	4	4	4	2	2	1	4	3	3	3	2	12	2	99	99.0	36
13	1.0	12	5	3	2	2	2	3	4	4	2	2	1	4	2	4	3	2	13	4	99	1.0	12
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ID	C6	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	E1	E2	E3	E4	E5	F1	F2	F3	G1	G2	G3	G4
15	.4	5	5	5	5	5	5	5	5	5	1	1	1	5	2	4	3	4	15	4	3	.4	5
16	33.0	24	5	4	3	4	3	4	3	4	2	2	2	3	3	4	3	4	16	1	1	33.0	24
17	.7	8	5	4	3	4	4	4	2	2	2	2	2	3	4	4	3	3	17	4	3	.7	8
18	12.0	16	5	4	4	3	3	4	4	2	2	2	2	4	4	4	3	4	18	2	2	12.0	16
19	13.0	11	1	5	5	5	5	5	5	5	1	1	1	5	3	3	3	4	19	3	3	13.0	11
20	19.0	15	5	4	4	3	2	3	3	4	2	2	2	4	4	3	3	4	20	1	1	19.0	15
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22	3.0	31	1	5	2	5	2	4	2	2	5	5	3	2	3	4	4	3	22	4	3	3.0	31
23	4.5	12	5	4	5	5	5	5	4	2	5	5	3	4	3	4	2	4	23	3	3	4.5	12
24	7.0	18	5	4	2	4	4	4	2	5	2	2	2	4	4	4	3	3	24	4	3	7.0	18
25	18.0	14	5	3	4	3	3	2	1	4	2	1	3	4	4	4	3	2	25	2	1	18.0	14
26	4.5	13	2	4	4	3	2	3	3	4	2	2	2	4	4	3	2	4	26	3	3	4.5	13
27	3.0	13	2	4	4	3	2	3	3	4	2	2	2	4	4	3	3	3	27	4	3	3.0	13
28	2.0	14	2	4	4	3	2	3	3	4	2	2	2	4	4	3	2	4	28	4	3	2.0	14
29	1.0	12	5	5	4	5	3	5	4	5	1	1	1	2	5	5	4	4	29	4	3	1.0	12
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31	8.0	10	5	4	5	5	5	4	3	4	2	1	1	5	4	5	3	4	31	3	3	8.0	10
32	14.0	24	1	5	5	5	5	5	4	4	1	2	1	5	4	4	3	5	32	2	2	14.0	24
33	18.0	24	1	3	2	4	3	3	4	3	2	2	1	3	4	4	1	4	33	1	1	18.0	24
34	20.0	7	1	4	2	3	4	4	3	2	3	4	1	4	4	3	2	4	34	1	1	20.0	7
35	1.0	12	5	4	3	2	2	2	2	3	3	3	1	3	3	3	4	3	35	4	2	1.0	12
36	14.0	18	4	4	2	2	2	4	3	4	4	4	2	2	4	4	5	4	36	2	1	14.0	18
37	8.0	12	5	4	4	4	2	4	3	4	2	2	2	3	4	5	2	4	37	3	99	8.0	12
38	37.0	24	1	3	3	3	3	3	5	3	3	3	5	3	5	5	4	2	38	1	1	37.0	24
39	18.0	12	5	4	3	3	3	3	4	3	2	2	4	3	4	4	4	5	39	2	1	18.0	12
40	26.0	24	1	4	2	2	2	2	2	2	3	3	3	3	3	3	4	3	40	2	1	26.0	24
41	2.0	20	4	5	4	4	1	2	2	4	2	2	1	2	5	3	1	5	41	4	3	2.0	20
42	1.2	6	3	4	3	2	2	2	2	3	3	3	1	3	4	4	2	4	42	99	2	1.2	6
43	26.0	7	1	4	3	3	3	4	4	3	3	2	1	2	1	3	2	4	43	1	1	26.0	7
44	10.0	12	1	4	3	3	3	4	4	3	2	2	1	2	1	3	2	4	44	2	1	10.0	12
45	4.5	10	1	4	4	3	4	3	3	3	3	4	2	4	4	4	2	4	45	3	1	4.5	10
46	2.5	14	1	4	3	3	4	4	4	4	1	2	2	3	4	4	3	4	46	3	3	2.5	14
47	15.0	18	99	3	4	3	4	3	3	4	4	3	2	4	3	3	2	3	47	1	1	15.0	18
48	5.0	4	99	3	4	3	4	3	4	4	4	3	2	3	3	3	2	3	48	3	3	5.0	4
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50	4.5	8	99	1	1	2	1	1	5	4	1	1	1	4	5	2	4	3	50	2	2	4.5	8
51	14.0	7	5	3	4	4	2	4	3	3	3	2	3	4	5	4	3	4	51	2	1	14.0	7
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53	6.0	9	1	5	5	5	5	5	3	99	1	1	99	5	5	5	1	4	53	3	2	6.0	9
54	5.0	11	3	5	5	5	5	4	5	4	2	2	1	5	2	4	2	4	54	2	2	5.0	11
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56	4.5	12	1	4	4	3	3	4	4	3	2	2	1	4	2	2	3	3	56	2	2	4.5	12
57	4.5	15	3	5	5	5	5	4	4	4	2	4	2	4	2	4	2	3	57	2	2	4.5	15
58	5.0	12	5	5	2	5	4	5	2	4	1	2	1	3	2	4	4	3	58	2	2	5.0	12
59	12.0	18	5	4	4	4	4	4	4	4	2	2	2	4	2	4	2	4	59	2	2	12.0	18
60	5.0	20	1	5	4	4	4	4	4	4	1	2	2	4	4	4	3	3	60	2	2	5.0	20

ID	C6	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	E1	E2	E3	E4	E5	F1	F2	F3	G1	G2	G3	G4
61	10.0	30	1	4	2	2	2	3	3	4	3	4	1	4	1	4	2	4	61	2	2	10.0	30
62	5.0	16	1	4	3	3	3	3	4	3	3	3	99	4	4	3	4	3	62	2	2	5.0	16
63	10.0	24	2	5	5	5	3	5	5	5	2	1	1	5	4	5	1	5	63	2	2	10.0	24
64	6.5	18	5	5	5	5	5	5	4	3	1	1	1	5	4	5	3	5	64	2	1	6.5	18
65	5.0	24	1	2	3	2	3	4	4	3	4	2	3	4	3	3	3	4	65	2	2	5.0	24
66	30.0	1	4	3	2	2	2	2	1	2	3	3	1	2	2	2	5	3	66	2	1	30.0	1
67	22.0	18	4	4	4	4	2	2	2	3	2	2	1	2	2	4	4	2	67	1	1	22.0	18
68	22.0	15	4	4	3	3	3	3	4	2	4	4	5	4	4	3	1	4	68	2	2	22.0	15
69	33.0	36	5	2	2	2	2	2	1	3	3	4	2	2	2	2	4	3	69	1	1	33.0	36
70	15.0	6	5	4	2	2	2	2	4	3	2	2	1	2	2	2	2	4	70	1	1	15.0	6
71	11.0	3	5	5	4	4	4	3	3	3	4	4	1	3	3	5	4	4	71	2	2	11.0	3
72	7.0	24	5	3	4	3	3	4	2	4	2	4	1	1	4	3	2	4	72	3	3	7.0	24
73	6.0	24	1	5	4	4	4	4	4	3	2	2	2	4	4	4	4	3	73	4	3	6.0	24
74	5.0	6	1	5	3	3	4	4	4	4	2	2	2	4	3	3	3	2	74	99	99	5.0	6
75	20.0	12	3	5	5	4	4	4	3	4	3	3	2	4	4	5	4	2	75	2	1	20.0	12
76	2.0	12	2	4	4	4	4	4	4	2	3	3	3	3	4	4	3	4	76	4	3	2.0	12
77	2.0	16	3	5	5	4	4	4	3	4	3	3	2	4	4	5	1	4	77	4	3	2.0	16
78	8.0	12	3	5	5	4	4	4	3	4	3	3	2	4	4	5	3	3	78	3	3	8.0	12
79	25.0	12	5	5	5	4	4	4	3	4	2	3	2	4	4	5	2	5	79	1	1	25.0	12
80	4.0	36	5	5	4	4	4	4	5	3	2	2	1	4	2	3	3	3	80	3	3	4.0	36
81	2.0	12	5	4	4	4	4	4	4	4	2	2	1	4	2	3	4	3	81	4	3	2.0	12
82	1.5	12	5	4	4	4	4	3	5	3	5	2	1	4	2	3	4	4	82	4	3	1.5	12
83	2.0	7	5	5	4	3	4	3	5	3	2	2	1	3	2	3	3	3	83	4	3	2.0	7
84	11.0	70	5	5	5	5	5	5	4	5	1	1	2	5	5	5	2	5	84	3	3	11.0	70
85	1.0	5	5	5	5	5	5	5	4	5	1	1	2	5	5	5	2	5	85	4	3	1.0	5
86	1.0	12	5	5	5	5	5	5	4	5	1	1	2	5	5	5	2	5	86	4	3	1.0	12
87	10.0	24	5	4	4	4	4	4	4	2	4	4	4	4	2	4	3	2	87	3	3	10.0	24
88	20.0	36	5	4	5	5	4	4	4	4	2	2	2	4	4	4	2	2	88	1	1	20.0	36
89	2.0	14	5	4	4	4	3	3	4	4	4	4	2	4	3	4	2	2	89	4	3	2.0	14
90	6.0	30	3	4	4	4	4	3	4	4	2	2	1	4	4	5	2	4	90	3	3	6.0	30
91	2.0	5	3	4	4	4	3	2	2	5	1	1	2	4	2	5	2	5	91	4	3	2.0	5
92	5.0	30	3	4	4	4	3	4	4	4	2	2	1	3	4	4	2	4	92	4	3	5.0	30
93	21.0	60	5	4	5	5	4	4	4	4	2	2	2	4	4	4	2	2	93	1	1	21.0	60
94	12.0	24	5	4	4	4	4	4	4	2	4	4	4	4	2	4	3	2	94	3	3	12.0	24
95	8.0	32	1	4	4	4	4	5	4	4	2	2	1	4	3	4	3	4	95	3	3	8.0	32
96	6.0	24	3	4	2	4	4	5	5	4	2	1	1	5	3	5	2	4	96	3	3	6.0	24
97	1.0	11	2	5	2	5	4	5	3	5	1	1	1	2	3	5	2	5	97	4	3	1.0	11
98	6.0	24	3	5	4	5	4	5	5	4	2	1	1	5	3	5	1	5	98	3	3	6.0	24
99	5.0	19	5	4	4	4	4	4	4	2	2	2	1	4	2	4	3	4	99	3	3	5.0	19
100	10.0	3	5	4	3	2	2	3	4	4	3	3	1	3	3	4	2	4	100	3	3	10.0	3
101	2.5	14	5	5	4	4	4	4	3	3	4	4	1	3	3	4	3	2	101	4	3	2.5	14
102	1.2	2	5	3	4	4	2	4	5	4	3	2	1	4	4	4	3	4	102	4	3	1.2	2
103	1.5	5	3	4	4	3	3	4	3	3	2	1	2	4	2	4	2	2	103	4	3	1.5	5
104	1.5	5	3	4	3	4	3	4	3	3	2	2	3	4	4	5	3	3	104	4	3	1.5	5
105	8.0	32	1	4	4	4	4	5	3	4	2	2	1	4	3	4	3	4	105	3	3	8.0	32
106	2.0	7	5	5	4	3	4	3	4	3	2	2	1	3	2	3	2	4	106	4	3	2.0	7

ID	C6	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	E1	E2	E3	E4	E5	F1	F2	F3	G1	G2	G3	G4
107	4.0	36	5	5	4	4	4	4	5	3	2	2	1	4	2	3	2	4	107	3	3	4.0	36
108	2.0	12	5	4	4	4	4	4	4	4	2	2	1	4	2	3	2	4	108	4	3	2.0	12
109	1.5	12	5	4	4	4	4	3	5	3	5	2	1	4	2	3	4	4	109	4	3	1.5	12
110	5.0	24	5	5	9	5	5	5	3	4	2	2	2	3	5	4	2	4	110	3	3	5.0	24
111	6.0	33	3	4	3	3	3	3	3	5	1	2	2	3	3	4	2	3	111	3	3	6.0	33
112	1.5	11	5	4	4	4	4	4	3	3	1	2	1	3	4	5	2	5	112	4	99	1.5	11
113	5.5	20	5	4	4	4	3	4	3	4	2	2	1	4	4	4	2	4	113	4	99	5.5	20
114	2.0	13	5	4	4	4	4	4	2	3	2	2	1	4	4	5	2	5	114	4	99	2.0	13
115	5.0	24	5	4	5	4	4	4	5	2	1	1	1	5	4	5	4	4	115	4	99	5.0	24
116	8.0	24	5	4	4	5	4	4	2	2	2	2	2	4	4	5	4	4	116	3	99	8.0	24

Appendix C

C.1 AIS Survey Data (Questionnaire Grouped According to AIS User Satisfaction Model)

ID	Rank	CofC	Seatime	AIStime	AISdis	Training	Traintype	SQ1	SQ2	SQ3	SQ4	SQ5	SQ6	SQ7	SQ8	SQ9	SQ10	SQ11	SQ12	SQ13	SE1	SE2	SE3
1	2	1	12	27	2	2	999	4	4	4	4	5	4	1	4	4	4	3	3	4	99	2	4
2	1	1	14	12	5	2	999	4	3	3	3	4	3	3	2	2	4	3	3	2	3	4	4
3	4	3	5.5	24	5	2	999	3	4	2	2	3	4	3	4	1	1	2	3	3	4	4	4
4	3	99	6	30	5	2	999	3	4	2	2	3	4	3	4	1	1	2	3	3	2	3	3
5	4	3	3	3	3	2	999	4	4	4	4	4	4	3	4	4	3	4	4	4	4	4	3
6	2	2	12	28	5	1	4	3	3	2	3	4	3	4	2	3	4	2	2	2	4	3	4
7	4	3	0.3	4	3	1	2	4	3	4	2	4	4	4	3	2	4	2	2	2	2	3	3
8	4	3	7	7	3	1	2	4	4	4	4	4	4	4	4	4	4	4	3	3	3	2	3
9	3	3	3.5	16	5	2	999	4	3	3	3	3	3	3	4	4	2	4	3	2	99	4	4
10	2	1	27	27	5	1	4	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4
11	4	3	2	11	5	2	999	4	4	4	4	4	4	4	4	4	4	3	4	5	4	3	3
12	2	99	99	36	5	1	1	3	3	4	4	3	4	99	4	4	4	3	4	2	4	4	3
13	4	99	1	12	5	2	999	3	4	4	3	3	4	4	4	4	4	2	4	2	99	1	1
14	4	99	1	12	5	2	999	4	4	4	3	4	4	4	4	4	4	2	4	2	99	99	2
15	4	3	0.4	5	5	2	999	4	5	4	5	3	4	4	4	4	4	2	2	2	3	3	3
16	1	1	33	24	5	2	999	4	3	3	3	4	4	3	4	3	4	2	2	2	99	99	4
17	4	3	0.7	8	5	1	2	3	3	2	3	4	3	4	2	3	4	3	3	3	4	3	4
18	2	2	12	16	5	1	2	3	3	2	3	4	3	4	2	3	4	2	2	2	4	3	4
19	3	3	13	11	1	2	999	5	5	4	5	2	4	3	4	4	3	2	2	2	3	2	4
20	1	1	19	15	5	2	999	2	3	4	4	4	3	3	4	4	4	3	3	4	3	3	3
21	4	3	2	12	5	1	4	4	4	3	3	4	4	4	4	4	4	2	3	2	3	2	4
22	4	3	3	31	1	1	2	4	4	3	99	2	4	2	4	4	2	2	2	2	4	4	5
23	3	3	4.5	12	5	1	4	5	4	3	4	4	4	4	4	4	2	3	3	2	4	4	5
24	4	3	7	18	5	2	999	3	3	4	4	4	4	3	4	4	4	3	4	2	4	3	4
25	2	1	18	14	5	2	999	4	2	2	3	2	2	2	2	2	3	2	3	2	3	5	2
26	3	3	4.5	13	2	2	999	2	3	4	4	4	3	3	4	4	4	3	3	4	3	3	3
27	4	3	3	13	2	2	999	2	3	4	4	4	3	3	4	4	4	3	3	4	3	3	3
28	4	3	2	14	2	2	999	2	3	4	4	4	3	3	4	4	4	3	3	4	3	3	3
29	4	3	1	12	5	2	999	4	4	4	4	5	4	5	3	4	4	4	3	4	4	4	4
30	4	3	2	10	5	2	999	3	4	4	3	4	4	4	3	4	4	2	2	2	4	4	4
31	3	3	8	10	5	2	999	5	3	3	3	4	4	4	3	4	3	2	3	2	99	2	4
32	2	2	14	24	1	1	1	5	4	4	3	4	3	2	3	2	1	4	3	5	5	5	5
33	1	1	18	24	1	2	999	4	3	3	4	4	4	3	4	4	2	3	3	1	99	4	2
34	1	1	20	7	1	2	999	4	3	2	3	4	4	2	4	4	3	3	3	2	99	4	4
35	4	2	1	12	5	2	999	3	3	1	2	3	3	3	2	3	2	2	3	2	3	3	3

ID	Rank	CofC	Seatime	AIStime	AISdis	Training	Traintype	SQ1	SQ2	SQ3	SQ4	SQ5	SQ6	SQ7	SQ8	SQ9	SQ10	SQ11	SQ12	SQ13	SE1	SE2	SE3
36	2	1	14	18	4	2	999	3	4	3	4	3	4	4	2	3	3	2	3	2	99	99	3
37	3	99	8	12	5	2	999	4	3	1	2	3	3	4	3	3	4	3	4	2	99	3	4
38	1	1	37	24	1	2	999	2	3	3	3	3	3	3	2	2	3	1	1	4	3	5	3
39	2	1	18	12	5	2	999	3	4	3	4	4	4	2	3	3	3	4	3	2	1	4	3
40	2	1	26	24	1	2	999	3	3	2	2	2	3	2	3	4	2	2	2	2	2	4	2
41	4	3	2	20	4	2	999	2	3	3	2	5	5	2	3	4	3	3	3	1	99	3	3
42	99	2	1.2	6	3	2	999	2	3	3	3	4	3	2	3	2	3	3	4	2	99	3	2
43	1	1	26	7	1	2	999	2	4	4	4	4	4	4	4	4	4	2	2	1	99	99	2
44	2	1	10	12	1	2	999	2	4	4	4	4	4	4	4	4	4	2	2	1	99	99	2
45	3	1	4.5	10	1	2	999	3	4	4	4	4	4	4	4	4	3	2	2	1	99	99	3
46	3	3	2.5	14	1	2	999	3	3	4	4	4	4	4	4	4	3	2	2	2	99	99	3
47	1	1	15	18	99	2	999	3	3	3	3	3	4	4	3	3	4	3	3	2	99	3	4
48	3	3	5	4	99	2	999	3	3	3	3	3	4	4	3	3	4	3	4	2	99	3	4
49	3	3	2.5	9	1	1	1	3	4	4	4	4	4	4	4	4	4	3	3	2	4	4	4
50	2	2	4.5	8	99	2	999	2	4	4	4	4	4	3	4	4	5	4	2	2	99	99	4
51	2	1	14	7	5	2	999	3	4	3	3	4	4	3	4	4	3	1	2	1	99	4	4
52	2	2	4	12	1	2	999	3	2	3	4	4	4	2	4	3	4	3	3	2	99	4	2
53	3	2	6	9	1	99	99	3	4	4	1	1	1	3	1	1	1	99	99	4	99	99	1
54	2	2	5	11	3	2	999	4	3	4	3	4	4	3	4	4	4	3	3	2	99	99	4
55	2	2	5	8	1	2	999	5	5	5	5	4	5	4	5	5	4	3	4	2	99	99	2
56	2	2	4.5	12	1	2	999	4	5	4	4	3	4	3	3	3	3	4	3	3	99	3	4
57	2	2	4.5	15	3	2	999	3	3	3	3	2	3	2	4	2	4	4	3	4	2	2	3
58	2	2	5	12	5	2	999	4	4	4	4	4	4	3	4	4	4	4	3	2	99	5	4
59	2	2	12	18	5	2	999	4	3	4	4	5	4	5	4	3	4	4	4	4	99	4	3
60	2	2	5	20	1	2	999	4	3	4	4	4	4	3	4	4	2	3	3	3	99	99	4
61	2	2	10	30	1	2	999	3	2	4	3	4	4	4	4	4	4	1	2	2	1	1	2
62	2	2	5	16	1	1	4	4	3	4	3	2	3	2	3	4	3	3	2	2	3	3	3
63	2	2	10	24	2	2	999	4	5	5	5	5	5	5	5	5	3	3	3	2	99	2	5
64	2	1	6.5	18	5	2	999	4	3	4	5	3	5	4	5	5	5	4	4	3	99	5	3
65	2	2	5	24	1	1	2	4	4	4	4	1	4	2	5	4	2	2	1	1	4	4	4
66	2	1	30	1	4	2	999	2	3	1	1	3	3	4	3	3	3	3	3	1	99	99	3
67	1	1	22	18	4	2	999	4	3	3	5	3	4	3	4	4	5	3	4	4	3	4	3
68	2	2	22	15	4	2	999	4	3	2	4	4	4	3	4	3	3	3	3	2	4	3	4
69	1	1	33	36	5	2	999	2	3	3	2	3	3	3	4	3	3	3	3	3	2	99	3
70	1	1	15	6	5	2	999	2	3	4	4	4	4	4	4	4	4	4	4	4	1	1	2
71	2	2	11	3	5	1	3	4	4	2	1	3	3	1	2	2	4	3	3	3	5	5	4
72	3	3	7	24	5	2	999	4	4	5	5	4	5	4	4	4	4	3	3	1	99	99	3
73	4	3	6	24	1	2	999	4	4	4	4	4	4	4	4	4	4	3	4	2	4	2	4
74	99	99	5	6	1	2	999	3	4	3	4	4	4	4	4	5	3	3	4	2	4	3	3
75	2	1	20	12	3	2	999	4	3	3	4	3	4	4	4	4	2	2	3	2	3	3	4

ID	Rank	CofC	Seatime	AIStime	AISdis	Training	Traintype	SQ1	SQ2	SQ3	SQ4	SQ5	SQ6	SQ7	SQ8	SQ9	SQ10	SQ11	SQ12	SQ13	SE1	SE2	SE3
76	4	3	2	12	2	1	2	4	3	4	4	3	4	2	4	4	3	3	3	2	4	4	4
77	4	3	2	16	3	2	999	4	3	3	4	3	4	4	4	4	2	2	3	2	3	3	4
78	3	3	8	12	3	2	999	4	3	3	4	3	4	4	4	4	2	2	3	2	3	3	4
79	1	1	25	12	5	2	999	4	3	3	4	3	4	4	4	4	1	2	3	2	99	3	4
80	3	3	4	36	5	2	999	4	4	3	3	4	4	5	2	4	3	3	4	3	1	2	4
81	4	3	2	12	5	2	999	4	4	3	4	4	4	4	4	4	3	3	4	3	1	2	4
82	4	3	1.5	12	5	2	999	4	4	3	3	4	4	5	2	4	3	3	4	3	1	2	2
83	4	3	2	7	5	2	999	4	4	3	3	4	4	5	2	4	1	3	4	2	1	2	4
84	3	3	11	70	5	2	999	4	3	4	3	4	4	4	5	4	4	2	4	4	99	3	5
85	4	3	1	5	5	2	999	5	5	5	5	5	5	4	5	5	5	2	4	4	99	3	5
86	4	3	1	12	5	2	999	3	4	4	4	3	5	4	3	5	4	2	4	4	99	3	5
87	3	3	10	24	5	2	999	4	4	3	3	3	4	4	4	4	2	2	2	2	2	4	3
88	1	1	20	36	5	2	999	4	4	4	3	2	4	4	4	3	4	2	3	2	3	2	4
89	4	3	2	14	5	2	999	3	2	4	3	4	4	2	4	4	4	2	2	2	99	2	3
90	3	3	6	30	3	2	999	3	4	4	4	4	4	3	4	4	4	4	3	2	99	4	4
91	4	3	2	5	3	2	999	4	4	4	3	4	4	3	4	4	4	2	3	2	99	3	4
92	4	3	5	30	3	2	999	4	3	3	4	4	4	4	3	4	4	2	3	2	3	3	4
93	1	1	21	60	5	2	999	4	4	4	3	2	4	4	4	3	4	2	3	2	3	2	3
94	3	3	12	24	5	2	999	4	4	3	3	3	4	4	4	4	2	2	2	2	2	3	3
95	3	3	8	32	1	2	999	4	4	4	3	4	4	4	3	3	4	2	3	2	99	5	4
96	3	3	6	24	3	2	999	4	4	4	4	4	4	3	4	4	3	3	3	2	99	4	5
97	4	3	1	11	2	2	999	4	2	4	4	5	4	3	4	4	3	3	3	3	99	3	5
98	3	3	6	24	3	2	999	4	2	4	4	5	4	3	4	4	3	3	3	3	99	3	5
99	3	3	5	19	5	1	3	4	3	4	4	4	4	4	4	4	2	3	3	2	2	2	1
100	3	3	10	3	5	2	999	3	2	3	3	4	4	4	4	4	3	4	3	2	2	3	3
101	4	3	2.5	14	5	2	999	4	3	4	4	4	4	4	4	4	2	2	3	2	99	3	3
102	4	3	1.2	2	5	2	999	2	3	3	4	4	4	4	4	2	4	2	3	4	4	3	3
103	4	3	1.5	5	3	2	999	3	3	4	4	3	4	3	4	4	3	2	3	3	99	2	4
104	4	3	1.5	5	3	2	999	4	4	4	4	3	4	3	4	4	3	3	3	2	3	3	3
105	3	3	8	32	1	2	999	4	4	4	3	4	4	4	3	3	4	2	3	2	99	5	4
106	4	3	2	7	5	2	999	4	4	3	3	4	4	5	2	4	1	3	4	2	1	2	4
107	3	3	4	36	5	2	999	4	4	3	3	4	4	5	2	4	3	3	4	3	1	2	4
108	4	3	2	12	5	2	999	4	4	3	4	4	4	4	4	4	3	3	4	3	1	2	4
109	4	3	1.5	12	5	2	999	4	4	3	3	4	4	5	2	4	3	3	4	3	1	2	2
110	3	3	5	24	5	2	999	4	4	4	4	2	4	4	4	4	4	3	4	3	4	4	4
111	3	3	6	33	3	2	999	3	3	3	4	3	4	2	4	4	1	2	2	2	3	3	4
112	4	99	1.5	11	5	1	2	4	4	4	3	4	4	4	4	3	4	4	4	1	4	3	5
113	4	99	5.5	20	5	1	2	3	3	4	4	3	4	4	4	4	4	3	3	2	4	4	5
114	4	99	2	13	5	1	3	4	4	4	3	2	4	4	4	3	4	4	4	1	4	3	4
115	4	99	5	24	5	1	4	5	4	4	4	4	4	4	4	4	4	3	4	2	4	3	4

ID	Rank	CofC	Seatime	AIStime	AISdis	Training	Traintype	SQ1	SQ2	SQ3	SQ4	SQ5	SQ6	SQ7	SQ8	SQ9	SQ10	SQ11	SQ12	SQ13	SE1	SE2	SE3
116	3	99	8	24	5	1	2	5	4	4	4	4	4	4	5	4	4	3	4	2	4	3	5

ID	PU1	PU2	PU3	PU4	PU5	PU6	PU7	PU8	PU9	PU10	PEOU1	PEOU2	PEOU3	PEOU4	AISUS1	AISUS2	AISUS3	AISUS4	TSQ	TSE	TPU	TPEOU	TAISUS
1	4	4	4	3	4	4	4	4	4	4	4	2	4	4	3	4	2	3	3.69	.	3.9	3.5	3
2	5	4	3	4	4	4	2	4	2	4	3	4	4	3	3	3	2	4	3	3.67	3.6	3.5	3
3	4	3	4	3	3	2	4	3	4	4	4	2	4	4	4	2	3	5	2.69	4	3.4	3.5	3.5
4	4	3	2	3	3	2	4	3	4	2	4	2	4	4	4	2	3	5	2.69	2.67	3	3.5	3.5
5	5	5	5	3	3	3	2	5	4	3	5	4	4	4	4	4	2	2	3.85	3.67	3.8	4.25	3
6	4	3	4	2	4	4	4	4	5	3	3	4	3	4	4	3	4	4	2.85	3.67	3.7	3.5	3.75
7	5	4	4	4	4	4	4	2	4	4	3	3	4	4	4	4	3	4	3.08	2.67	3.9	3.5	3.75
8	3	5	4	4	4	4	2	3	4	4	3	3	2	3	3	5	2	3	3.85	2.67	3.7	2.75	3.25
9	4	4	4	4	3	3	2	5	4	2	4	3	3	4	3	3	2	4	3.15	.	3.5	3.5	3
10	4	5	4	4	4	4	4	4	4	4	4	4	4	4	3	4	3	3	3.85	4	4.1	4	3.25
11	4	4	4	4	4	4	3	4	5	4	4	3	3	3	3	2	4	4	4	3.33	4	3.25	3.25
12	4	3	4	4	4	4	3	3	3	3	3	2	4	4	4	3	4	4	.	3.67	3.5	3.25	3.75
13	3	2	3	4	4	4	2	4	4	4	3	2	4	4	2	2	4	4	3.46	.	3.4	3.25	3
14	3	2	3	4	5	5	2	4	4	3	4	2	4	4	2	2	4	2	3.62	.	3.5	3.5	2.5
15	5	5	5	5	5	5	2	4	4	4	3	4	3	3	5	5	5	5	3.62	3	4.4	3.25	5
16	4	4	4	4	4	4	3	4	4	4	3	4	4	4	3	3	3	3	3.15	.	3.9	3.75	3
17	4	4	4	2	4	4	4	4	5	3	3	3	3	4	3	4	2	3	3.08	3.67	3.8	3.25	3
18	4	3	4	2	4	4	4	4	5	3	3	4	3	4	4	3	4	4	2.85	3.67	3.7	3.5	3.75
19	5	5	5	5	5	5	3	3	4	3	3	4	4	4	5	5	5	5	3.46	3	4.3	3.75	5
20	4	3	3	4	4	4	4	3	2	2	3	4	3	4	4	2	3	4	3.46	3	3.3	3.5	3.25
21	4	5	5	4	3	2	4	5	5	4	4	4	3	4	5	4	4	4	3.46	3	4.1	3.75	4.25
22	5	5	4	2	1	1	3	4	4	2	2	3	3	4	2	2	2	2	.	4.33	3.1	3	2
23	4	5	5	2	1	1	3	4	5	3	4	4	4	5	5	5	4	4	3.54	4.33	3.3	4.25	4.5
24	4	4	4	5	4	4	4	4	4	4	3	3	2	4	2	4	2	4	3.54	3.67	4.1	3	3
25	3	3	2	4	4	5	4	4	5	4	3	2	2	2	4	3	1	4	2.38	3.33	3.8	2.25	3
26	4	3	3	4	4	4	4	3	2	2	4	4	4	4	4	2	3	4	3.46	3	3.3	4	3.25
27	4	3	3	4	4	4	4	3	2	2	3	3	3	3	4	2	3	4	3.46	3	3.3	3	3.25
28	4	3	3	4	4	4	4	3	2	2	4	4	4	4	4	2	3	4	3.46	3	3.3	4	3.25
29	5	5	5	5	5	5	5	5	4	3	2	4	3	3	4	3	4	2	4	4	4.7	3	3.25
30	5	5	5	5	5	5	5	5	4	3	4	4	4	4	3	3	2	5	3.31	4	4.7	4	3.25
31	4	5	4	4	4	5	4	5	5	4	3	4	4	4	5	5	3	5	3.31	.	4.4	3.75	4.5
32	5	5	5	4	5	4	4	4	5	4	3	5	4	5	5	5	4	5	3.31	5	4.5	4.25	4.75
33	3	4	3	3	4	4	4	4	3	4	5	4	5	4	2	3	4	3	3.23	.	3.6	4.5	3
34	4	3	4	2	3	2	4	3	2	2	4	4	3	4	2	4	3	4	3.15	.	2.9	3.75	3.25
35	4	2	2	3	3	3	3	3	3	2	2	3	4	3	3	2	2	3	2.46	3	2.8	3	2.5

ID	PU1	PU2	PU3	PU4	PU5	PU6	PU7	PU8	PU9	PU10	PEOU1	PEOU2	PEOU3	PEOU4	AISUS1	AISUS2	AISUS3	AISUS4	TSQ	TSE	TPU	TPEOU	TAISUS
36	4	2	4	4	2	2	4	4	1	1	1	4	4	4	2	2	3	2	3.08	.	2.8	3.25	2.25
37	4	4	4	4	4	4	4	5	2	2	4	4	4	4	4	2	3	3	3	.	3.7	4	3
38	3	3	3	3	3	3	5	5	5	1	2	2	3	3	3	3	5	3	2.54	3.67	3.4	2.5	3.5
39	4	3	3	3	4	4	4	4	3	3	2	5	4	4	3	3	4	3	3.23	2.67	3.5	3.75	3.25
40	4	2	2	2	3	3	3	3	5	2	2	3	3	2	2	2	2	3	2.46	2.67	2.9	2.5	2.25
41	5	4	2	4	4	4	5	3	4	3	5	5	3	5	4	1	2	2	3	.	3.8	4.5	2.25
42	4	2	2	3	3	3	4	4	3	3	4	4	3	4	3	2	2	3	2.85	.	3.1	3.75	2.5
43	4	3	4	3	3	4	1	3	4	2	4	4	4	5	3	3	4	2	3.31	.	3.1	4.25	3
44	4	3	4	3	4	4	1	3	4	2	4	4	4	5	3	3	4	2	3.31	.	3.2	4.25	3
45	4	3	3	3	3	2	4	4	4	1	4	4	4	3	4	4	3	4	3.31	.	3.1	3.75	3.75
46	4	3	4	4	5	4	4	4	4	99	3	4	4	4	3	4	4	3	3.31	.	.	3.75	3.5
47	3	3	3	4	2	3	3	3	3	3	4	3	4	3	4	4	3	4	3.15	.	3	3.5	3.75
48	3	3	3	4	2	3	3	3	3	3	4	3	4	3	4	4	4	3	3.23	.	3	3.5	3.75
49	4	4	3	3	2	2	4	4	4	4	3	2	2	3	3	3	4	2	3.62	4	3.4	2.5	3
50	1	2	1	4	5	5	5	2	2	1	2	3	3	3	1	1	5	4	3.54	.	2.8	2.75	2.75
51	3	4	4	3	3	4	5	4	4	3	3	4	4	4	4	2	3	4	3	.	3.7	3.75	3.25
52	4	4	4	4	4	3	4	2	4	4	4	4	4	4	4	4	3	4	3.15	.	3.7	4	3.75
53	5	5	5	99	5	5	5	5	99	99	5	4	4	5	5	5	3	5	.	.	.	4.5	4.5
54	5	5	4	4	4	4	2	4	2	3	4	4	4	3	5	5	5	5	3.46	.	3.7	3.75	5
55	5	5	4	4	5	5	2	5	5	5	5	5	5	5	5	5	5	5	4.31	.	4.5	5	5
56	4	3	4	3	4	4	2	2	4	3	3	3	4	4	4	3	4	4	3.54	.	3.3	3.5	3.75
57	5	5	4	4	4	2	2	4	2	2	4	3	3	2	5	5	4	4	3.08	2.33	3.4	3	4.5
58	5	5	5	4	5	4	2	4	5	5	2	3	2	4	2	4	2	3	3.69	.	4.4	2.75	2.75
59	4	4	4	4	4	4	2	4	4	4	4	4	3	4	4	4	4	4	4	.	3.8	3.75	4
60	5	4	4	4	5	4	4	4	4	3	3	3	4	3	4	4	4	4	3.46	.	4.1	3.25	4
61	4	2	3	4	3	2	1	4	4	2	4	4	4	4	2	2	3	4	3.15	1.33	2.9	4	2.75
62	4	3	3	3	3	3	4	3	3	3	2	3	4	3	3	3	4	4	2.92	3	3.2	3	3.5
63	5	5	5	5	4	5	4	5	5	4	5	5	5	5	5	3	5	5	4.23	.	4.7	5	4.5
64	5	5	5	3	5	5	4	5	5	5	3	5	5	5	5	5	4	5	4.15	.	4.7	4.5	4.75
65	2	2	4	3	2	4	3	3	4	1	3	4	3	3	3	3	4	4	2.92	4	2.8	3.25	3.5
66	3	2	2	2	3	3	2	2	3	3	1	3	3	3	2	2	1	2	2.54	.	2.5	2.5	1.75
67	4	4	2	3	4	4	2	4	3	1	2	2	3	2	4	2	2	2	3.77	3.33	3.1	2.25	2.5
68	4	3	3	2	2	2	4	3	2	3	5	4	4	4	3	3	4	4	3.23	3.67	2.8	4.25	3.5
69	2	2	2	3	3	2	2	2	2	2	2	3	3	3	2	2	1	2	2.92	.	2.2	2.75	1.75
70	4	2	2	3	4	4	2	2	3	4	4	4	4	4	2	2	4	2	3.77	1.33	3	4	2.5
71	5	4	3	3	2	2	3	5	5	3	2	4	4	4	4	4	3	3	2.69	4.67	3.5	3.5	3.5
72	3	3	4	4	4	2	4	3	1	3	4	4	5	5	4	3	2	1	3.85	.	3.1	4.5	2.5
73	5	4	4	3	4	4	4	4	4	2	2	3	3	3	4	4	4	4	3.77	3.33	3.8	2.75	4
74	5	3	4	4	4	4	3	3	4	4	3	2	3	3	3	4	4	4	3.62	3.33	3.8	2.75	3.75
75	5	4	4	4	3	3	4	5	4	3	2	2	3	4	5	4	3	4	3.23	3.33	3.9	2.75	4

ID	PU1	PU2	PU3	PU4	PU5	PU6	PU7	PU8	PU9	PU10	PEOU1	PEOU2	PEOU3	PEOU4	AISUS1	AISUS2	AISUS3	AISUS4	TSQ	TSE	TPU	TPEOU	TAISUS
76	4	4	4	2	3	3	4	4	4	3	3	4	4	4	4	4	4	3	3.31	4	3.5	3.75	3.75
77	5	4	4	4	3	3	4	5	4	3	5	4	4	4	5	4	3	4	3.23	3.33	3.9	4.25	4
78	5	4	4	4	3	3	4	5	4	3	3	3	3	4	5	4	3	4	3.23	3.33	3.9	3.25	4
79	5	4	4	4	4	3	4	5	4	4	4	5	4	4	5	4	3	4	3.15	.	4.1	4.25	4
80	5	4	4	3	4	4	2	3	3	4	3	3	4	3	4	4	5	4	3.54	2.33	3.6	3.25	4.25
81	4	4	4	4	4	4	2	3	3	4	2	3	3	3	4	4	4	4	3.69	2.33	3.6	2.75	4
82	4	4	3	3	1	4	2	3	3	4	2	4	2	4	4	4	5	4	3.54	1.67	3.1	3	4.25
83	5	3	3	3	4	4	2	3	3	4	3	3	3	4	4	4	5	3	3.31	2.33	3.4	3.25	4
84	5	5	5	5	5	5	5	5	5	1	4	5	5	5	5	5	4	5	3.77	.	4.6	4.75	4.75
85	5	5	5	5	5	5	5	5	5	1	4	5	5	5	5	5	4	5	4.54	.	4.6	4.75	4.75
86	5	5	5	5	5	5	5	5	5	1	4	5	5	5	5	5	4	5	3.77	.	4.6	4.75	4.75
87	4	4	4	2	2	2	2	4	5	3	3	2	4	4	4	4	4	4	3.15	3	3.2	3.25	4
88	4	5	4	4	4	4	4	4	4	4	4	2	4	4	5	4	4	4	3.31	3	4.1	3.5	4.25
89	4	4	3	4	2	2	3	4	3	3	4	2	5	5	4	3	4	4	3.08	.	3.2	4	3.75
90	4	4	3	4	4	4	4	5	4	4	4	4	4	5	4	4	4	4	3.62	.	4	4.25	4
91	4	4	2	5	5	5	2	5	4	2	4	5	4	4	4	3	2	4	3.46	.	3.8	4.25	3.25
92	4	4	4	4	4	4	4	4	4	4	4	4	5	4	4	3	4	3	3.38	3.33	4	4.25	3.5
93	4	5	4	4	4	4	4	4	4	4	4	2	4	4	5	4	4	4	3.31	2.67	4.1	3.5	4.25
94	4	4	4	2	2	2	2	4	5	3	3	2	4	4	4	4	4	4	3.15	2.67	3.2	3.25	4
95	4	4	5	4	4	4	3	4	4	3	3	4	4	4	4	4	4	4	3.38	.	3.9	3.75	4
96	4	4	5	4	4	5	3	5	5	4	4	4	5	4	2	4	5	5	3.54	.	4.3	4.25	4
97	5	5	5	5	5	5	3	5	5	4	4	5	4	5	2	4	3	2	3.54	.	4.7	4.5	2.75
98	5	5	5	4	4	5	3	5	5	4	5	5	4	4	4	4	5	5	3.54	.	4.5	4.5	4.5
99	4	4	4	2	4	4	2	4	4	4	3	4	4	4	4	4	4	4	3.46	1.67	3.6	3.75	4
100	4	2	3	4	3	3	3	4	4	3	4	4	4	4	3	2	4	3	3.31	2.67	3.3	4	3
101	5	4	4	3	2	2	3	4	4	3	3	2	4	3	4	4	3	3	3.38	.	3.4	3	3.5
102	3	4	4	4	3	4	4	4	4	4	3	4	3	2	4	2	5	4	3.31	3.33	3.8	3	3.75
103	4	3	4	3	4	5	2	4	4	4	4	2	3	3	4	3	3	4	3.31	.	3.7	3	3.5
104	4	4	4	3	4	4	4	5	3	3	3	3	4	4	3	3	3	4	3.46	3	3.8	3.5	3.25
105	4	4	5	4	4	4	3	4	4	3	3	4	4	4	4	4	3	4	3.38	.	3.9	3.75	3.75
106	5	3	3	3	4	4	2	3	3	4	4	4	4	4	4	4	4	3	3.31	2.33	3.4	4	3.75
107	5	4	4	3	4	4	2	3	3	4	4	4	4	4	4	4	5	4	3.54	2.33	3.6	4	4.25
108	4	4	4	4	4	4	2	3	3	4	4	4	4	4	4	4	4	4	3.69	2.33	3.6	4	4
109	4	4	3	3	1	4	2	3	3	4	2	4	2	4	4	4	5	4	3.54	1.67	3.1	3	4.25
110	5	5	5	4	4	4	5	4	4	3	4	4	4	4	9	5	3	3	3.69	4	4.3	4	5
111	4	3	3	5	5	4	3	4	4	4	4	3	4	4	3	3	3	3	2.85	3.33	3.9	3.75	3
112	4	4	4	3	5	4	4	5	4	2	4	5	5	5	4	4	3	3	3.62	4	3.9	4.75	3.5
113	4	4	4	4	4	4	4	4	4	3	4	4	4	5	4	3	3	4	3.46	4.33	3.9	4.25	3.5
114	4	4	4	3	4	4	4	5	4	2	4	5	5	5	4	4	2	4	3.46	3.67	3.8	4.75	3.5
115	4	4	4	2	5	5	4	5	4	4	2	4	4	4	5	4	5	5	3.85	3.67	4.1	3.5	4.75

ID	PU1	PU2	PU3	PU4	PU5	PU6	PU7	PU8	PU9	PU10	PEOU1	PEOU2	PEOU3	PEOU4	AISUS1	AISUS2	AISUS3	AISUS4	TSQ	TSE	TPL	TPEOU	TAISUS
116	4	5	4	2	4	4	4	5	4	4	2	4	5	5	4	4	2	4	3.92	4	4	4	3.5

C.2 Statistics and Frequency Tables for Total Scores (TSQ, TSE, TPU, TPEOU, and TAISUS)

N	Valid	113
	Missing	3
Mean		3.3710
Median		3.3846
Std. Deviation		.38970
Skewness		-.037
Std. Error of Skewness		.227
Kurtosis		.614
Std. Error of Kurtosis		.451
Minimum		2.38
Maximum		4.54

Statistics (Total System Quality)

		Frequency	Percent	Valid Percent	Cumulative
Valid	2.38	1	.9	.9	.9
	2.46	2	1.7	1.8	2.7
	2.54	2	1.7	1.8	4.4
	2.69	3	2.6	2.7	7.1
	2.85	4	3.4	3.5	10.6
	2.92	3	2.6	2.7	13.3
	3.00	4	3.4	3.5	16.8
	3.08	5	4.3	4.4	21.2
	3.15	9	7.8	8.0	29.2
	3.23	7	6.0	6.2	35.4
	3.31	15	12.9	13.3	48.7
	3.38	4	3.4	3.5	52.2
	3.46	14	12.1	12.4	64.6
	3.54	11	9.5	9.7	74.3
	3.62	6	5.2	5.3	79.6
	3.69	5	4.3	4.4	84.1
	3.77	5	4.3	4.4	88.5
	3.85	5	4.3	4.4	92.9
	3.92	1	.9	.9	93.8
	4.00	3	2.6	2.7	96.5
	4.15	1	.9	.9	97.3
	4.23	1	.9	.9	98.2
	4.31	1	.9	.9	99.1
	4.54	1	.9	.9	100.0
	Total	113	97.4	100.0	
Missing	System	3	2.6		
Total		116	100.0		

Frequencies (Total System Quality)

N	Valid	69
	Missing	47
Mean		3.2029
Median		3.3333
Std. Deviation		.76955
Skewness		-.346
Std. Error of Skewness		289
Kurtosis		082
Std. Error of Kurtosis		.570
Minimum		1.33
Maximum		5.00

Statistics (Total Self Efficacy)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.33	2	1.7	2.9	2.9
	1.67	3	2.6	4.3	7.2
	2.33	7	6.0	10.1	17.4
	2.67	8	6.9	11.6	29.0
	3.00	12	10.3	17.4	46.4
	3.33	11	9.5	15.9	62.3
	3.67	11	9.5	15.9	78.3
	4.00	10	8.6	14.5	92.8
	4.33	3	2.6	4.3	97.1
	4.67	1	.9	1.4	98.6
	5.00	1	.9	1.4	100.0
	Total	69	59.5	100.0	
Missing	System	47	40.5		
Total		116	100.0		

Frequencies (Total Self Efficacy)

N	Valid	114
	Missing	2
Mean		3.6553
Median		3.7000
Std. Deviation		.53017
Skewness		.040
Std. Error of Skewness		.226
Kurtosis		-.304
Std. Error of Kurtosis		.449
Minimum		2.20
Maximum		4.70

Statistics (Total Perceived Usefulness)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2.20	1	.9	.9	.9
	2.50	1	.9	.9	1.8
	2.80	5	4.3	4.4	6.1
	2.90	3	2.6	2.6	8.8
	3.00	4	3.4	3.5	12.3
	3.10	8	6.9	7.0	19.3
	3.20	5	4.3	4.4	23.7
	3.30	7	6.0	6.1	29.8
	3.40	8	6.9	7.0	36.8
	3.50	6	5.2	5.3	42.1
	3.60	7	6.0	6.1	48.2
	3.70	8	6.9	7.0	55.3
	3.80	11	9.5	9.6	64.9
	3.90	11	9.5	9.6	74.6
	4.00	4	3.4	3.5	78.1
	4.10	8	6.9	7.0	85.1
	4.30	3	2.6	2.6	87.7
	4.40	3	2.6	2.6	90.4
	4.50	3	2.6	2.6	93.0
	4.60	3	2.6	2.6	95.6
	4.70	5	4.3	4.4	100.0
	Total	114	98.3	100.0	
Missing	System	2	1.7		
Total		116	100.0		

Frequencies (Total Perceived Usefulness)

N	Valid	116
	Missing	0
Mean		3.6379
Median		3.7500
Std. Deviation		.62323
Skewness		-.023
Std. Error of Skewness		.225
Kurtosis		-.537
Std. Error of Kurtosis		.446
Minimum		2.25
Maximum		5.00

Statistics (Total Perceived Ease of Use)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2.25	2	1.7	1.7	1.7
	2.50	4	3.4	3.4	5.2
	2.75	8	6.9	6.9	12.1
	3.00	12	10.3	10.3	22.4
	3.25	13	11.2	11.2	33.6
	3.50	18	15.5	15.5	49.1
	3.75	17	14.7	14.7	63.8
	4.00	15	12.9	12.9	76.7
	4.25	13	11.2	11.2	87.9
	4.50	7	6.0	6.0	94.0
	4.75	5	4.3	4.3	98.3
	5.00	2	1.7	1.7	100.0
	Total	116	100.0	100.0	

Frequencies (Total Perceived Ease of Use)

N	Valid	116
	Missing	0
Mean		3.5754
Median		3.5000
Std. Deviation		.72847
Skewness		-.090
Std. Error of Skewness		.225
Kurtosis		-.224
Std. Error of Kurtosis		446
Minimum		1.75
Maximum		5.00

Statistics (Total AIS User Satisfaction)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.75	2	1.7	1.7	1.7
	2.00	1	.9	.9	2.6
	2.25	3	2.6	2.6	5.2
	2.50	6	5.2	5.2	10.3
	2.75	4	3.4	3.4	13.8
	3.00	16	13.8	13.8	27.6
	3.25	14	12.1	12.1	39.7
	3.50	15	12.9	12.9	52.6
	3.75	15	12.9	12.9	65.5
	4.00	16	13.8	13.8	79.3
	4.25	7	6.0	6.0	85.3
	4.50	6	5.2	5.2	90.5
	4.75	6	5.2	5.2	95.7
	5.00	5	4.3	4.3	100.0
	Total	116	100.0	100.0	

Frequencies (Total AIS User Satisfaction)

C.3 Table of Z-Scores for Each Variable (TSQ, TSE, TPU, TPEOU, and TAISUS)

ID	ZTSQ	ZTSE	ZTPU	ZTPEOU	ZTAISUS
1	1.07332	.	0.46162	-0.07988	0.35464
2	-1.28938	.	-0.10424	-0.44457	0.35464
3	-2.33947	.	-0.48148	-0.44457	-0.31857
4	-2.33947	.	-1.23595	-0.44457	-0.31857
5	1.59837	.	0.273	0.28481	.
6	-1.81443	-0.25206	0.08438	-0.44457	0.01803
7	-1.02686	-2.10046	0.46162	-0.44457	0.01803
8	1.59837	0.36408	0.08438	-0.07988	1.36445
9	-0.76434	.	-0.29286	-0.44457	.
10	1.59837	0.36408	0.83886	-1.53864	1.36445
11	2.12341	.	0.65024	0.28481	-0.65518
12	.	-0.25206	-0.29286	-0.80926	0.01803
13	0.28575	.	-0.48148	-1.53864	-0.99178
14	0.8108	.	-0.29286	-1.90333	-1.66499
15	0.8108	.	1.40472	-1.17395	1.70105
16	-0.76434	.	0.46162	-1.53864	0.35464
17	-1.02686	-0.25206	0.273	-0.80926	0.35464
18	-1.81443	-0.25206	0.08438	-0.44457	0.01803
19	0.28575	.	1.2161	0.28481	1.70105
20	0.28575	.	-0.6701	0.28481	-0.65518
21	0.28575	-1.48432	0.83886	-0.07988	0.69124
22	.	0.98021	-1.04733	0.6495	0.35464
23	0.54828	0.98021	-0.6701	1.01419	1.02785
24	0.54828	.	0.83886	0.6495	-0.31857
25	-0.50181	.	0.273	-1.53864	-0.99178
26	0.28575	.	-0.6701	0.28481	-0.65518
27	0.28575	.	-0.6701	0.28481	-0.65518
28	0.28575	.	-0.6701	0.28481	-0.65518
29	0.02323	.	1.97058	0.6495	1.36445
30	-0.23929	.	1.97058	-0.44457	1.36445
31	-0.23929	.	1.40472	0.6495	1.02785
32	-0.23929	2.21248	1.59334	1.37888	1.36445
33	-0.50181	.	-0.10424	1.37888	-0.31857
34	-0.76434	.	-1.42457	-0.07988	-0.65518
35	-1.02686	.	-1.61319	-1.53864	-1.66499
36	0.28575	.	-1.61319	.	-2.00159
37	-1.28938	.	0.08438	0.6495	-0.31857
38	0.02323	.	-0.48148	-1.90333	-0.31857
39	-0.50181	.	-0.29286	0.28481	-0.65518
40	-0.23929	.	-1.42457	-1.53864	-2.00159
41	-1.28938	.	0.273	1.74357	-2.00159
42	-1.81443	.	-1.04733	-1.17395	-1.66499
43	-0.23929	.	-1.04733	.	-0.99178
44	-0.23929	.	-0.85871	.	-0.99178
45	-0.23929	.	-1.04733	.	0.01803
46	-0.23929	.	.	1.01419	-0.65518
47	-0.76434	.	-1.23595	-0.44457	-0.65518
48	-0.50181	.	-1.23595	-0.44457	-0.65518
49	0.8108	0.36408	-0.48148	0.28481	-1.32838
50	0.54828	.	-1.61319	.	-1.32838
51	-1.28938	.	0.08438	-0.07988	-0.65518
52	-0.76434	.	0.08438	0.28481	0.01803
53	.	.	.	.	1.02785

ID	ZTSQ	ZTSE	ZTPU	ZTPEOU	ZTAISUS
54	0.28575	.	0.08438	.	1.70105
55	1.07332	.	1.59334	1.74357	1.70105
56	0.54828	.	-0.6701	-0.44457	0.01803
57	-1.02686	.	-0.48148	-1.53864	1.02785
58	1.07332	.	1.40472	0.6495	1.70105
59	0.02323	.	0.273	-0.07988	0.35464
60	0.28575	.	0.83886	.	-0.31857
61	-0.76434	.	-1.42457	-1.90333	-1.32838
62	-1.5519	-1.48432	-0.85871	-1.17395	-0.31857
63	1.33585	.	1.97058	1.74357	1.02785
64	1.59837	.	1.97058	1.74357	1.36445
65	-1.5519	0.36408	-1.61319	-0.07988	-0.31857
66	-0.76434	.	-2.17905	.	.
67	-0.23929	.	-1.04733	-1.53864	-1.66499
68	-0.50181	.	-1.61319	-0.07988	.
69	-1.5519	.	-2.74491	.	-2.6748
70	1.33585	.	-1.23595	-0.07988	-1.66499
71	-2.33947	1.59635	-0.29286	-0.80926	-0.31857
72	1.59837	.	-1.04733	.	-1.66499
73	1.33585	.	0.273	0.6495	0.35464
74	0.8108	.	0.273	1.01419	0.01803
75	-0.50181	.	0.46162	-1.17395	0.35464
76	-0.23929	0.36408	-0.29286	0.28481	0.01803
77	-0.50181	.	0.46162	0.6495	0.35464
78	-0.50181	.	0.46162	-1.17395	0.35464
79	-0.76434	.	0.83886	0.6495	0.01803
80	0.54828	.	-0.10424	-0.80926	0.69124
81	1.07332	.	-0.10424	0.6495	0.35464
82	0.54828	.	-1.04733	-0.80926	0.69124
83	-0.23929	.	-0.48148	0.6495	0.35464
84	1.86089	.	1.78196	1.74357	1.36445
85	1.86089	.	1.78196	1.74357	1.36445
86	1.86089	.	1.78196	1.74357	1.36445
87	-0.76434	.	-0.85871	-1.17395	-0.31857
88	-0.23929	.	0.83886	-0.44457	0.69124
89	-1.02686	.	-0.85871	-0.07988	-0.65518
90	0.8108	.	0.65024	1.01419	0.35464
91	0.28575	.	0.273	-1.53864	-0.65518
92	0.02323	.	0.65024	0.6495	-0.31857
93	-0.23929	.	0.83886	-0.44457	0.69124
94	-0.76434	.	-0.85871	-1.17395	-0.65518
95	0.02323	.	0.46162	-0.44457	0.35464
96	0.54828	.	1.2161	-0.07988	-0.31857
97	0.54828	.	1.97058	2.10826	1.70105
98	0.54828	.	1.59334	2.10826	1.02785
99	0.28575	-0.25206	-0.10424	-0.07988	0.35464
100	-0.23929	.	-0.6701	0.28481	-0.99178
101	0.02323	.	-0.48148	0.6495	-0.31857
102	-0.23929	.	0.273	-1.17395	0.01803
103	-0.23929	.	0.08438	0.6495	-0.31857
104	0.28575	.	0.273	-0.07988	-0.65518
105	0.02323	.	0.46162	-0.44457	-0.65518
106	-0.23929	.	-0.48148	0.6495	0.35464
107	0.54828	.	-0.10424	-0.44457	0.69124
108	1.07332	.	-0.10424	0.6495	-1.32838
109	0.54828	.	-1.04733	-0.80926	0.69124
110	1.07332	.	1.2161	0.6495	1.70105
111	-1.81443	.	0.46162	0.28481	-0.99178

ID	ZTSQ	ZTSE	ZTPU	ZTPEOU	ZTAISUS
112	0.8108	0.36408	0.46162	1.74357	0.35464
113	0.28575	-0.86819	0.46162	1.01419	0.35464
114	0.28575	-0.86819	0.273	1.74357	0.35464
115	1.59837	-0.25206	0.83886	-0.07988	1.36445
116	1.86089	0.36408	0.65024	-0.44457	1.70105

C.4 Descriptive Table for Total Scores of Each Variable

			Statistic	Std. Error
Total System Quality	Mean		3.3710	.03666
	95% Confidence Interval	Lower Bound	3.2984	
		Upper Bound	3.4436	
	5% Trimmed Mean		3.3722	
	Median		3.3846	
	Variance		.152	
	Std. Deviation		.38970	
	Minimum		2.38	
	Maximum		4.54	
	Range		2.15	
	Interquartile Range		.46	
	Skewness		-.037	.227
	Kurtosis		.614	.451
Total Self Efficacy	Mean		3.2029	.09264
	95% Confidence Interval	Lower Bound	3.0180	
		Upper Bound	3.3878	
	5% Trimmed Mean		3.2201	
	Median		3.3333	
	Variance		.592	
	Std. Deviation		.76955	
	Minimum		1.33	
	Maximum		5.00	
	Range		3.67	
	Interquartile Range		1.00	
	Skewness		-.346	.289
	Kurtosis		.082	.570
Total Perceived Usefulness	Mean		3.6553	.04965
	95% Confidence Interval	Lower Bound	3.5569	
		Upper Bound	3.7536	
	5% Trimmed Mean		3.6542	
	Median		3.7000	
	Variance		.281	
	Std. Deviation		.53017	
	Minimum		2.20	
	Maximum		4.70	
	Range		2.50	
	Interquartile Range		.70	
	Skewness		.040	.226
	Kurtosis		-.304	.449
Total Perceived Ease of Use	Mean		3.6379	.05787
	95% Confidence Interval	Lower Bound	3.5233	
		Upper Bound	3.7526	
	5% Trimmed Mean		3.6394	
	Median		3.7500	
	Variance		.388	
	Std. Deviation		.62323	
	Minimum		2.25	
	Maximum		5.00	
	Range		2.75	
	Interquartile Range		.75	
	Skewness		-.023	.225
	Kurtosis		-.537	.446
Total AIS User Satisfaction	Mean		3.5754	.06764
	95% Confidence Interval	Lower Bound	3.4415	
		Upper Bound	3.7094	
	5% Trimmed Mean		3.5838	
	Median		3.5000	
	Variance		.531	
	Std. Deviation		.72847	
	Minimum		1.75	
	Maximum		5.00	
	Range		3.25	
	Interquartile Range		1.00	
	Skewness		-.090	.225
	Kurtosis		-.224	.446

C.5 Table for Frequencies of Absolute Z-Scores for Each Variable (TSQ, TSE, TPU, TPEOU, and TAISUS)

Total System Quality

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Absolute z-score less than 2	104	89.7	92.0	92.0
	Absolute z-score grater than 1.96	8	6.9	7.1	99.1
	Absolute z-score greater than 2.58	1	.9	.9	100.0
	Total	113	97.4	100.0	
Missing	System	3	2.6		
Total		116	100.0		

Total Self-Efficacy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Absolute z-score less than 2	63	54.3	91.3	91.3
	Absolute z-score grater than 1.96	6	5.2	8.7	100.0
	Total	69	59.5	100.0	
Missing	System	47	40.5		
Total		116	100.0		

Total Perceived Usefulness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Absolute z-score less than 2	107	92.2	93.9	93.9
	Absolute z-score grater than 1.96	6	5.2	5.3	99.1
	Absolute z-score greater than 2.58	1	.9	.9	100.0
	Total	114	98.3	100.0	
Missing	System	2	1.7		
Total		116	100.0		

Total Perceived Ease of Use

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Absolute z-score less than 2	112	96.6	96.6	96.6
	Absolute z-score grater than 1.96	4	3.4	3.4	100.0
	Total	116	100.0	100.0	

Total AIS User Satisfaction

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Absolute z-score less than 2	113	97.4	97.4	97.4
	Absolute z-score grater than 1.96	3	2.6	2.6	100.0
	Total	116	100.0	100.0	