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Assessing the competency of seafarers using simulators in bridge resource management (BRM) training

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ASSESSING THE COMPETENCY OF SEAFARERS USING SIMULATORS IN BRIDGE RESOURCE MANAGEMENT (BRM) TRAINING

By

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DISSERTATION DECLARATION FORM

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

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

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ABSTRACT

Title of Dissertation : **Assessing the Competency of Seafarers Using Simulators in Bridge Resource Management (BRM) Training**

Degree : **MSc**

This dissertation aims to assess the Bridge Resource Management (BRM) competency of seafarers by instructors in simulator-based training. It is intended that the results can serve as a support for implementing International Convention on Standards of Training, Certification and Watch keeping for Seafarers (the STCW Convention) and Seafarers' Training, Certification and Watchkeeping Code (the STCW Code) by designing the scenarios and assessments which can aid in achieving the relevant competencies through simulator-based training.

A brief look is taken at present methods of assessing seafarer competency in BRM tasks in the maritime field, and at the historical developments behind them. The definition and effects of BRM and the combination of soft skills and hard skills in BRM simulator-based training are considered. The assessment elements and their weights as contributory parts to a final assessment score are researched, and the respective weights of the different assessment elements are determined using the Analytic Hierarchy Process (AHP) method. Finally, the outcome of this researching is the development of BRM simulator-based training and the training scenarios design methodology in different training centers of maritime countries.

The STCW Code defines the range of BRM soft skills that seafarers at the operational level should be trained in and assessed for. When using simulators for such training and assessment, there is a need to define and establish relevant criteria in respect of competencies and methods of teaching and assessment. This research attempts to explore an approach to define and establish such criteria and to align these to practical activities.

The concluding chapters examine the results of the assessment method, and discuss the implications of the work as well as its limitations. A number of recommendations are also made concerning the need for further research in the subject area.

KEY WORDS: Assessment, Competency, BRM, Soft skills, Simulator, Training

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ARPA	Automatic Radar Plotting Aid
BRM	Bridge Resources Management
COLREGS	International Regulations for Preventing Collisions at Sea
DCPA	Distance at the Closest Point of Approach
DMU	Dalian Maritime University
EMSA	European Maritime Safety Agency
GPS	Global Positioning System
GRA	Grey Relational Analysis
HF&E	Human Factors and Ergonomics
HTW	Human Element, Training and Watchkeeping
IBS	Integrated Bridge System
IMO	International Maritime Organization
MET	Maritime Education and Training
MSC	Maritime Safety Committee
OOW	Officer on Watch
ROC	Risk of Collision
SA	Situational Awareness
SAS	Scandinavian Airline Systems
SMU	Shanghai Maritime University
STCW	International Convention on Standards of Training, Certification and Watch keeping for Seafarers
TSS	Traffic Separation Scheme
VTS	Vessel Traffic Service

1. Chapter I - General introduction

1.1. General background

Assessing competencies is an important part of the philosophy on which the STCW Convention is based (IMO, 2017a). The 2010 Manila Amendments to STCW Convention and Code (Part A, Chapter II – "Master and deck department"-Table A-II/1 regarding the Function: Navigation at the operational level), requires that competencies in both soft skills and hard skills be demonstrated by relevant methods (IMO, 2010). The methods suggested by the STCW Code for demonstrating competency include approved training ship experience, approved in-service experience and approved simulator training. Simulator training is the emphasis/focus of this research with the view of contributing to the development of reliable, valid, feasible and objective assessment methods for soft skills and hard skills. Aiming at this outcome, an integrated and systematic BRM competency training, the methodology of which is based on scenarios and assessment sheet, has been designed for simulator-based BRM training. The original thinking of BRM training is based on the statement of BRM in the STCW Code, so the general introduction starts here with a discussion of BRM in the STCW Code.

1.1.1. Background of BRM

It is obvious that the reliability of maritime technology is increasing gradually

(Kristiansen, 1995). However, good maritime education and training (MET) is still critical to the success of the maritime industry, not only because, currently, the operation of technological equipment needs to be done by humans, but also because human factors are still key contributors to the causation of maritime incidents and accidents (Ando, 2006). Seafarers have to be educated and trained according to the criteria in the International Convention on Standards of Training, Certification and Watch keeping for Seafarers (the STCW Convention) and its Seafarers' Training, Certification and Watchkeeping Code (the STCW Code) at a minimum to be deemed qualified (IMO, 2011). In Table 1-1, Competence of "Maintain a safe navigational watch" is in Column 1, and relevant knowledge, methods and criteria are described in Columns 2, 3 and 4 respectively. The knowledge, understanding and proficiency required for BRM are emphasized in Column 2 and they indicate ten soft skills. These are emphasized because of their importance and relate to assignment, allocation, communication, decision-making, leadership, consideration of team experience, assertiveness, teamwork, prioritization of resources and situational awareness. Furthermore, BRM competency has been moved from part B (guidance) to part A (mandatory requirement) in the STCW Manila amendments (IMO, 2011). Similarly, in column 3, approved simulator training is stated as a method for demonstrating competence. So simulators can be used during training and assessment for BRM to decrease the incidents caused by human factors. Generally, the importance of BRM is emphasized in the STCW Code, not only because the human factors issue has yet to be resolved absolutely, but also because BRM training is a good way to improve this. Simulator-based training is appropriate for achieving the required learning outcomes. BRM simulator-based training development will thus be one of the research priorities.

1.1.2. Bridge Resources Management (BRM)

According to (Kristiansen, 1995), the main cause of incidents/accidents is not lack of hard skills and intelligence, but lack of correct working attitudes, sense of responsibility, mutual cooperation and effective bridge resource management on the part of seafarers. On one hand, the crew does not even have the least professional ethics in some accident cases. On the other hand, some people have the perspective that if the shipping company's crew has good knowledge and skills with the suitable operating procedures and regulations (Kobyashi, 2003), the ship's safety and operational benefits will be ensured. In that case, the improvement of soft skills is needed in the future.

The majority of maritime accidents are due to human factors (O'Neil, 2003). This suggests that it is not only training in human factors that is important, but also the combination of hard skills and soft skills is necessary. Hard skills are the abilities which are reflected in the activities of regular operating procedures. Soft skills, on the other hand, are the abilities that help strengthen situational awareness, correct working attitudes and improve BRM (Salas, Wilson& Burke, 2006).

1.1.3. STCW Code

Table 1-1 STCW Table A-II/1-function: Navigation at the operational level

Column 1	**Column 2**	**Column 3**	**Column 4**
Competence	**Knowledge, understanding and proficiency**	**Methods for demonstrating competence**	**Criteria for evaluating competence**
Maintain a safe navigational Watch	Bridge resource management: Knowledge of bridge resource management principles, including:	Assessment of evidence obtained from one or more of the following: 1, approved	The frequency and extent of monitoring of traffic, the ship and the environment conform with accepted principles and procedures A proper record is maintained of the

	1, allocation, assignment, and prioritization of resources 2. effective communication 3. assertiveness and leadership 4. obtaining and maintaining situational awareness 5. consideration of team experience	training 2, approved in-service experience 3, approved simulator training	movements and activities relating to the navigation of the ship Responsibility for the safety of navigation is clearly defined at all times, including periods when the master is on the bridge and while under pilotage Resources are allocated and assigned as needed in correct priority to perform necessary tasks Communication is clearly and unambiguously given and received Questionable decisions and/ or actions result in appropriate challenge and response Effective leadership behaviours are identified Team member(s) share accurate understanding of current and predicted vessel state, navigation path, and external environment

(Source: IMO, 2011)

Table 1-2 STCW Table A-II/2-function: Controlling the operation of the ship and care for persons on board at the management level

Column 1	Column 2	Column 3	Column 4
Competence	**Knowledge, understanding and proficiency**	**Methods for demonstrating competence**	**Criteria for evaluating competence**
Use of leadership and managerial skill	Knowledge of shipboard personnel management and training; A knowledge of related international maritime conventions and recommendations, and national legislation; Ability to apply task and workload management, including:	Assessment of evidence obtained from one or more of the following: .1 approved training .2 approved in-service experience .3approved	The crew are allocated duties and informed of expected standards of work and behavior in a manner appropriate to the individuals concerned Training objectives and activities are based on assessment of current competence and capabilities and operational requirements Operations are demonstrated to be in

	.1 planning and co-ordination .2 personnel assignment .3 time and resource constraints .4 prioritization Knowledge and ability to apply effective resource management: .1 allocation, assignment and prioritization of resources .2 effective communication on board and ashore .3 decisions reflect consideration of team experiences .4 assertiveness and leadership, including motivation .5 obtaining and maintaining situation awareness Knowledge and ability to apply decision-making techniques: .1 situation and risk assessment .2 identify and generate options .3 selecting course of action .4 evaluation of outcome effectiveness Development, implementation, and oversight of standard	simulator training	accordance with applicable rules Operations are planned and resources are allocated as needed in correct priority to perform necessary tasks Communication is clearly and unambiguously given and received Effective leadership behaviours are demonstrated Necessary team member(s) share accurate understanding of current and predicted vessel state and operational status and external environment Decisions are most effective for the situation Operations are demonstrated to be effective and in accordance with applicable rules

(Source: IMO, 2011)

The content of Table 1-1 states the competence of Navigation at the operational level, which is referenced from STCW Table A-II/1-function. The content of Table 1-2 states the competence of controlling the operation of the ship and care for persons on board at the management level, which is referenced from STCW Table A-II/2-function. As indicated in Tables 1-1 and 1-2, the requirements for competence, knowledge, methods and criteria regarding BRM are given in the STCW Code (IMO, 2011) in the four columns. However, in practical terms, the contents of column 4 are not adequate for specific training and assessment outcomes (Manuel, 2017). It is necessary that the indicated criteria be translated into more detailed form in the context of practical training/assessment for optimum implementation of the STCW Convention and Code (Cross, 2017).

The principal purpose of this research was to analyze this increased level of detail and to identify the necessary concrete knowledge for the instructors and resulting enhanced methods of training underpinned by relevant theories of training. This work, thus, sought to improve the training course for instructors using a simulator to meet the requirements of the STCW Convention.

1.1.4. Assessment on simulators

In light of the general development of education, student-oriented education is the trend of MET development, which needs assessment to motivate trainees (UTDC, 2004). In this context, student guidance related to closed-loop education and feedback is necessary for checking, selection and grading. Assessment is an important part of the learning process as much as learning and teaching (Cross, 2003). Assessment is a tool to help achieve effective teaching and learning (Robinson & Mania, 2007).

According to Cross (2003, 2007, 2017), there has been much research done about assessment in education. However, different types of training require different assessment methods, which may explain the wide diversity of under-used methods (Cross, 2017). Assessments should match the aim and the outcome of the training (Cross, 2003).

Miller, (as cited by Ender, 2014) has proposed a framework for assessment. Four levels of assessment for learners have been addressed, and the content is "knows (Knowledge), knows how (Competence), shows how (Performance), and does (Action)". BRM simulator-based training is mandatory per the 2010 amendments of the STCW Convention. An assessment method for demonstrating competence should be addressed in the following six aspects (Ender, 2014):

1. Identifying performance criteria (the criteria should be stated clearly and explicitly; the criteria should be valid and available to candidates);
2. Assessment criteria (the uniform assessment should optimize objective process, and ensure that subjective judgments are minimized);
3. The task should be brief and clear to the trainees;
4. Assessment of group and individual performance;
5. Scoring or grading methods should be used to assess performance;
6. The prime criterion is that the trainees demonstrate the abilities as indicated in the assessment sheet.

These elements are also worthy of consideration in the assessment procedure for the implementation of BRM Competency.

1.2. The training background and literature review of BRM

In recent years, traffic safety authorities and shipping companies in Europe have done a thorough and comprehensive investigation into maritime incidents and have researched several prevention methods in general (Marine Accident Investigation Board, 2011). On the basis of the research, there have been a great number of training models in soft skills' training and the experiences of knowledge and skills delivery methods should be considered (Baldauf et al., 2016).

According to the relevant conventions of the International Maritime Organization (IMO), and in order to ensure safety at sea, transport and maritime safety authorities, ship owners' associations, shipping companies and pilots associations in European countries such as Sweden, Norway, Finland and the Netherlands, have established a training course - "Training in Bridge Resources Management (BRM)", which draws on the successful training undertaken in Scandinavian Airline Systems (SAS) in conducting flight team management for aeronautical flight attendants (Cross, 2017), which is the basis of air pilot soft skills. This is the origin of BRM training.

After the STCW 2010 amendments, and due to the BRM being made compulsory at the management level and operational level, ship navigating officers have to participate in the mandatory course on training on the management of bridge resources to meet relevant requirements. These requirements and guidance are found in the STCW Convention and Code (IMO, 2010). Even though some training institutions and maritime administrations have developed some appropriate training methods and training programs, the training involves higher training costs. There is no integrated model course for BRM; some elements of BRM can be found in Model Course 1.21 on Personal Safety and Social Responsibilities, Model Course 1.22 - Ship Simulator and Bridge Teamwork and Model Course 1.39 - Leadership and Teamwork. Arguably, it is wrong to refer to a Model Course from 2002 to support current BRM training; a lot has changed between 2002 and 2017 (IMO, 2002, 2004, 2011). Furthermore, there were no Manila Amendments during the periods when these model courses were produced. Similarly, Model Course 6.10 on Train the Simulator Trainer and Assessor is too broad and does not address the specific and detailed requirements of BRM. Finally, to date, there is no corresponding and integrated MODEL COURSE as a guideline, so the domestic maritime education and training institutions have no uniform training curriculum and training standards, or corresponding training carried out in the various regions of a country, which could cause several problems in equal assessment. Nevertheless, domestic and foreign institutions have started this kind of training (Naweed, 2012) (Cross, 2007). However, the training content, training curriculum, and practical assessment methods are different, and each of them has its own advantages and disadvantages.

At present, BRM training courses have been set up by institutions for their domestic shipping companies, such as in Japan, South Korea, Philippines, India, US, UK, and some other European countries. The Norwegian Ship Owners' Association has established this special training for the seafarers employed from the Philippines. Similarly, in China, Dalian Maritime University (DMU) and Shanghai Maritime University (SMU) have also set up BRM courses to provide soft skills training for seafarers from shipping companies.

Origin of BRM: Scandinavian Airline Systems (SAS):

Even though planes do not have bridges (instead they have cockpits) and some of the underlying factors for ship bridges are different from airplane cockpits, there are some similarities. The original training of BRM was established by SAS (Cross, 2017), so the research of SAS is worthy of consideration. The training content of SAS is as follows:

1, Attitudes & Management Skill

2, Cultural Awareness

3, Communications and Briefings

4, Challenge and Response

5, Short Term Strategy

6, Authority and Assertiveness

7, Management Styles

8, Workload

9, State of the Bridge

10, Human Involvement in Errors

11, Judgment and Decision Making

12, Leadership in Emergencies

Dalian Maritime University (DMU) in China:

DMU has been responsible for the establishment of criteria for BRM assessors in China. The research of DMU is worthy of consideration. The training content of DMU is as follows:

1, Attitudes & Management Skills

2, Human Involvement in Errors

3, Cultural Awareness

4, Communication

5, Organizing and planning

6, Decision Making and Short Term Strategy

7, Management Style and Leadership

8, Directing and controlling

9, Team work and Master/Pilot Relationship

10, Workload and Fatigue

11, State of the Bridge and Stress Management

12, Emergency

United Marine Training Center in Philippines

The United Marine Training Center is one of the most important training centers in the Philippines, which could represent the training status of private shipping company. Furthermore, a considerable number of seafarers are trained in the Philippines each year; the training experience is very rich. Therefore, the research of the United Marine Training Center is worthy of consideration. The training content is as follows:

1, Resource Management

2, Error Chains

3, Situation Awareness

4, Communications

5, Decision-Making

6, Master and Pilot Relationship

7, Teamwork

8, Leadership

9, Passage planning

10, Emergencies & Contingencies

11, Procedures

12, Introduction to International Regulations

13, Job Hazard Analysis

14, Stress

Tokyo University of Marine Science and Technology in Japan:

In order to enrich the research, the research of Tokyo University of Marine Science and Technology in Japan should be noted. The training content is as follows:

1, Management

2, Rule of Road

3, Positioning

4, Lookout

5, Maneuvering

6, Communication

7, Instrument Manipulations

8, Emergency Treatments

9, Planning

Marine Maritime Academy in Turkey

In order to enrich the researching, the research of Marine Maritime Academy in Turkey is worthy of consideration. The training content is as follows:

1, Appraisal

2, Planning

3, Execution

4, Monitoring

5, Cooperation

6, Leadership

7, Managerial skills

8, situation awareness

9, Decision making

The literature reviewed for this research includes studies on human factors, accident causation theory and the training content of different institutions in domains of BRM and research into the assessment of soft skills and hard skills, which has been reviewed deeply. The resources of the WMU library were fully utilized. In addition, interviews were conducted in the context of WMU field studies, and associated documents were studied.

Finally, the research objective was to establish the relationship between BRM and its influencing elements as well as the assessment methods used in BRM training.

As observed earlier, the content of BRM courses offered by various institutions is different (Cross, 2017), although all of them appear to be searching for a combination of methods of soft skills and some practical conditions that may be encountered during a sea passage (Ender, 2014). The objective in the delivery of such courses is to make full use of various facilities, non-technical skills and material resources on the bridge, and to achieve the outcome of ensuring that seafarers have the requisite competency in respect of correct thinking, working attitudes and the ability to clarify their obligations and responsibilities in regular work on the bridge (Baldauf et al., 2016). When this is achieved, normal safe navigation of the ship could be maintained, and potential human error could be reduced and/or averted (Kavanagh, 2006). Furthermore, all kinds of emergencies and contingencies should be considered to make sure that trainees can take effective emergency measures to prevent accidents (Kobyashi, 2003).

1.3. Problem statement and research questions

Although institutions of different countries have set up BRM training courses, there are still some problems, which are mainly reflected in:

The training does not match the criteria of the STCW code

Given the emergence, development and requirement for BRM training, strengthening BRM training is necessary. It is obvious that BRM training is still in its infancy. Determining how to train and assess trainees' ability comprehensively is the aim of this research (Benedict et al., 2011). Seafarers need to gain not only operational hard skills, but also soft skills. Furthermore, effective BRM training will help reduce maritime accidents, loss of property and marine pollution that may be caused by human factors.

Over the recent past, the development of BRM training has been improving gradually, not only in training method (Kobyashi, 2003) (Cox, 2012) (James & Floystonn, 2014) (Ender, 2012), but also in assessment approaches, and through the use of advanced training equipment. Full-mission simulators have been widely used by most countries and these have played a key role in addressing the application of advanced technology on board (Cross, 2000). The use of advanced technology on board is a clear developmental trend. However, there appears to be insufficient training of soft skills, such as leadership, communication, situational awareness, delegation, team awareness and other non-technical factors (James & Floystonn, 2014). This situation implies that the training requirements may not meet the training criteria and requirements of the STCW Code.

Academic research is insufficient and the training concept needs to be changed

In recent years, there questions have been raised which suggest that there is not always a full understanding of BRM (Cox, 2012; Emad & Roth, 2008; Ender, 2012; Fisher & Muirhead, 2013; James & Floystonn, 2014; Kobyashi, 2003). Such questions include: “Why is BRM compulsory in STCW Code?” and “Which elements are suitable for the training and evaluation of BRM?”.

According to the STCW Code, the training concept has changed from looking out for “error chain” to generating “situational awareness”. Combining soft skills and hard skills should be considered in practical simulator training to improve on this change.

According to the training experience in maritime institutes, the present situation of training sometimes leads to insufficient and subjective results. Seafarers coming from such inadequate training processes show behaviors which manifest their incompetency in the relevant areas. The reasons for this are limitations in training due to less-than-optimum scenario designing by incompetent instructors, and lack of uniformity in training centers with regard to the understanding and implementation of the criteria in STCW. Setting objective assessments is an important part of the BRM instructor's competence, thus objective factors and parameters of BRM training scenarios, which are given by instructors, need to be improved. To this end, the questions to be answered in this paper are as follows:

1. Of what relevance are soft skills and hard skills training in the BRM context?
2. What are the objective factors and parameters that can be used to assess the competency of seafarers using simulator scenarios in BRM training?
3. How can these factors in the scenarios be ranked with respect to priority/importance?
4. How can assessment mechanisms be designed using these factors?

1.4. Research methodology and ethics

This research primarily follows a qualitative methodological approach and two specific methods are used for the research. In Chapter 3, scenario design is used to combine hard skills and soft skills. In Chapters 4 and 5, a quantitative calculation of the weight of elements in the assessment sheet is used, drawing from the qualitative findings. In this case, interviews are used for data collection, and typical locations were chosen to ensure the quality of the outcome.

1.4.1. Interviews on BRM training status

Interviews of different stakeholders were conducted in the following locations

1. During a field trip to London, the assessment elements in scenarios were researched with respect to the Sub-Committee on Human Element, Training and Watchkeeping (HTW).
2. During a field trip to the Philippines, the assessment elements in scenarios from the perspective of training centers of a private shipping company were researched.
3. During a field trip to Norway, the assessment elements in scenarios from the perspective of simulator manufacturers (Kongsberg) were researched.
4. During a field trip to Lisbon, the assessment elements in scenarios from the perspective of auditing authorities (European Maritime Safety Agency – EMSA) were researched.
5. Based on BRM instructor training in Tokyo University of Mercantile Marine of Japan, the assessment elements in scenarios were researched regarding a simulator training center done in partnership with a shipping company.

The findings of the research indicated above and as evidenced in assessment sheets, scenario-setting processes, methods of combining soft skills and hard skills are presented and analyzed in Chapter 3 and Chapter 4.

In addressing the research objective, a critical analysis was undertaken using the literature review and practical training data as well as the interviews (which showed existing views and perspectives explained by different stakeholders in the maritime industry as a whole). Drawing from all of these, the assessment elements in BRM training scenarios were found.

1.4.2. Establishing an integrated and systematic BRM training

To draw from the data collected in the interviews and to identify and weight the different elements that need to be considered in BRM competency assessment, it is important to acknowledge that many factors will influence the outcome and that these elements and the assigned weights can possibly change with time. Even though this is, therefore, a difficult and complex operation, methods need to be put forward to solve this problem.

To build an assessment sheet (the actual operation and measuring of parameters), it is necessary not only to have an objective assessment of performance with respect to soft skills, but also to establish a framework of the assessment based on the hard skills. The Analytic Hierarchy Process (AHP) was used to analyze the influencing factors of trainees' competency of BRM and also to calculate the weighting of the different assessment elements to be considered.

Finally, the research concludes with an integrated and systematic approach to analyzing the BRM assessment system of BRM simulator training using scenarios.

Figure 1-1 shows the methodological approach taken in this research.

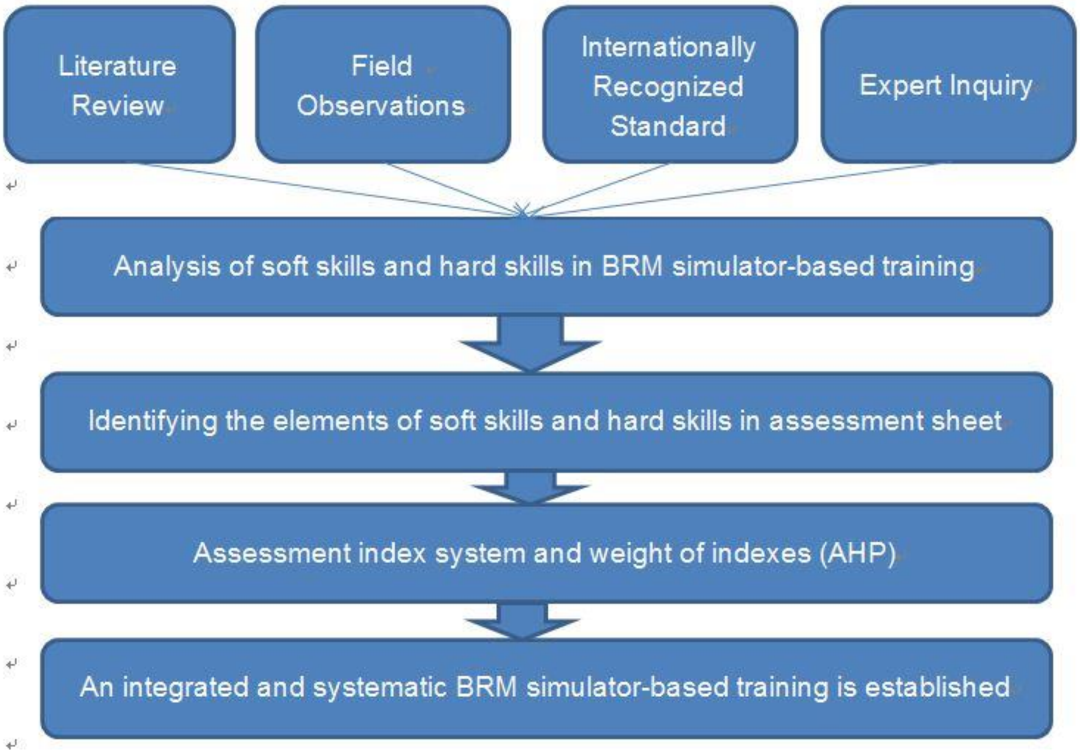

Figure 1-1 Structure and methodological approach of the research

This work concludes with a summary of all the above together with recommendations for future research.

2. Chapter II - Human factors theory and Assessment elements in BRM

2.1. Human factors and BRM

2.1.1. The importance of human factors

Research results from eight research institutions (Table 2-1) in the world's shipping industry show that human factors are the main causative factor in maritime accidents (Xi, 2010). Similarly, the statistical analysis of major accidents in Europe for a specific period showed that more than 80% of accidents were related to human factors (Gregory & Shanahan, 2010). This shows the importance of human factors in the maritime industry. Nowadays, according to the HTW Sub-Committee of IMO's Maritime Safety Committee (MSC), IMO's work on human factors will be one of the key areas of focus over the next decades. The Organization recognizes that human factors research is very important to the maritime industry (IMO, 2004).

Table 2-1. Eight Institutions' Research on the Causes of Maritime Incidents

Institutions for investigation	**Period of accidents**	**Total number of investigation**	**Types of accidents**	**Caused by human factors**
Det Norske Veritas, Norway	1970-1978	2742	Collision/ Grounding	61.6%
Helsinki Commission, Finland	1979-1981	471	All	17%
UK P&I Club,UK	1987-1991	123	All	90%
JMARI,Japan	1985-1991	2491	All	>90%

ISE,Brehmen,Germany	1977-1978	1528	All	88%
Tavistoek,UK	1970	415	All	>92%
JordbruksdePartementet,Sweden	1975-1977	54	Collision	90%
Wagenaar&Groeneweg,Holland	1982-1985	100	All	15.3%

(Source: Xi, 2010)

2.1.2. The Human Factors and Ergonomics (HF&E) approach

Human factors or ergonomics refers to the area of study concerned with the interaction between humans and machines under certain conditions and how that interaction makes the system safe, reliable and efficient or otherwise. Where humans and machines combine, the human becomes a key part of the system, and their performance must be in accordance with the unified requirements of the system's objectives (Nikitakos & Sirris, 2011).

In this research, seafarers of different ranks form the human component of the shipboard system, while the vessel they are working on and its equipment form the machine component. Nowadays, many researchers are paying more attention to the challenges of how to use simulators in the delivery and assessment of curriculum (Cox, 2012). Accordingly, this research examines the human-machine interaction in the context of simulator training and assessment. The analysis focuses on three aspects:

1. A holistic system approach: Based on the criteria of the STCW Code, coordination among different stakeholders (such as manufacturers, shipping industry and training institutions) is needed to improve effectiveness at different stages of simulator training.
2. HF&E approach: In order to achieve a safe learning environment to learn BRM skills in an effective and uniform way, the author explores the problems of the design and development of a full mission simulator and its training

curriculum, and an integrated human factor & ergonomics (HF&E) perspective to coordinate efforts from different stakeholders to improve the effectiveness of the BRM simulator.

3. Content of hierarchical task analysis

First of all, BRM training tasks can be subdivided into five different scenarios: voyage planning, collision avoidance, safe sailing, indicated operation and emergency/ contingency operation.

Secondly, in designing the scenarios, various roles should be established for the trainees (Dunn & Williamson, 2012), such as the third officer being responsible for the Integrated Bridge System (IBS) operation and the control of the navigational situation between own ship and the target vessel, the captain being responsible for command procedures and the second officer being responsible for the paper work, communication and voyage planning, and the helmsman being responsible for steering.

Firstly, the HF&E approach theory is used to combine the soft skills and hard skills for scenario design (Emad & Roth, 2008). This is described in Chapter 3. Secondly, the assessment result contributes directly to guide the operation of through data obtained from the Task Approach, which is also the outcome of this research. Finally, improvements related to integrated and systematic simulator-based training were established in simulator training programs according to the STCW Code.

2.1.3. Human factors in researching

The study area of human factors has been approached differently by different researchers as has the classification of these factors (e.g. IMO Resolution, 741(18) – the ISM Code - and statement on BRM in STCW Code (IMO, 1993). This research focuses on the approach taken and requirements in the STCW Code with a focus on the human side of the system.

According to the STCW Code, as amended, Part A, Chapter II – "Master and deck department": Table A-II/1, the areas to be addressed in the context of BRM are stated as: Assignment, Allocation, Prioritization of resources, Communication, Decision-making, Teamwork, Consideration of team experience, Situational awareness, Assertiveness and Leadership (IMO, 2011). This research on soft skills will focus on these ten areas, referring to them as elements.

2.1.4. The key elements of BRM

Assignment:

The meaning of *Assignment* is given in the IMO Model Course 1.22- Ship Simulator and Bridge Teamwork, which describes the training of "Ship Simulator and Bridge Team". According to that, *assignment* is a task or piece of work allocated to someone as part of a job or task to complete (IMO, 2002), which is emphasized by the STCW Code; this is a key element of team elements.

Allocation:

According to Resolution A 23/Res.947- "Human element vision, principles and goals for the Organization", allocation is the action or process of allocating or sharing out bridge resources (IMO, 2004). The allocation of someone or something as belonging to a bridge team is the basis of fully using bridge resources, so allocation is one element of team elements.

Prioritization of resources:

The term prioritization of bridge resources describes the process whereby the bridge team determines which task should receive the highest priority and which should receive the lowest according to their available resources (IMO, 2012), which is emphasized by Model Course 6.10 on "Training the Simulator Trainer and Assessor".

Resource allocation depends on prioritization of resources, availability of adequate human resources and team management, which is the base of command and decision-making (IMO, 2012).

Communication:

According to Model Course 1.21- personal safety and social responsibilities personal safety and social responsibilities, communication is important in the transfer of information and understanding by the bridge team. Communication includes both internal communication and external communication. Furthermore, it is an essential requirement in ensuring that a bridge team is effective and efficient in its operational procedures (IMO, 2016).

Decision-making:

According to Model Course 1.39- Leadership and Teamwork (IMO, 2014), decision-making is regarded as the cognitive process resulting in the selection of a belief or a course of action among several alternative possibilities. A lot of situations need decision-making, involving judgment, situation and risk assessment, consideration of corrective options available, and selection of the action to avoid collision. Decision-making is essential for command.

Teamwork:

According to Model Course 1.22, teamwork is the combined action of a bridge team, especially when effectiveness and efficiency is the aim (IMO, 2002).

Consideration of team experience:

Teamwork is identified in the amendments to the STCW Code as a specific individual competency. Furthermore, it is mentioned again as “consideration of team experiences” in the context of BRM. The impact of positive and negative behaviors in teams has been clearly identified and emphasized; teamwork (including the consideration of team experience) should thus be seen as an essential behavioral element of a team (Katherine & Simon, 2013).

Situational awareness (SA):

Situational awareness is the correct/accurate perception of the elements (such as dangers, marks, ships, lighthouses) that make up a current situation as well as the comprehension and projection of their status in the near future i.e. the developing navigational situation (Manuel, 2017). Situational awareness is very important to the command of the bridge team (Bornhorst, 2011). It also includes the appreciation of the tools/processes/mechanisms for maintaining control in the developing situation (not core to SA in essence but critical to expert decision-making), which is the basis of good command.

Assertiveness:

Assertiveness is the quality of being self-assured and confident without being aggressive (Carson-Jackson, 2010). Again, this is a key requirement for good teamwork, not only with respect to individual performance, but also for team performance.

Leadership:

According to Model Course 1.39- "Leadership and Teamwork", leadership is the ability of an individual in a bridge team to "lead" or guide other individuals, teams, or entire organizations (IMO, 2014). It is a practical skill which involves the process whereby the leader of the bridge team influences respective, individually and together, to achieve a common goal. Leaders carry out this process by applying their leadership knowledge and skills.

2.2. Situational awareness and BRM

According to the IMO (2012), the nature of the STCW Convention 1978 is technical, regulatory and preventive, aiming at knowledge. The amendments of 1995 focused on verifiable, detailed and explicit competence (IMO, 1996) with a focus on the behaviors associated with carrying out shipboard tasks. Finally, the amendments of 2010 (the Manila Amendments) further improved the cognitive requirements of the Convention. Together with this development of the Convention and Code, there has been a shift in the core approach of addressing the problem of human factors from “error chain” to “situational awareness”.

The concept of BRM based on Situational Awareness (SA), Proficiency and Leadership, researched by James (2014), means keeping the bridge team aware of dangerous and emergency situations (see figure 2-1). SA addresses the bridge team’s consciousness of all the variables that influence the operational situation/context they are involved in, and their ability to respond adequately to the dynamism in that situation. Optimum BRM requires the effective interaction of SA, Proficiency and Leadership. On one hand, SA focuses on whether the bridge team understands the situation they are encountering in respect of the specific operation they are involved in. Leadership could become the pivot point of the BRM triangle (In Figure 2-1) and leadership could keep the balance between Proficiency and SA. On the other hand, SA must be kept by bridge team to detect potential error chains that are developing (James, 2014). Furthermore, proficiency could be developed by training and experience, so it can be improved by SA, and SA could also influence leadership and leadership could influence proficiency. This indicates a closed loop between SA, leadership and proficiency, the three being the essence of BRM performance.

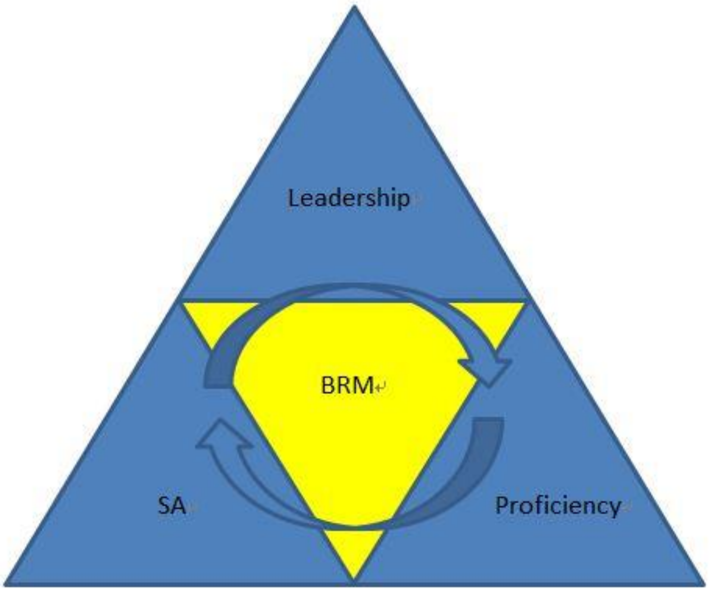

Figure 2-1 Relations between SA and BRM
(Source: James, 2014)

Finally, the function of SA is emphasized by the STCW Code, but SA is described in a very implicit way; it should be structured, researched, and applied for MET. SA is a very important element of BRM. It is the basis for decision making and performance of hard skills. Furthermore, SA is very important for any professional competence (such as Figure 2-2). The methodology of SA can also be applied to both training and education processes of seafarers, such as familiarization, practical training, and assessment procedures.

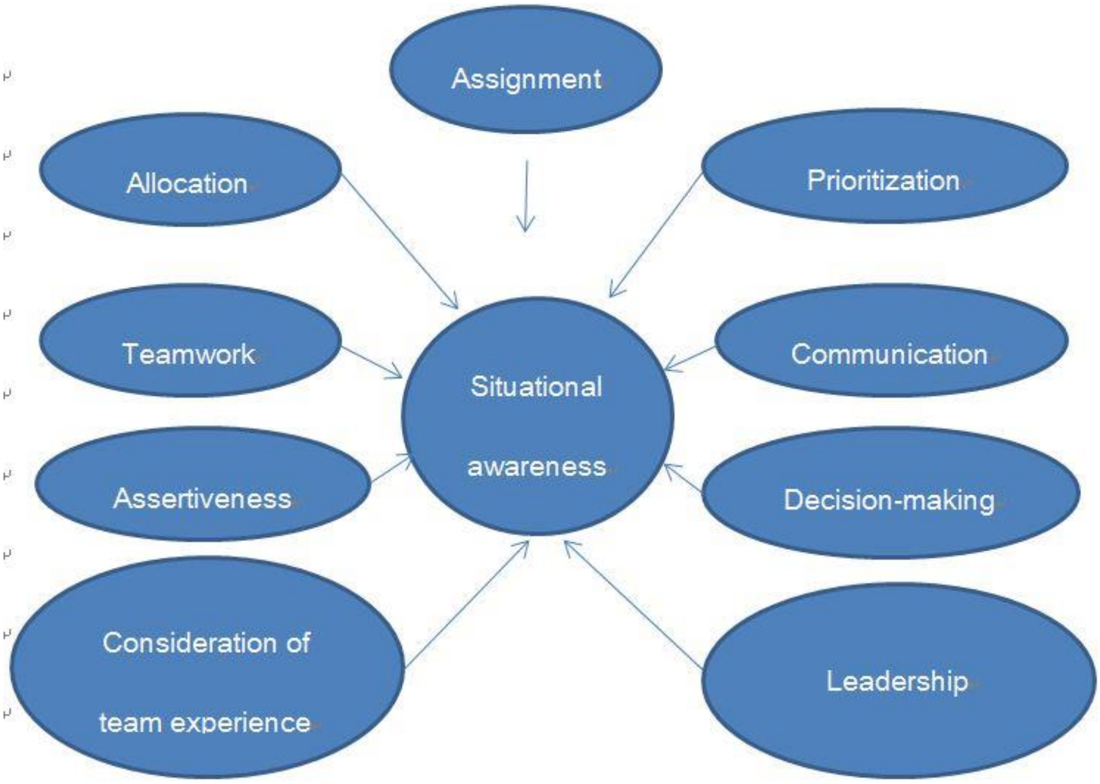

Figure 2-2 Influencing elements of BRM

2.3. BRM course

In order to reduce human error caused by human factors, some Maritime Education and Training (MET) institutions have set up corresponding BRM training content (Cross, 2017). The content of the BRM courses is not the key point of this research. However, given that it forms the basis for BRM simulator-based training, it is described briefly. After the interviews conducted at different training centers, a summary analysis of the content of BRM lectures was obtained. The main contents of the BRM courses are as follows:

BRM lecture:

(1) Safety awareness and judgment of the situation of the ship

(2) Error chain analyzing

(3) Internal and external communication

(4) Bridge teamwork

(5) Decision- making regarding collision avoidance

(6) Emergency response

(7) Bridge procedure

(8) Checklist and contingency plan

(9) Relevant regulation, code and policy

(10) Case study

BRM practical training:

(1) Familiarization of simulator

(2) Voyage planning

(3) Sailing in particular waters

(4) Ship handling in indicated water

(5) Emergency response

The application of BRM simulator-based training is mainly accomplished through four steps: The basic knowledge acquisition of the essentials of BRM; Simulator training by one bridge team participating and role playing; Analyzing and discussing major and typical case studies; Briefing and debriefing after task training. The training outcomes include: full use of internal and external resources of a vessel; clarifying seafarers' respective responsibilities and obligations in regular operations on the bridge; combining soft skills and hard skills to meet different situations which may occur or be encountered, correctly using the various facilities of the bridge to maintain normal safe navigation of the vessel, reducing potential human errors; and implementing of emergency procedures in different emergency situations to avoid incidents becoming worse (Cross & Muirhead, 1998).

Since human factors have been emphasized by the IMO as the main cause of maritime incidents, various maritime experts and institutions continue to study human factors, but only advanced maritime equipment was supported and the entry into force of relevant IMO Conventions was not enough to solve the human errors, fundamentally (de-Winter et al., 2012).

In conclusion, BRM training is considered to be a better way to ensure the achievement of seafarers' competency and to reduce the many incidents caused by human factors. Furthermore, the content and activities of BRM training should not only follow the criteria of the STCW Code, but also the training should apply to practical procedures on the vessel. The training of soft skills cannot be separated from hard skills, and the training scenarios set must combine soft skills and hard skills together (Cross, 2017). This is because the performance of crew on the bridge depends on the activities engaged in during regular ship operation procedures, and soft skills are potential influencing factors. In this context, the combination of soft skills and hard skills is very important.

3. Chapter III - The combination of hard skills and soft skills

The combination of hard skills and soft skills of BRM should be addressed in bridge teams, to enhance bridge team work. Therefore, the analysis of both single control and bridge teamwork is a necessary foundation for research into this combination of hard and soft skills.

3.1. Single control and bridge teamwork

Normally, in regular day time watchkeeping, there may be a single officer on duty on the bridge. This situation is called "single control" and the safety of navigation depends on the ability and performance of the duty officer. Any activities of the single officer are performed individually, arising from the individual's behaviors. On the other hand, in the situation of accessing harbors, narrow fairways and navigation with pilot on board, there are many people on the bridge to share the relevant duties. This latter situation calls for "bridge teamwork", which has the purpose of enhancing the functioning of the bridge. Teamwork is used to prevent adverse incidents from happening. The activities of the bridge are dependent on group behaviors (Farmer et al., 1999).

3.2. Relationship between soft skills and hard skills

Human performance in relation to hard skills depends not only on the difficulty of the navigational environment, but also on human ability. In this section, the relationship between navigational difficulty and human ability is examined, and the perspective that performance of single control is different in different situations is stated (Fisher & Muirhead, 2013). The influencing factors of the navigational environment are as follows:

1. Maneuverability of the vessel
2. Navigating area
3. Weather and sea condition
4. Traffic condition (types of target vessels and traffic density)
5. Regional regulation

The probability of navigational difficulty is presented in Figure 3-1.

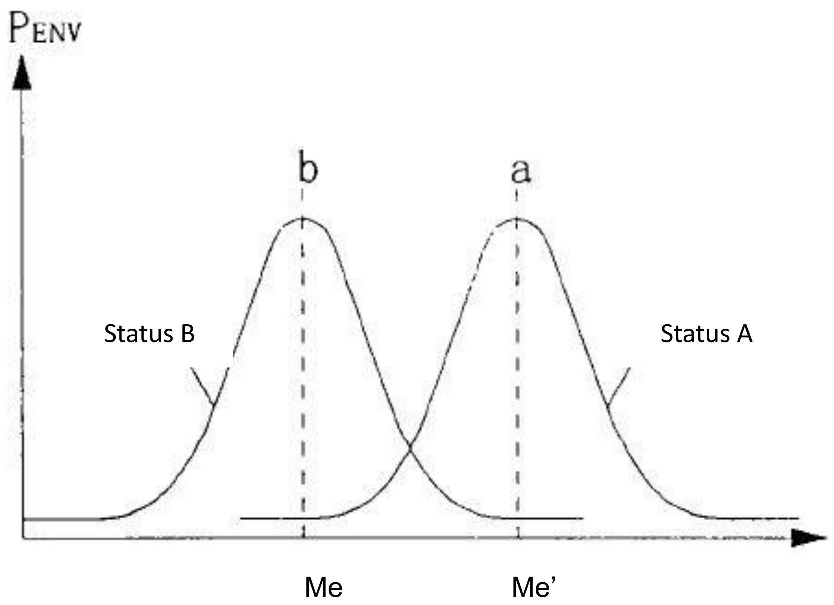

Figure 3-1 The distribution of navigational difficulty
(Source: Kobyashi, 2003)

The Me point is mean difficulty of Status B, which is caused by influencing factors indicated above. On one hand, if the influencing factors have changed to easy, such as sailing in an open area, in calm weather conditions, the navigational difficulty may decrease. On the other hand, if the influencing factors have changed to be difficult, curve b may change to curve a, which means the influencing factors are changeable; they can change over time according to the environment (Flin et al., 2008).

The influencing factors of human ability are as follows:

1. The rank of Certification of Competency (COC)
2. Experience
3. Leadership
4. Situational awareness
5. Management skills

The probability of human ability is presented in Figure 3-2

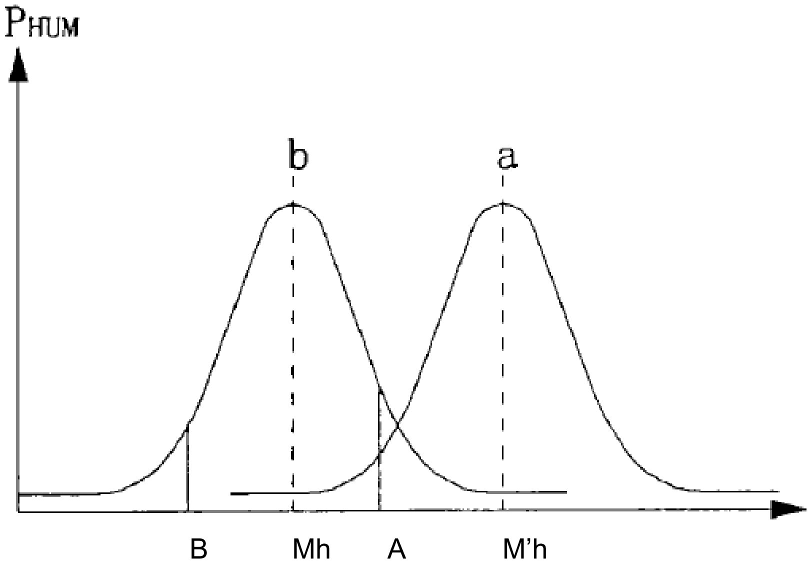

Figure 3-2 Distribution of human ability
(Source: Kobyashi, 2003)

Mh and M'h are the means of relevant human abilities, which are required by the influencing factors mentioned earlier, such as leadership, situational awareness, and management skills. On one hand, if the influencing factors are in normal status (curve b) with teamwork, good leadership, and qualified situational awareness, the human ability would be in higher quantity. On the other hand, if the influencing factors have changed to be single control, poor leadership and lack of situational awareness, curve b may change to curve a, which means the influencing factors of human ability are also changeable; they can change with time according to the BRM skills required (UTDC, 2004).

The combination of soft skills and hard skills should come out through system building, which should be based on the characteristics of human ability changes (Voorhees, 2001). The system consists of course design, learning activities, curriculum development, and scenario design. One function of the system is the support that should be given when the operator's ability becomes low. Another function is the feedback from the outcome of the operation, which also supports the system (Wesselink, 2010).

Finally, the support system could accomplish the tasks that people cannot always accomplish, i.e. some part of the support system could replace the tasks that people can accomplish under normal circumstances. The human behaviors cannot be considered useless because the training is based on communication between humans and the support system.

3.3. Relationship between bridge team and safety

The relationship between bridge team and safe navigation is examined in this section, and the conditions for incident occurrence are discussed. Practice has proved that when people with low levels of ability find it challenging to do something, it is even more difficult to complete that task in critical or highly tense situations (Baldauf et al., 2011). However, in the same situation, people with higher abilities, complete such tasks with relative ease. Accordingly, safe ship handling is determined not only by the state of navigation, but also by the person's ability. Accident occurrence is related to the combination of environmental conditions of navigation and the ability of the person. Figure 3-3 shows the relationship between the ability required to complete a safe navigational task and the ability that people can provide, which means that navigational safety is defined by both conditions of human ability and ability required by the navigational environment.

A straight line with a 45 degree angle shows the situation that human ability and required ability by navigation environment are the same. The area above this line is the safe area, which means navigation in normal conditions can be completed. Areas below this line, with red color, show a risky and dangerous situation that is prone to an accident, and in this area, it shows that the ability required by the environment is higher than the actual ability of the person. .

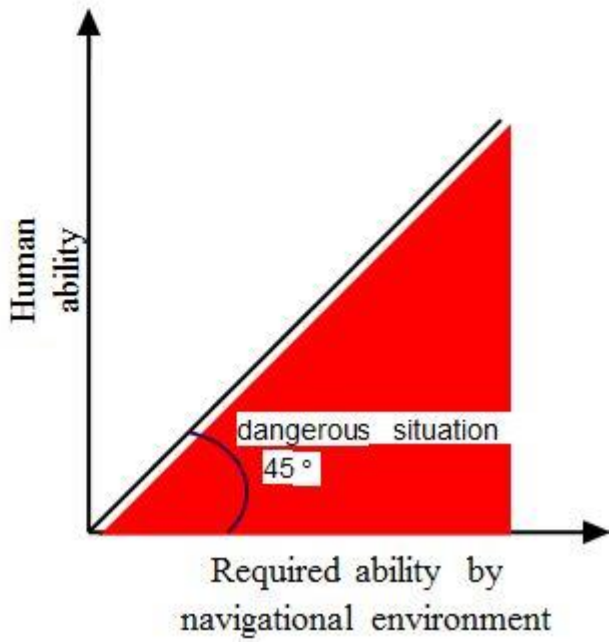

Figure 3-3 The navigational safety defined by both condition of human ability and required ability by navigational environment
(Source: Kavanagh, 2006)

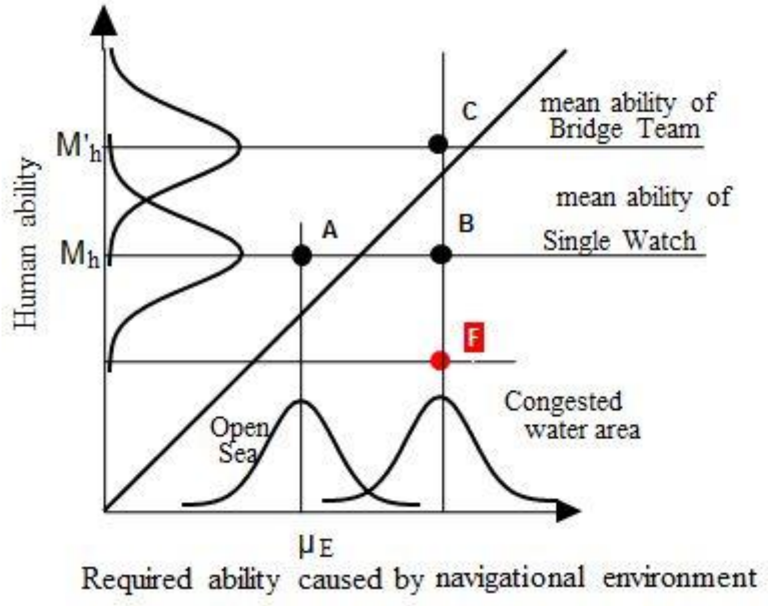

Figure 3-4 Condition of safe navigation
(Source: Kobyashi, 2003)

Figure 3-4 presents the theory on the safety degree of navigation. The horizontal axis indicates the required ability defined by the navigational environment, and the vertical axis indicates human ability. The line with a 45-degree incline shows the relationship between them. In the area above this line, human ability is greater than required ability. This condition can be considered as the safe situation. On the contrary, the area below the line indicates a dangerous situation; human ability is lower than required ability.

Figure 3-4 is the combination of Figures 3-1, 3-2 and 3-3. In the situation labeled A, where there is higher human ability and better environment, safe navigation is possible. As mentioned earlier, the environment is changeable, and the human ability can be trained. Accordingly, the focus of training becomes how to ensure the point will be located above the 45 ° line. The ability required by the environment may be temporarily increased due to changes in weather or increase in traffic density (Hutchins, 1996). In this situation, the mean human ability cannot by itself address the safety of navigation by completing all relevant tasks. If the individual has been trained and has higher ability, there can be a responsive change to point C, which means that navigation becomes safe again. On the other hand, if the required ability in the navigation environment is in a congested water area status with only mean ability of single watch, it is also more dangerous as shown by point B.

3.4. Function of bridge team

In most of the sailing time, the vessel is handled by one OOW in single control status. When a ship sails in narrow waters or fairway, the number of bridge team members would be increased; teamwork and assignment would be used to enrich the individual human ability. In that case, the function of the bridge team is to provide more capacity to maintain safe navigation under difficult conditions (IMO, 2012). Figure 3-4 shows the relationship between the single person's control work and bridge team work. When the ability required for the environment is low, the safety resulting from a single person’s work can still be guaranteed (as shown in point A). When the ability required for the environment in a narrow waterway is increased, a single person cannot achieve safe navigation (as shown in point B). In this case, organizing a bridge team could improve the ability to provide countermeasures to avoid danger (as shown in point C).

The purpose of bridge teamwork, therefore, is to complete the task and to achieve safe navigation by sharing the necessary tasks. In a limited time, it is difficult to complete high-quality work with one single OOW. According to the STCW code, five elements are necessary for the bridge team: teamwork, assignment, allocation, leadership and consideration of team experience. The overall elements require communication to be completed.

When an OOW on watchkeeping visually observes a vessel in risk of collision (ROC), (s) he could double check the location on radar for detailed information and make a decision by herself or himself. On the other hand, if there is a team on the bridge, the cooperation of the team could optimize the performance of watchkeeping (Lines, 1999). The function of bridge team work is that even though a task is able to be completed by a single OOW, a bridge team could have higher control over the function/tasks than a single OOW. However, the bridge team's performance of the tasks could also be lower than the single OOW if the functioning of bridge group is lacking in teamwork. Most of incidents occur due to the lack of sufficient function coverage at that time. Inadequate action often causes accidents when the vessel is sailing in a difficult environment. Figure 3-4 (point F ') shows an insufficient team status, and in this point the team's ability would be lower than the single OOW's ability. It is, therefore, difficult to complete the needed tasks without good teamwork, excellent command and good communication, although each member of the bridge team has completed their own work, such as positioning, or look out. Then the team is not in the position to handle the tasks of ship operation optimally (Muirhead, 2006).

3.5. Guiding ideology of BRM

As mentioned above, the three most important soft skills of a bridge team are:

1. Command: Each member completes his or her shared task
2. Communication: Members exchange information
3. Teamwork: Cooperation among each member of the bridge team

Everyone in a bridge team should complete the basic tasks first, either in “single control” situation or “bridge team” situation. These should not be included in the function of the bridge team. Furthermore, good communication is indispensable when a group of people is organized to complete the bridge team work. Finally, the function of BRM is to activate the function of the bridge team (National Research Council, 1996). In order to improve the crew behavior, the crew in the bridge team should complete their own work first, and then all members could master the BRM to improve individual human ability. In addition, the team leader should use good leadership to organize an excellent bridge team. The purpose of BRM is to make sure each member on the bridge understands the work, and that he or she could share and complete the indicated task. The excellent command of the team leader is also indispensable to BRM.

3.6. Combining soft skills and hard skills by scenario design

As mentioned above, both hard skills and soft skills are necessary for BRM simulator-based training. The design of scenarios should not only be based on the function of the bridge team with an emphasis on the necessity of teamwork, but should also design the soft skills in different procedure activities, which are addressed in hard skills (Tichon & Wallis, 2010). In that case, the activities on the bridge are guided by procedure operations, which are based on hard skills, but the performance of the activities is influenced by potential elements, which are soft skills. Finally, the scenarios and assessment design should address hard skills operation and hard skill performance. The soft skills can be separated individually; the procedure operation of hard skills is the platform of soft skills.

Figure 3-5 shows the combination of ship-handling situation and related soft skills in different situations. In BRM simulator-based training, a real ship-handling situation would be created, and soft skills contained in each handling situation could be recognized and assessed as shown in Figure 3-5. For instance, in “Action to avoid collision”, three soft skills, such as communication, decision-making and situational awareness, are necessary for the performance of lookout, so the hard skills- “Action to avoid collision” and three soft skills are combined together to guide scenario design. In the next chapter, the necessary preparations for the design of BRM simulator-based training assessment methodology will be discussed based on this theory.

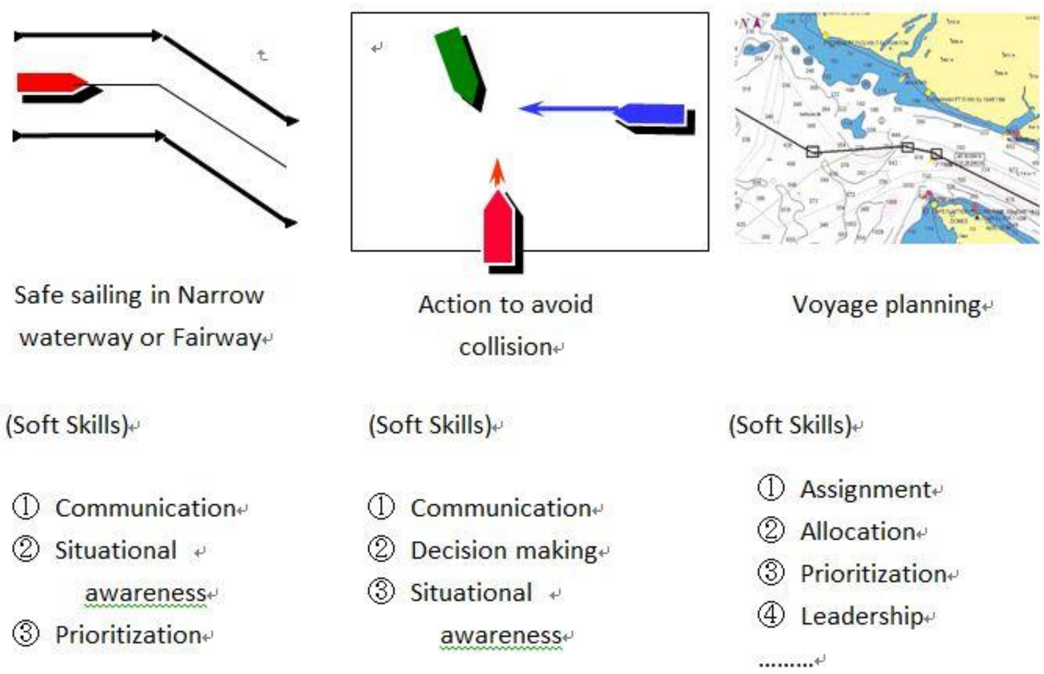

Figure 3-5. Combination of hard skills and soft skills by scenarios design

3.7. Improvement of scenario design by BRM training centres

Currently, full mission simulators are used for BRM by MET in many countries. The STCW Code should be the basis of training. However, based on the interviews, it was found that BRM training in various training centres is very different. It is necessary to research and conduct interviews among different training centres to find the reason and optimize BRM training.

The content of Table 3-1 shows the BRM part of the STCW code. The relevant competence is BRM, of which knowledge is required for all conditions. Competence in all ten elements is required. But the number of elements in practical operation is not only ten. Even though all elements should be considered, BRM competency is very difficult to be defined within a limited number of elements. Furthermore, the methods of assessment of BRM competency and curriculum content are not defined concretely. In that case, training scenarios, assessment sheet and assessment factors have to be defined by each training institution.

Table 3-1 Basic concept of BRM (Table A-II/1 in Chapter II, Part A of STCW Code, as amended)

Competence	Maintain a safe navigational watch
Knowledge, Understanding and Proficiency	Bridge resource management
Criteria for Evaluating Competency	Responsibility for the safety of navigation is clearly defined at all times, including periods when the master is on the bridge and while under pilotage。 Resources are allocated and assigned as needed in correct priority to perform necessary tasks. Communication is clearly and unambiguously given and received. Questionable decisions and/or actions result in appropriate challenge and response Effective leadership behaviours are identified Team member(s) share accurate understanding of current and predicted vessel state, navigation path, and external environment

(Resource: IMO, 2011)

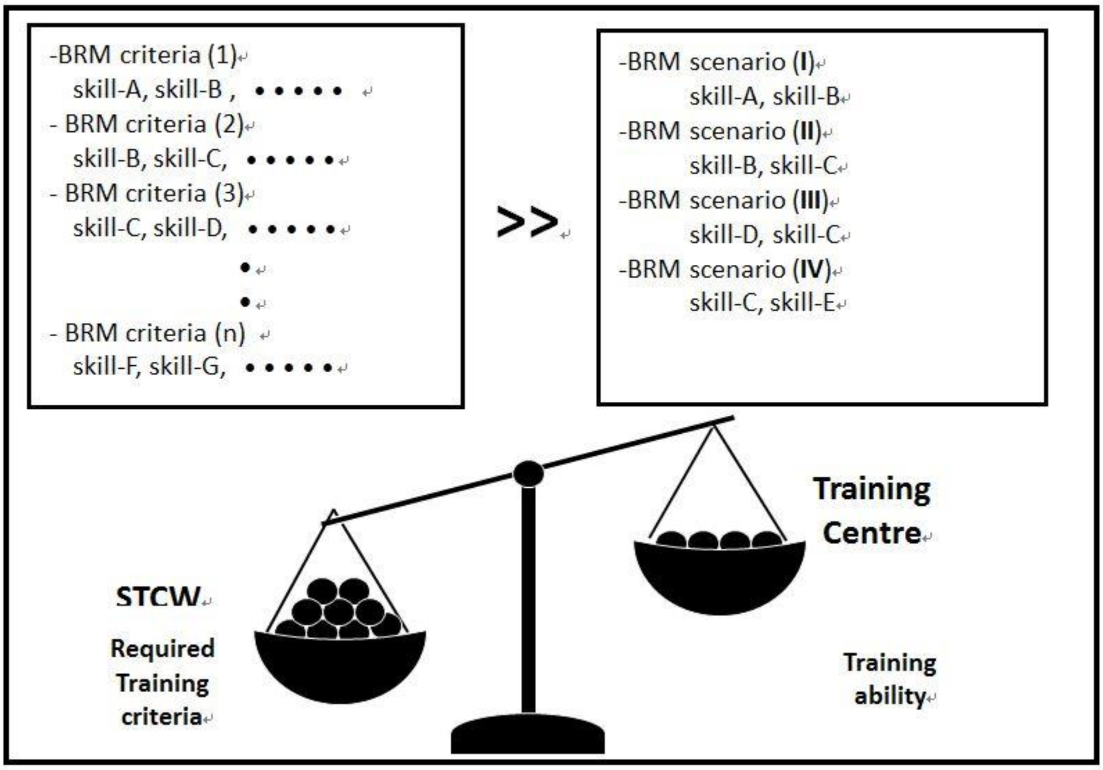

Figure 3-6 STCW Requirement and Training Situation

In STCW, required criteria and the soft skills for scenarios are very "heavy" as shown in Figure 3-6, but now the training ability of most training centres is not enough to achieve balance. The translations from criteria to training curriculum and training scenarios are very different in different training institutions. This may be because of the training ability or understanding of the STCW Code. As a result, the implementations of different institutions are very different (Fisher & Muirhead, 2013).

As shown in Figure 3-6, the translation from criteria in the STCW Code to training activities should use scenario training on simulators. If a training centre translates directly from skills required by criteria to skills in each scenario, the skills from the STCW Code criteria are difficult to list totally. In that case, skills become concrete, and the implementation becomes obscure. However, the necessary ten skills do exist.

Therefore, the training theory should be changed for good implementation of the STCW Code and achievement of safe navigation. The changed process and theory are shown in Figure 3-6.

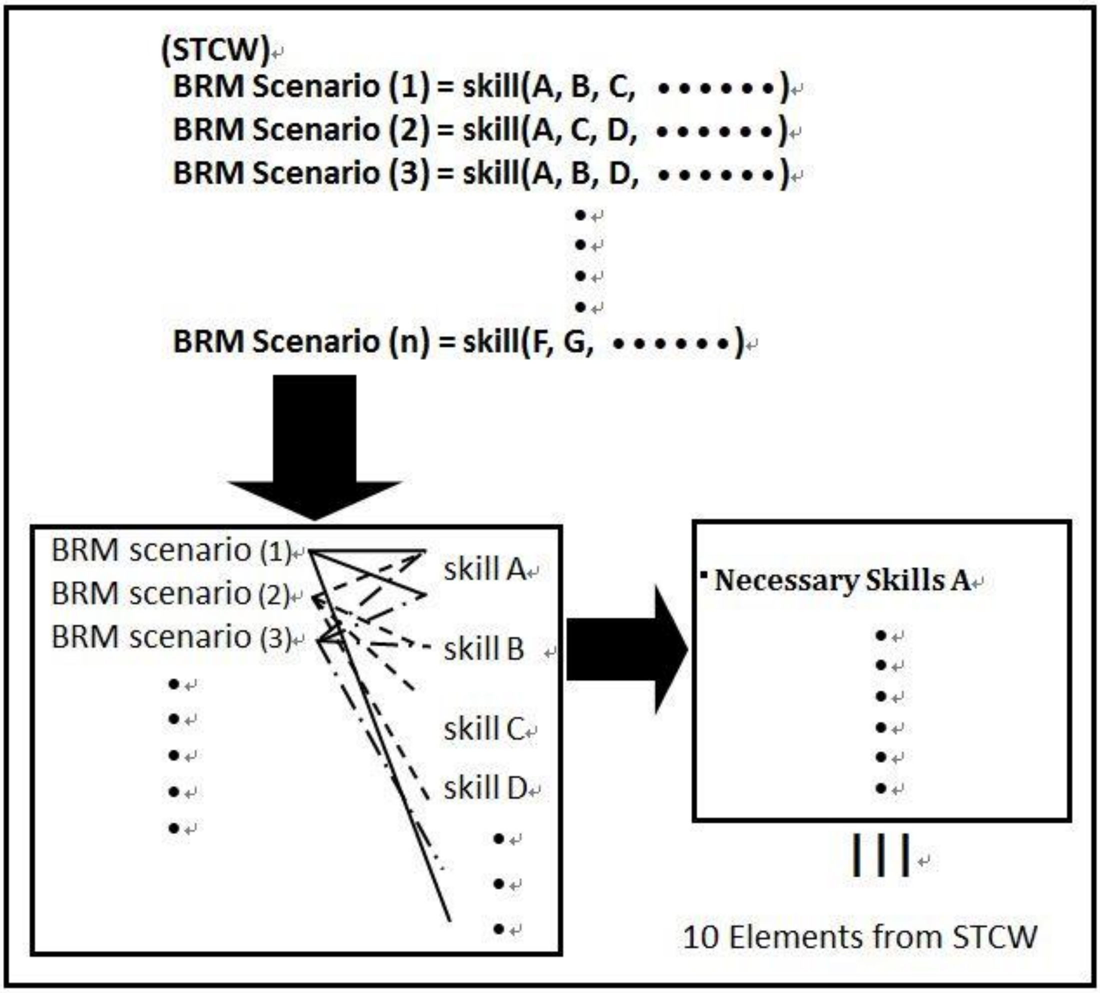

Figure 3-7 The Process of BRM training according to STCW

As shown in Figure 3-7, after the change from "skills to skills" to "skills to scenarios", it is obvious that the same skills are trained repeatedly. Although the skills are designed in different situations, each skill is trained several times to ensure the outcome of training, and efficient training would be carried out. As was discussed above, the ten elements of soft skills for BRM are the essence of the necessary skills.

These 10 elements of soft skills are defined as necessary techniques for BRM training.

More than twenty years ago, the concept of 'Functional Approach' was proposed by IMO. The necessary function for safe navigation was given by this concept. After that, the concrete definition of the necessary function was proposed as 'Elemental Technique Development', which has been researched by Hiroaki Kobayashi from Tokyo University of Mercantile Marine (Kobyashi, 2003). The original thinking of BRM scenarios training is based on the "Functional Approach".

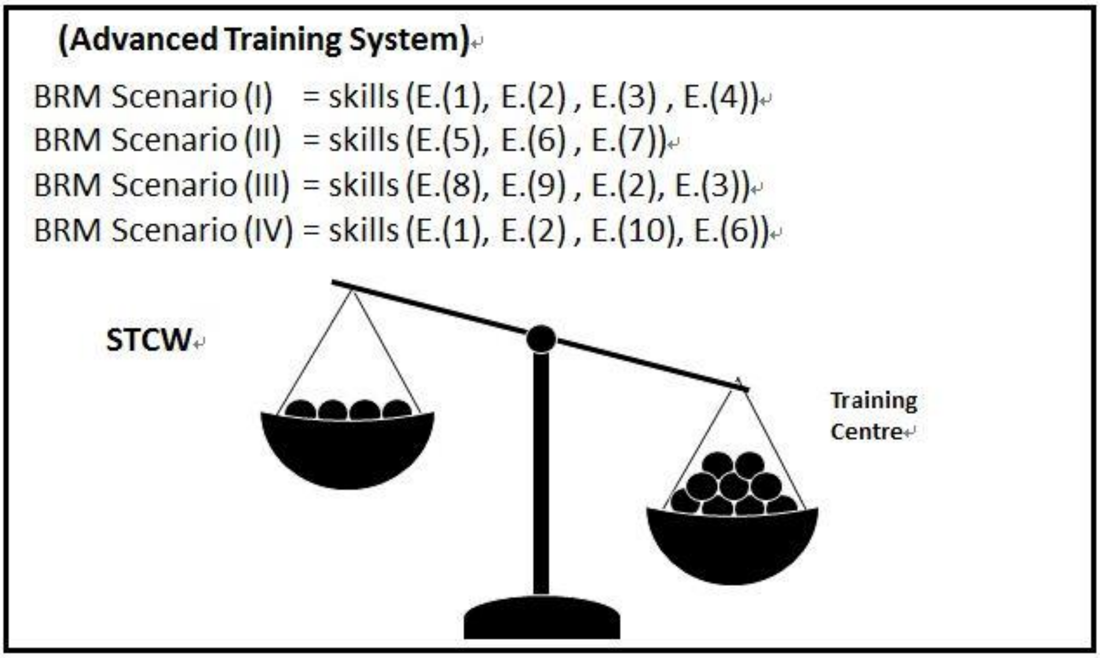

Figure 3-8 The Training Based on Elemental Technique Development

The outcome of the BRM training system is presented in Figure 3-8.

The implementation of the criteria in STCW Code becomes possible, which means that necessary soft skills are included in the scenarios training system. The training would be effective, because the necessary skills are defined with a limited number, and all skills are necessary in the STCW Code. Furthermore, the training on important soft skills can be carried out repeatedly and efficiently as shown in Figure 3-7. The relevant assessment sheets according to the scenarios would be designed. In that case, BRM simulator-based training on soft skills can be carried out by different scenarios and assessment sheet on simulator, and that could ensure that the training of the institution would be "heavier" than the criteria of the STCW Code, and that is presented in Figure 3-8.

4. Chapter IV - Optimizing of the BRM assessment methodology

4.1. The importance of BRM simulator-based training assessment sheet

As mentioned above, BRM has become mandatory in the STCW Convention 2010 Manila amendments. Assessment sheets have to be integrated in BRM simulator-based training, covering the competencies in both hard skills and soft skills. This is strongly needed by MET during simulator-based training. A reliable, valid, objective and feasible assessment method should be researched (Gerling, 1988).

Assessment sheet is very important for BRM training. It is not only the content of the training, but also a guideline for the instructor. It is the connection between training purpose and training outcome, which could ensure the quality of BRM training (IMO, 2012). Furthermore, the design of BRM training scenarios is based on the assessment sheet. The assessment sheet should also aim at training scenarios to give evaluation and feedback.

4.2. Designing training scenarios

The design of training scenarios is based on interview conducted at training centres in different countries, such as the United Marine Training Centre in the Philippines, Tokyo University of Mercantile Marine in Japan, Mokpo Maritime University in South Korea, Shanghai Maritime University in China and Dalian Maritime University in China. The assessment sheets of different centres were adopted as the foundation of scenario design, and the content of scenario design is based on the analysis and combination of interview results. On that basis, the training scenarios are divided into five parts: Voyage planning, Action to avoid collision, Safe sailing, Indicated operation in special area, Contingency and emergency.

4.3. Description of scenarios

As mentioned earlier, most of the sailing tasks in "single control" are completed under normal circumstances. When the vessel changes to a difficult situation, the "bridge team" would be formed to correspond to the increased difficulty of navigation. Therefore, the design of scenarios would be aimed at the difficult task that the bridge team should complete, for example: fairway sailing, berthing, anchoring, man overboard and so on. Consequently, the conditions of the mission to complete the task were analyzed in different water areas. The assessing elements show the activities, which could complete the tasks in each scenario (IMO, 2012). For example, the task of a narrow channel is divided into several elements, which are the activities the bridge team should complete, such as: captain on board, look-out, steering, and collision avoidance. Dividing the task into several skills means developing the skills for each member of the bridge team and the activities on the bridge are fixed, making the skills structure very clear.

Generally, the training scenarios are designed based on hard skills, which are divided into five parts:

1) Voyage planning

This part is used to collect information on navigation conditions to develop operational plans, voyage plans, contingency plans and emergency plans, which include the relevant nautical publications to develop the best route.

2) Action to avoid collision

This part is used to identify moving objects and fixed objects, detect the ROC, taking action, keep safe Distance at the Closest Point of Approach (DCPA), and check efficiency, which is the application of International Regulations for Preventing Collisions at Sea (COLREGS). Effective collision avoidance should be taken considering the current environment and conditions.

3) Safe sailing

In this part, navigation aid facility should be properly used for lookout, positioning, ship handling and so on. On the other hand, the position should be double-checked by plotting, ARPA or GPS to ensure safe sailing.

4) Indicated operation in special area

In this part, special tasks are given for training, such as berthing, anchoring, picking and up pilot. Course and speed should be used to control the vessel by using the rudder and engine control to complete the indicated task.

5) Contingency and emergency

In this part, various emergencies on board are used for training, such as firefighting, man overboard, and engine failure. Furthermore, contingency and emergency should be classified and correct emergency and contingency response should be completed.

4.4. Soft skills in the scenarios

In the context of medical care (Fletcher & Glavin, 2002), soft skills are defined as the skills without knowledge and technical procedures, but instead including cognitive skills (such as decision-making, situational awareness and prioritization judgment). These are called command skills. Another one is interpersonal skills, which can be separated into two aspects: exchanging information (communication) and interaction in team (team). Soft skills assessments were developed and introduced initially in the aviation industry (Flin, 2002) and then adopted by other safety fields, such as healthcare, nuclear and rail industries (Naweed et al., 2013). Finally, the classification methods of soft skills are almost similar, so there are three levels of soft skills in BRM soft skills assessment:

Three levels of soft skills:

1) Communication

Communication is a very important skill for each member of the bridge team (Bocanegra-Valle, 2010), which means the exchange of information between members, including internal and external. The efficiency of communication is very important, which includes efficient communication between bridge and engine room, target boat, VTS and so on (Froholdt, 2010).

2) Team

The team skill is to combine the skills of the bridge team to complete a higher skill function (Flin et al., 2002). The ability of individuals in a team could be enriched; and the disadvantages of the team could be avoided by the elements of team skill under the common goal of the bridge team. According to the STCW Code and the interviews conducted at different training centers, there are six elements of team skill: Teamwork, Assignment, Allocation, Leadership, Assertiveness and Consideration of team experience.

3) Command

On the bridge, a captain and OOW who has held a command position prior to others (Haslett, 2011) will have higher self-perceived abilities to function as a successful commander than those who have not held a command position (Flin et al., 2002). The command skill is the premise of full use of resources. Decision-making is an important instrument of command for judgment, and situational awareness is the guarantee of good command. There are, therefore, three elements in command skill, which are Prioritization of resources, Situational awareness and Decision-making.

4.5. Content of soft skills and hard skills assessment sheets

Based on the training scenarios, each training centre should form unified assessment criteria for BRM simulator-based training. The hard skills assessment form was adapted to the maritime field and combined with the soft skills assessment, as mentioned in Chapter Three, to form the assessment sheet. The content of the resulting assessment sheet would be divided into five parts, which are based on the five indicated hard skills. There are several activities for each hard skill to support the relevant element. However, the performance of the activities is influenced by some other elements, which are soft skills.

In the assessment sheet, the assessor cannot see the weight of each element, connection between activities and soft skills or relevant criteria directly (IMO, 2017b). This means the judgment of the assessor needs to be made more objective. As mentioned in Chapter Three, the relation of soft skills and activities would be obtained by the combination method, e.g. soft skills (Communication, Situational awareness and Prioritization of resources) corresponding with “Safe sailing in Narrow waterway or Fairway”, soft skills (Communication, Decision making and Situational awareness) corresponding with “Action to avoid collision”, and soft skills (Assignment, Allocation, Prioritization of resources and Leadership) corresponding with “Voyage planning”.

The training assessment sheets are different for different designed scenarios. This research only presents one model of assessment design (IMO, 2017a), but the format of different assessment sheets should be similar because the method and criteria are the same. There are eight columns in an assessment sheet, shown in Table 4-1.

Table 4-1 BRM skills assessment sheet[1]

Part 1:

BRM skills Assessment sheet										
Hard skills	Assessment activities	content		Types	Soft skills	Criteria	Score: C	C/O	S/O	Remarks
Planning	Captain on Bridge in Suitable position		arrangement	C			10			
			operation	C				10	10	
	Plotting		Y/N	C			10	10	10	
	Caution in special area		Y/N	C			10			
	Safe distance and speed			C			10			
	Nautical publication			C			10			
	Key points of Communication	Delegation		C			10			
		Relevant operation		C			10			
		Communication (in-, ex-)		C			10			
		method and frequency		C			10			
	Contigency	reply		C			10			
	Emergency			C			10			

Part 2:

Action to avoid collision	Observation moment (ROC)			C			10	10	10	
	means of look-out			C			10	10	10	
	Operation of radar			C				10	10	
	DCPA			C			10	10	10	
	In-Communication			C			10	10	10	
	Ex-Communication			C			10	10	10	
	Means of action	correct or not?		C			10	10	10	
		Ruder order by ruder angle without couse		C			10	10	10	
	Efficiency of Communication			C			10	10	10	
	Checking effectiveness	Communication		C				10	10	
		corrected		C			10			

1 In table 4-1, there are three levels of trainees: Management level (C), Operational level (B) and Support level(A), letter C in Colum "Types" means that this BRM assessment sheet is designed for management level trainees. And in Colum "score", C means Captain; C/O means Chief Officer; S/O means Second Officer.

Part 3:

safe sailing	Sailing speed			C			10	10	10	
	Correction of deviation			C			10	10	10	
	multiple positioning			C			10			
	Familiarization of facility on bridge (Radar, VHF, AIS, Depthometer, etc.)			C			10	10	10	
	TSS and local regulation	TSS		C			10	10	10	
		Local regulation		C			10	10	10	
		othe rules		C			10	10	10	
	Deal with environmental change	visibility		C			10	10	10	
		receiv command from VTS		C			10	10	10	
		others		C			10	10	10	

Part 4:

Emergency	Procedure operation	Effective or not?		C			10	10	10	
Contigency	Contigency reply			C			10	10	10	
Indicated operation in special area	Cap. on bridge			C				10	10	
	cooperation			C			10			
	Relevant operation			C			10			
	Communication			C			10			
	Course changing opportunity			C			10			
	Bow thruster and tug assistance			C			10			
	Turn speed and rudder angle speed control			C			10			

5. Chapter V Weight Calculation of BRM assessment sheet

5.1. Assessment methodology and technology

Based on the research done, the assessment sheet has been designed, but the weight of each element in the assessment should also be obtained. This can be done using a decision evaluation method. There are a lot of decision evaluation methods (Saaty, 2008), such as Multivariate Statistical Analysis, Operational Research, Fuzzy Math, Grey Relational Analysis (GRA), Artificial Neural Network, and Artificial Intelligence.

Generally, they are classified into:

Multivariate statistical analysis methods: such as principal component analysis, factor analysis, discriminant analysis, and cluster analysis;

Operational research methods: such as analytic hierarchy process, and data envelopment analysis;

Qualitative and quantitative analysis methods: such as causal analysis method, target analysis method, permutation method, comprehensive safety assessment, risk assessment method and so on.

Fuzzy theory method: such as fuzzy clustering, fuzzy comprehensive evaluation and pattern recognition;

Grey relational analysis (GRA): grey correlation degree, grey comprehensive evaluation, grey clustering and;

Neural network method.

Even though, there are several methods that could be used as the Indicator synthesis method (Saaty, 2008), after the literature review AHP was chosen as a suitable method to help solve the problem. In that case, the weight of elements in the assessment sheet could be calculated.

5.1.1. The reason for choosing AHP method

After an analysis of the different evaluation methods, the Analytic Hierarchy Process (AHP) decision evaluation method was chosen to be used for weight calculation. The AHP method is a mathematical tool, which uses the nature of the object in focus to determine the decision.

AHP is a suitable decision evaluation tool for this research, compared with other evaluation methods, because of its obvious advantages (Saaty, 2008). The first of these is its applicability. The decision-making process fully reflects the decision-maker's understanding of the decision-making process, which makes it less difficult for the decision-makers and decision-making analysts to communicate with each other to improve the situation, thus increasing the effectiveness of decision-making. The second is its simplicity. Understanding the basic principles of AHP and mastering its basic steps is not difficult; the results are simple and clear at a glance. The third is its practicality. AHP combines qualitative and quantitative factors in a unified way. The fourth is that it uses a systemic approach. It regards the problem as a system, making decisions on the basis of the interrelationships of the various parts of the system and the environment in which the systems are located, which is a better systemic approach than the causal inference and the inductive form of the probabilistic approach, which is widely applicable to hierarchical systems.

AHP is therefore considered suitable for the weight calculations of BRM assessment sheet.

5.2. The principle and procedure of AHP method

5.2.1. Theoretical background of AHP method

In this research, the Analytic Hierarchy Process (AHP) will be applied to calculate the weight of the assessment indexes (Saaty, 2008). The analysis of pair-wise comparison matrixes would be adopted to calculate the weight of each factor. In accordance with the final result of the assessment sheet, soft skills and hard skills are separated in the first level.

The AHP method (Saaty, 2008) was developed by Thomas Saaty, and was then a new, concise, and practical decision-making method. Some complex problems can be solved by this multi-criteria decision-making tool, which is one of the best known and most widely-used decision-making methods. The method can address both the qualitative and quantitative aspects of the problems. Desirable characteristics of such an approach include simplicity, usefulness, practicality and suitability for calculating the weight of assessment indexes, such as communication, team and command. The basic procedure to carry out the AHP consists of the following steps (Saaty, 2008):

(a) Clarifying the problem and structuring the decision hierarchy

Clarifying the problem is the first step of the AHP, which aims to determine the scope of the problem and the relevant requirements. This includes separating a decision problem into several levels, such as a goal of decision at the topmost level, criteria at the intermediate levels, and a set of activities at the lowest level.

(b) Constructing a set of pair-wise comparison matrixes

For the sorting calculation of each pair of criteria, how many times one criterion compared to another criterion should be given by the interviewees, which means the interviews could answer relative weights of each pair criteria by making pair-wise comparisons in each hierarchy level, and a series of pairs-wise comparisons should be taken to judge the relevant weight.

In order to make quantity comparisons, the 1-9 ratio scale method recommended by Saaty (2008) is used to indicate the relative importance of the elements. In Table 5-1, intensity 1 means two elements are of equal importance, and intensity 9 means one element is extremely more important than the other, with increasing degrees of importance in between 1 and 9. The definition of the intensity of importance is presented in Table 5-1, and the meaning of 1-9 intensity is very clear in the table.

Table 5-1 Definition of importance intensity

Intensity of importance	Definition
1	Two elements compared: Equal importance
3	Two elements comparing: Moderate difference in importance
5	Two elements comparing: Strong difference in importance
7	Two elements comparing: Very strong difference in importance
9	Two elements comparing: Extreme difference in importance
2,4,6,8	Difference in importance between the stated definitions e.g. the definition of 2 is difference in importance between that for 1 and 3.

(c) Calculating the weight of each factor

Step 1: The comparison matrix A composed of factors S_j is constructed based on the sorting of each element in one row of the matrix.

$$S_j = \sum_{i=1}^{n} a_{ij} \qquad (j = 1, 2, \ldots, n),$$

Step 2: A normalized matrix: A_{norm} which sum of each row equal to 1:

$$A_{norm} = \{a_{ij}^*\}, \qquad then : a_{ij}^* = \frac{a_{ij}}{S_j} \qquad (i,j = 1,2,\dots,n)$$

Step 3: W_i is average of each row in matrixA_{norm}, then the feature vector W is weight of each element in one level.

$$W_i = \frac{\sum_{j=1}^{n} a_{ij}^*}{n}, (i = 1,2,\dots,n)$$

Then, W = $[W_1, W_2, \wedge \quad, W_i, \ \wedge \quad, W_n]^T$ is the desired weight.

(d) Consistency inspection

According to the AHP method (Saaty, 2008), redundant comparisons should be involved in this method to recognize validity. Uncertain or unbelievable subjective answers that are given by interviewees should be picked out. The multiple comparisons caused by redundancy may lead to numerical inconsistencies. If consistencies ratios of these inspections are (10%) lower than the numbers in total, then the result is accepted. The comparisons consistency can be checked by the following steps:

Calculate the largest eigenvalue of the judgment matrix:

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i}, \lambda_{max \geq n}$$

Calculate the consistency index (CI):

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

Check the mean random consistency index RI in table 5-2;

Table 5-2 The mean random consistency index RI

Rank n	1	2	3	4	5	6	7	8	9	10
RI	0	0.52	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.52

Calculate the Consistency Ratios (CR):

$$CR = \frac{CI}{RI}$$

As long as CR $\leq$ 0.10, analysis can be accepted.

5.3. The Establishment of Hierarchical Hierarchy Model

According to the AHP, the hierarchical structure has the following characteristics: First, from top to bottom as the order of the relationship. This relationship is similar to the relationship between a set, a subset, and an element. Second, the number of levels in the whole structure is not limited; the number of levels depends on the needs of the decision analysis, but the number of elements in the highest level should not be more than nine, generally, because consistency of the two comparison judgments should be considered as much as possible. When the elements in the hierarchy are too many, the element can be divided to include sub-levels. The restriction of no more than 9 elements in the top level will avoid difficulty in the establishment of a hierarchy. Third, the relationship of elements in different levels should be stronger than those in the same level. If in the actual problem, the internal elements and links are very close, and some relations are difficult to ignore, then the basic principle of AHP would no longer be appropriate. In that case, a sorting method with the feedback system should be used. Therefore, the establishment of the

Hierarchy Model is very important. Finally, the categories of the hierarchy itself must be fixed, but the locations of the different elements need not be fixed.

According to the rules above, the weight calculation of the BRM assessment sheet would separate the elements into four levels, and the location of each element is shown as follows:

Level 1---Level 2:

BRM Competency	Soft skills
	Hard skills

Level 2---Level 3:

Hard skills	Voyage planning
	Action to avoid collision
	Safe sailing
	Indicated operation in special area
	Contingency and emergency

Soft skills	Communication
	Team
	Command

Level 3---Level 4:

Voyage planning	Captain on bridge
	Plotting
	Caution in special area
	Safe distance and speed
	Key points of communication
	Nautical publications
	Contingency plan and emergency plan

Action to avoid collision	Observation moment (Risk of Collision)
	Means of look-out
	DCPA
	Communication
	Means of action
	Operation of radar
	Checking effectiveness

Safe sailing	Safe speed
	Correction of deviation-(from route)
	Multiple positioning-(fixing sources)
	Traffic Separation Scheme (TSS) and local regulation
	Familiarization of instrumentation
	Dealing with environmental change

Indicated operation in special area	Captain on bridge
	Cooperation
	Relevant operation
	Turn speed and rudder angle speed control
	Course changing opportunity
	Bow thruster and tug assistance
	Communication

Contingency and emergency	Emergency plan
	Reporting in emergency
	Contingency plan
	Contingency response
	Communication

Communication	External communication
	Internal communication
	Efficiency of communication

Team	Teamwork
	Assignment
	Allocation
	Leadership
	Consideration of team experience
	Assertiveness

Command	Situational awareness
	Decision-making
	Prioritization of resources

Figure 5-1 The location of each element in AHP

5.4. The matrix of soft skills and hard skills

According to the above scale and sorting principle and level analysis, the establishment of the matrix based on the general goal is established. There are four levels in general, which are level 1- BRM competency level, level 2- soft skills and hard skills, level 3- groups of skills and level 4 –skills. In level 2, the BRM competency of level 1 is classified into soft skills and hard skills, and five groups of hard skills and three groups of soft skills in level 3 have been set up to support level 2. In level 4, thirty-two hard skills and ten soft skills are the elements to support the groups in level 3. This is the relationship among four levels, and the matrix tables for interviews are designed according to this. (See Appendix 1 for details). Table 5-3 is the matrix sample of (D7 TEAM) for interview.

Table 5-3 The matrix sample (D7 TEAM) for interview

D7 TEAM	Teamwork	Assignment	Allocation	Leadership	Consideration of team experience	Assertiveness
Teamwork	1					
Assignment		1				

Allocation			1			
Leadership				1		
Consideration of team experience					1	
Assertiveness						1

In the context of interviews, the answer of interviewees is one kind of thinking activity which relays the interviewees' choice or judgment, so the quality of interviewees are very important to the outcome of weight calculation. Furthermore, the answer is an art, because the choices and judgments for the answer are made by people. Whether the answer of the interviewee is correct or not, good or bad, and the quality of the interview depend on the background, experience and ability of the interviewees. Therefore, in this research, interviews were conducted with instructors and assessors from different countries, who come from training centers, administrations and auditing organizations (DNV-Det Norske Veritas, EMSA -European Maritime Safety Agency). Finally, the evaluation and judgment of contents were analyzed to allow for the development of a final judgment matrix.

5.5. Calculation of weight in system indicator

5.5.1. The square root method in AHP calculation is used to calculate each judgment matrix

1) Calculate the product of each elements in one row of judgment matrix

$$M_i = \prod_{j=1}^{n} b_{ij} \qquad i = 1, 2, 3, \ldots \ \ldots, n$$

2) Calculate the root of M_i : $\bar{W}_i$

$$W_i = \sqrt[n]{M_i}$$

3) Normalize the vector $\bar{W} = \left[\overline{W_1}, \overline{W_2}, ,, \overline{W_n}\right]^{\tau}$, as

$$W_i = \frac{\overline{W_i}}{\sum_{j=1}^{n} \overline{W_j}}$$

Then $W = [W_1, W_2,,, W_n]^{\tau}$ is the required feature vector

4) Calculate the largest eigenvalue of the judgment matrix λ_{max}

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i}$$

And $(AW)_i$ in the formula means the number i element of the vector AW.

5) Hierarchical single order and consistency test

$$CI = \frac{\lambda_{max} - n}{n-1} \quad ;$$

$$CR = \frac{CI}{RI}$$

“n” in the formula means the order of the matrix

If the result of “CR< 0.1”, the judgment matrix is considered to be satisfactory.

For example: the square root method is used to calculate the maximum eigenvalue and its corresponding eigenvector of B2 judgment matrix.

Table 5-4 The matrix sample (B2) from interview

B2 judgment matrix	Communication	Team	Command
Communication	1	1	1/2
Team	1	1	1/2
Command	2	2	1

The specific calculation steps are as follows:

1. The Calculation of the product in each row element of the judgment matrix

M_1 = 1×1×1/2=0.5

M_2 = 1×1×1/2=0.5

M_3 = 2×2×1=4

2. Calculate the root of $\mathrm{M_i}$: $\overline{\mathrm{W}}_\mathrm{i}$

W_i = $\sqrt[n]{M_i}$

W_1= $\sqrt[3]{0.5}$ = 0.7937

W_2= $\sqrt[3]{0.5}$ = 0.7937

W_1= $\sqrt[3]{4}$ = 1.5874

3. Normalize the vector $\overline{\mathrm{W}} = \left[\overline{W_1}\ ,\ \overline{W_2}\ ,\ \ ,\ ,\ \overline{W_n}\right]^{\tau} = [0.7937, 0.7937, 1.5874]^{\tau}$

$\sum_{j=1}^{n} \overline{W_j}$= 0.7937 + 0.7937+ 1.5874 = 3.1748

$W_1 = \frac{\overline{W_1}}{\sum_{j=1}^{n} \overline{W_j}}$ = 0.7937/ 3.1748 = 0.25

$W_2 = \frac{\overline{W_2}}{\sum_{j=1}^{n} \overline{W_j}}$ = 0.7937/ 3.1748 = 0.25

$W_3 = \frac{\overline{W_3}}{\sum_{j=1}^{n} \overline{W_j}}$ = 1.5874/ 3.1748 = 0.5

Finally, The required feature vector W = $[0.25,\ 0.25, 0.5]^{\tau}$

4. Calculate the largest eigenvalue of the judgment matrix $\lambda_{\max}$

$$\mathrm{AW} = \begin{bmatrix} 1 & 1 & 1/2 \\ 1 & 1 & 1/2 \\ 2 & 2 & 1 \end{bmatrix} \times \begin{bmatrix} 0.25 \\ 0.25 \\ 0.5 \end{bmatrix}$$

$$AW_1 \quad = \quad 1 \times 0.25 + 1 \times 0.25 + \frac{1}{2} \times 0.5 = \quad 0.75$$

$$AW_2 \quad = \quad 1 \times 0.25 + 1 \times 0.25 + \frac{1}{2} \times 0.5 = \quad 0.75$$

$$AW_3 \quad = \quad 2 \times 0.25 + 2 \times 0.25 + 1 \times 0.5 = \quad 1.5$$

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(\mathrm{AW})_i}{\mathrm{nW_i}} = \frac{(AW)_1}{3W_1} + \frac{(AW)_2}{3W_2} + \frac{(AW)_3}{3W_3} = \frac{0.25}{3 \times 0.75} + \frac{0.25}{3 \times 0.75} + \frac{0.75}{3 \times 1.5} = 3$$

5. Hierarchical single order and consistency test

$$\mathrm{CI} \quad = \quad \frac{\lambda_{max} - n}{n-1} = (3 - 3) / 2 = 0$$

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} = 0 / 0.25 = 0 < 0.1$$

The result indicates that the judgment matrix has complete consistency.

If the judgment matrix does not meet the requirements of consistency, the judgment matrix should be changed. The changing principle is that the scale should be adjusted according to the scale in the first row of the matrix in order to ensure that it is consistent logically; otherwise the data collection should be canceled. The principle used in this research is to make the appropriate adjustments according to the first row of the judgment matrix, then the weights of the corresponding indicators calculated for all the survey samples are averaged to obtain the following weight data.

5.5.2. The weight of soft skills and hard skills in indicator system

Table 5-5 Weights of the corresponding indicators

Elements on first level	Elements on second level	Elements on third level	weight index relative to the previous level	weight index relative to the total indicator
B1 hard skills			0.5	0.5
	C1 Voyage planning		0.193	0.0965
		D11 Captain on bridge	0.119	0.0115
		D12 Plotting	0.157	0.0152
		D13 Caution in special area	0.114	0.0110
		D14 Safe distance and speed	0.133	0.0128
		D15 Key points of Communication	0.138	0.0133
		D16 Nautical publication	0.120	0.0116
		D17Contingency plan and Emergency plan	0.219	0.0211
	C2 Action to avoid collision		0.254	0.127
		D21 Observation moment (ROC)	0.143	0.0182
		D22 Means of look-out	0.134	0.0170
		D23 DCPA	0.145	0.0184
		D24 Communication	0.161	0.0205
		D25 Means of action	0.134	0.0170
		D26 Operation of radar	0.142	0.0180
		D27 Checking effectiveness	0.141	0.0179
	C3 Safe sailing		0.176	0.088
		D31 Safe speed	0.175	0.0154

		D32 Correction of deviation	0.162	0.0143
		D33 multiple positioning	0.192	0.0169
		D34 TSS and local regulation	0.145	0.0128
		D35 Familiarization of instrumentation	0.155	0.0136
		D36 Deal with environmental change	0.171	0.0150
	C4 Indicated operation in special area		0.182	0.091
		D41 Captain on bridge	0.145	0.0132
		D42 Cooperation	0.177	0.0161
		D43 Relevant operation	0.147	0.0134
		D44 Turn speed and rudder angle speed control	0.122	0.0111
		D45 Course changing opportunity	0.119	0.0108
		D46 Bow thruster and tug assistance	0.146	0.0133
		D47 Communication	0.144	0.0131
	C5 Contingency and emergency		0.195	0.0875
		D51 Emergency plan	0.216	0.0189
		D52 Reporting in emergency	0.199	0.0174
		D53 Contingency plan	0.205	0.0179
		D54 Contingency	0.192	0.0168

		response		
		D55Communication	0.188	0.0165
B2 Soft skills			0.5	0.5
	C6 Communication		0.268	0.134
		D61 External communication	0.293	0.0393
		D62 Internal communication	0.292	0.0391
		D64 Efficiency of Communication	0.415	0.0556
	C7 Team		0.391	0.1955
		D71 Teamwork	0.175	0.0342
		D72 Assignment	0.180	0.0352
		D73 Allocation	0.161	0.0315
		D74 Leadership	0.165	0.0323
		D75 Consideration of team experience	0.164	0.0321
		D76 Assertiveness	0.154	0.0301
	C8 Command		0.341	0.1705
		D81 Situational awareness	0.434	0.0740
		D82 Decision-making	0.275	0.0469
		D83 Prioritization of resources	0.291	0.0496

5.6. The integrated indicator system in BRM assessment system

According to the competence of “maintain a safe navigational watch” required in the STCW code, a qualified seafarer should gain two abilities, namely soft skills and hard skills. Figure 5-2 is an example of a training outcome of an integrated and systematic training system. The outcome is not the score of the trainees. The result of the training is the performance of the training process, which could present each soft skill separately and nine times as shown in Figure 5-2. On the other hand, the weight of the indicators can be obtained in two aspects: soft skills and hard skills, which are the key indicators for the assessment sheet; the assessment sheet can be used not only for a group evaluation, but also for an individual evaluation. It is convenient to meet the requirement of outcome. Furthermore, the result of soft skills and hard skills can be gained separately; the training could aim at the special skills, and make sure lacking skills can be improved. According to this, the different skills for each member on the bridge in BRM training could be presented separately in the figure. It is very useful and helpful in the briefing and debriefing step.

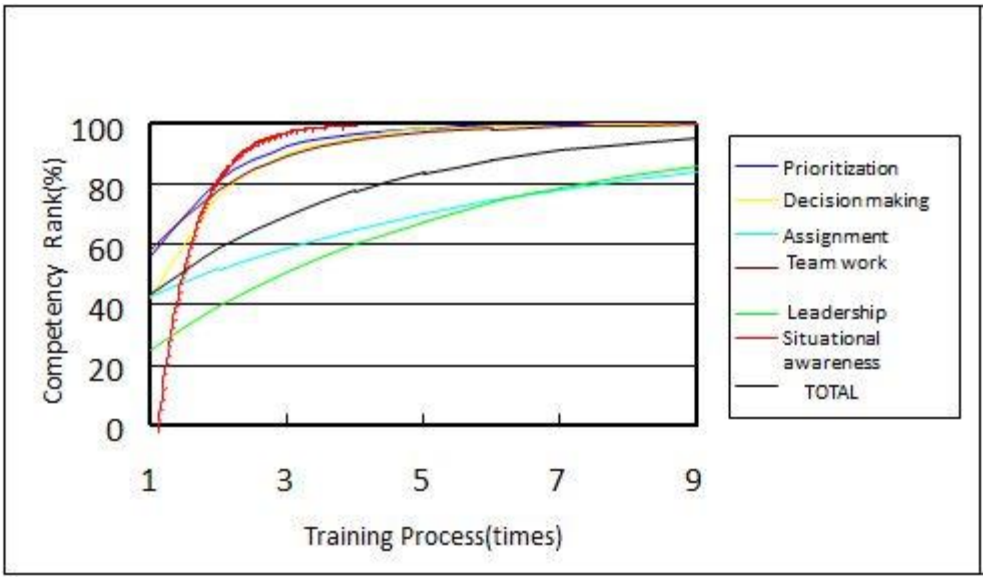

Figure 5-2 An assessing result sample

In this case, the result of the assessment is a process or trend. During the process of the training, an assessor can assess each of the three levels by skill index for a training group or an individual member because the three levels could be assessed separately. If the weights of the three goals are multiplied, and then multiplied by the weight of each group or individual, the score can be gained. If the previous level indicators are multiplied by the weight, the secondary indicators can be obtained as a result. Followed by analogy, skills of total score can also be gained. Finally, this method can help the instructor to identify which skills are lacking in a group or an individual so that targeted education and training can subsequently be carried out.

6. Chapter VI, Conclusions and recommendations

6.1. Conclusions

This research is based on interviews regarding BRM training status in domestic and international training centers. The development of BRM training is necessary for the proper understanding and implementation of the criteria of the STCW Code. BRM is the product of interdisciplinary research and, currently, this kind of competency is mandatory. All training centers have emphasized the importance and necessity of BRM training, and good results will be achieved gradually. The benefits of BRM training are not limited to the crews, but also extend to aspects involving the safe operation of the vessel. In a greater sense, it has improved and perfected the traditional ship safety management system. The further contribution of MET will be very positive and supportive.

As a result, the four research questions have been answered as follows:

1. Of what relevance are soft skills and hard skills training in the BRM context?

On the Basis of the HF&E theory analyzed in Chapter II and bridge team function examined in Chapter III, the question was answered by way of scenarios design.

2. What are the objective factors and parameters that can be used to assess the competency of seafarers using simulator scenarios in BRM training?

On the basis of an extensive review of literature, field observation and the study background, generally five groups of hard skills and three groups of soft skills emerged.

3. How can these factors in the scenarios be ranked with respect to priority/importance?

On the basis of scenarios design, an assessment sheet has been designed, and the weight of each element in the assessment has been obtained by the AHP method.

4. How can assessment mechanisms be designed using these factors?

Firstly, assessment mechanisms should be based on the designed scenarios and relevant assessment sheet, and secondly, the integrated indicator system is also very important to the outcome. An example of training outcome is introduced in Chapter V, which is a sample of assessment mechanisms.

With the development of advanced full mission simulators and the improvement of hard skills over many years, the enhancement of soft skills is now the challenge that is being faced. Such soft skills include developing teamwork and reducing human errors of the bridge team. This has to be the focus of research. On this basis, extensive research was carried out by the AHP evaluation method to establish the assessment sheet applied to the hard skills and soft skills to support weighting of relevant elements, to improve training on simulators. In order to ensure BRM training is carried out more effectively, the assessment sheet was improved. The advantage of this assessment sheet is simple, informative and easy to understand. The outcome of this work derived from a combination of the researcher's own teaching experience and data collected from multinational training centers and the training experiences of the instructors there. This kind of training approach could enhance students' intuitive understanding of BRM.

6.2. Recommendations

Firstly, this research, however, still has some limitations. The assessment sheet design was not perfect as the elements selected were not sufficient to cover every aspect of BRM. If evaluation elements can be refined better and in more detail, the system will be better. The evaluation system combination method will be carried out in the future. Furthermore, a database of past training results should be established in the future. If such a database existed, not only could assessment based on the data distribution be realized, but the result could contribute to accident investigation for human factor research.

Secondly, the BRM training method should not be fixed, because different training centers have different training simulator. The scenarios and assessment sheet design should also be based on the status of the simulator, and the BRM training will be different as a result. Finally, this research provides recommendations on how to implement STCW Convention and Code through practical training activities.

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Appendix A – Letter and interview guide used

Dear Mr. /Mrs.

Thank you for taking the time to respond to this survey. Both your work as an instructor and your contribution to this research work are deeply appreciated.

I am a student at the World Maritime University, Malmo, Sweden, studying to complete a Master degree in Maritime Affairs. As part of my studies, I am seeking to collect data about the combination of soft skills and hard skills in BRM training which are affecting the seafarers' competency and performance at sea, for the purpose of improving the training on simulator. I will be grateful if you would kindly take a few minutes to answer the attached questions and help me to collect the necessary data and scenarios setting and assessment sheets for my studies. Responding to these questions should not take more than 30 minutes, because of already having had a chat with you during my field study trip.

The data collected will be used for academic purposes only. Any personal and private information about participants and organizations will be treated with utmost confidentiality. All data will be analyzed in aggregate and no individual elements will be isolated without your direct permission. As a recipient of the interview, you have every right not to participate in the survey and withdraw at any stage. It is my hope, however, that you will participate and help in the completion of this work, with a view to contributing to the enhancement of the training of seafarers and for the safety of the maritime industry.

Thanks, once again.

Part I: Personal information in general

Name: ___________

Gender: __________

Nationality:___________

Age:__________

Service organization: _________

Rank: ________________

Service years: _________

Part II: Interview on the priority of evaluation indexes for BRM assessment sheet

Requirement: The scale of numbers for interviewees to choose, and indicate the relative importance in between

Intensity of importance	Definition
1	Two elements comparing: Equal importance
3	Two elements comparing: Moderate importance
5	Two elements comparing: Strong importance
7	Two elements comparing: Very strong importance
9	Two elements comparing: Extreme importance
2,4,6,8	Between the adjacent importance

Table (1):

B	Hard skills	Soft skills
Hard skills	1	
Soft skills		1

Table (2):

C2	Communication	Team	Command
Communication	1		
Team		1	
Command			1

Table (3):

C1	Voyage planning	Action to avoid collision	Safe sailing	Indicated operation in special area	Contingency and emergency
Voyage planning	1				
Action to avoid collision		1			
Safe sailing			1		
Indicated operation in special area				1	
Contingency and emergency					1

Table (4):

D1	Captain on bridge	Plottin g	Caution in special area	Safe distance and speed	Key points of Communication	Nautical publication	Contingency plan and Emergency plan
Captain on bridge	1						
Plotting		1					
Caution in special area			1				
Safe distance and speed				1			
Key points of Communication					1		
Nautical publication						1	
Contingency plan and Emergency plan							1

Table (5):

D2	Observation moment (ROC)	Means of look-out	DCPA	Communication	Means of action	Operation of radar	Checking effectiveness
Observation moment (ROC)	1						
Means of look-out		1					
DCPA			1				
Communication				1			
Means of action					1		
Operation of radar						1	
Checking effectiveness							1

Table (6):

D3	Safe speed	Correction of deviation	multiple positioning	TSS and local regulation	Familiarization of instrumentation	Deal with environmental change
Safe speed	1					
Correction of deviation		1				
multiple positioning			1			
TSS and local regulation				1		
Familiarization of instrumentation					1	
Deal with Environmental change						1

Table (7):

D4	Captain on bridge	Cooperation	Relev-ant oper-ation	Turn speed and rudder angle speed control	Course changing opportunity	Bow thruster and tug assistance	Communication
Captain on bridge	1						
Cooperation		1					
Relevant operation			1				
Turn speed and rudder angle speed control				1			
Course changing opportunity					1		
Bow thruster and tug assistance						1	
Communication							1

Table (8):

D5	Emergency plan	Reporting in emergency	Contingency plan	Contingency response	Communication
Emergency plan	1				
Reporting in emergency		1			
Contingency plan			1		
Contingency response				1	
Communication					1

Table (9):

D6	External communication	Internal communication	Efficiency of Communication
External communication	1		
Internal communication		1	
Efficiency of Communication			1

Table (10):

D7	Teamwork	Assignment	Allocation	Leadership	Consideration of team experience	Assertiveness
Teamwork	1					
Assignment		1				
Allocation			1			
Leadership				1		
Consideration of team experience					1	
Assertiveness						1

Table (11):

D8	Situational awareness	Decision-making	Prioritization of resources
Situational awareness	1		
Decision-making		1	
Prioritization of resources			1

Thank you for your time and participation!