

Training Effectiveness in Maritime Transport

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MM-MTH5001

15 May 2015

Abstract

Recent developments in training and assessment have focused on training of non-technical skills. The maritime industry has made significant investments in training and assessment in safety. Previous literature has discussed whether training an assessment pays off in terms of improved safety at the sharp end. However, they have not provided ample evidence on the effectiveness of CRM training on safety. The report also gives an overview of maritime transport. The emphasis here is maritime transport's safety performance compared to other transport modes. Resource Management and Simulation-Based Training have been introduced in the maritime industry. The aim of the thesis is to document the effectiveness of training and assessment. The method will be a literature review on the effectiveness of team training.

Keywords: maritime, teamwork, training and assessment

The purpose of the thesis is to find out whether training and assessment in the maritime industry affect safety performance at the sharp end. The method will be a literature review on the effectiveness of team training. Billions of dollars are spent on training and assessment annually (Salas, Tannenbaum, Kraiger, & Smith-Jentsch, 2012). Most research on team training evaluation have been conducted in the military and in aviation (Salas et al., 2008).

Safety at sea depends to a high degree on the interaction between bridge personnel, the deck department, and the engine department. Learning how to work in a team, and to perform functions in a timely and safely fashion is of utmost importance in the daily operation of a vessel. The master has the main responsibility for the safety of personnel and passengers on board.

Training and assessment of seafarers has traditionally focused on the training of technical and practical skills, such as navigation, manoeuvring, mooring, and maintenance (Øvergård et al., In Press). Only recently have maritime organisations laid an emphasis on training and assessment of non-technical skills. Most training and assessment courses in the maritime industry aim at training technical skills. The aim of training and assessment is to ensure that maritime personnel receive adequate training so that they can perform maritime operations in compliance with STCW, ISM, and ISPS codes.

In the maritime industry, on the job (OTB) training was the norm in the 19th and 20th century when young cadets received all their training and assessment on board in the British Navy. However, this changed when formal requirements were introduced in the 20th century following major maritime accidents such as the Titanic, compulsory schooling, and especially technological innovations revolutionized the maritime sector (container shipping, ECDIS and AIS, etc.). There was first a

transition from on the job training to the classroom. Innovations such as the Personal Computer and a tremendous increase in computational power, has transformed the training and assessment of operators. The development of advanced simulation technologies such as Virtual Reality (VR) changed the nature of training and assessment of seafarers.

The Manila Amendments to the STCW Code contains new requirements relating to training in modern technology such as ECDIS as well as new requirements for marine environment awareness and training in leadership and teamwork (IMO, 2011).

Recent developments in training and assessment have focused on the training of non-technical skills, as opposed to technical skills (Flin, O'Connor, & Crichton, 2008; Flin, Patey, Glavin, & Maran, 2010). Research has shown that improving individual team members' nontechnical skills may have an impact on team performance and overall safety (Flin & Patey, 2009).

Research on how pilots interact with machines in the cockpit has resulted in the development of *Crew Resource Management*. Crew Resource Management is a training method that aims at developing the operator's non-technical skills. The use of CRM for training team (non-technical) skills such as situational awareness, decision-making and communication has been used in high-reliability industries such as aviation and nuclear power plants. A high reliability organisation develops high reliability systems that can operate relatively error-free over a long period of time, and sometimes, in very hazardous environments (Bea, 1998, p. 110).

Previous research on training effectiveness on maritime safety include Fonne, Fredriksen, and Jensen (1995) and O'Connor (2011). There is a paucity of research on the effectiveness of training on safety in the maritime industry. However, there are

many studies on the effectiveness of CRM training in aviation and health care. Salas et al. (2012) mentions that “the research on training clearly shows two things: (a) training works, and b) the way training is designed, delivered, and implemented, matters”.

Salas, Burke, Bowers, and Wilson (2001) conducted a comprehensive review of 58 articles on CRM training for flight crews within the commercial and military domains. The results of the study show that CRM training produced a) positive reactions (i.e. affective and utility based), b) enhanced learning, and c) desired behavior change in the cockpit. However, it was not possible to determine the impact of CRM training on safety (Salas, Wilson, Burke, Wightman, & Howse, 2006). Salas, Burke, et al. (2001) found that CRM training led to positive attitudes, learning, and (potentially) safety in organisations. Three of the five studies that evaluated training at the organisational level suggested that CRM training had a positive impact on safety in terms of reduced human error or incidents (Salas, Wilson, Burke, & Wightman, 2006, p. 404). A subsequent study, Salas, Wilson, Burke, and Wightman (2006), mentioned that CRM training produces positive reactions, enhanced learning, and desired behavioral change in a simulated or real environment. However, the study was inconclusive with respect to the effect of CRM on safety.

Previous literature on human reliability in transport systems include Dhillon (2009).

The main research question in this thesis will be:

1. How do training and assessment programmes affect maritime safety?

Outline of thesis

The *first* chapter will be about human reliability. I will also explain the concept of human error and safety. The *second* chapter will present safety performance in the maritime industry and other transport modes, and will include a table on the reliability of transport systems. The *third* chapter will give an overview of maritime regulations, e.g. STCW 2010. The *fourth* chapter, theory of training, will give an overview of theories on training and assessment. The *fifth* chapter, method, will provide an overview of the concepts that have been used in the literature review, inclusion and exclusion criteria, and training and assessment procedures. The emphasis has been on the transfer of training. The *sixth* chapter includes the findings. The *seventh* chapter, analysis, will discuss the degree to which CRM training affects safety performance at the sharp end.

Human Reliability**Definition of Safety**

There is no commonly agreed definition of safety. The American Standards Institute defined safety as freedom from unacceptable risk, where unacceptable risk is indirectly defined as a risk for which the probability is too high (Hollnagel, 2014). Safety is a construct that may prove difficult to assess and interpret, as there are different perceptions of safety among maritime stakeholders. Safety assessment and measurement of maritime accidents can be difficult as the maritime industry consists of many different kinds of ships in complex environments (Lu & Tseng, 2012). As safety is a property of a system, it is not directly observable before one has a lack of safety. Many claim that they can document what affects safety performance, but the problem here is that there are no data to confirm it. We know about accidents, but little about their causes. Perrow (1999) postulated that accidents are the norm in high-

risk industries. Errors and accidents cannot be eliminated entirely; only the time interval between accidents.

Hollnagel (2014, pp. 39-40) distinguishes between the 'sharp end' and the 'blunt end'. The sharp end refers to the proximal factors (here and now) as opposed to the blunt end, which are the distal factors (working there and then) (Schröder-Hinrichs, Hollnagel, & Baldauf, 2012). The sharp end can also refer to the physical factors (i.e. navigating a vessel), whilst the blunt refers to the underlying factors (such as organisational and managerial). Although the blunt end (organisational and technical factors) may have an impact on safety performance, operational safety depends on the actions (psychological and physiological) that occur at the sharp end, when the operator is performing the task, e.g. navigation. Common features in the sharp end include uncertain and dynamic environments, multiple sources of concurrent information, an environment that is subject to stress and fatigue, introduction of new technologies with many redundancies, and differing goals and intentions among team members (Reason, 1995). Safety performance can be measured by errors or accidents, and is an important outcome of team performance (Flin et al., 2008).

Human Error

Human error is now widely recognised as the main cause of maritime accidents (Rothblum, 2007). Roughly 80 per cent of accidents in the maritime industry can be attributed to human error (Fenucci, 1990). Reason (2013, p. 10) defines human error as being: "... all those occasions in which a planned sequence of mental or physical activities fails to achieve its desired goal without the intervention of some chance agency".

There is now an increasing recognition in the human factors literature that part of the responsibility for human error lies with designers and operators and not just the end users of the socio-technical system (Johnson, 2011). According to Rasmussen (1997) society seeks to control safety behaviour through the socio-technical system. The socio-technical system includes many levels of decision-makers involved in the control of safety by means of laws and regulations, whose aim is to educate, guide, or constrain the work force's behaviour by rules and equipment design to improve their safety performance (Rasmussen, 1997).

Safety Performance

Maritime Transport

IHS Maritime world casualty statistics for 2013 (IHS Maritime, 2014) show that 138 ships with a total of 863 314 GT were reported as total losses. While the age of the world fleet increased from 12.5 years in 1980 to 22 years old in 2005, ship loss rates have fallen with 73% over the same period (Alderton, 2011). During the same period, the world fleet increased from 73,500 to 92,225.

In European waters there have been no significant accidents in the Passenger/Ro-Ro ship category since the foundering of the Estonia on 28 September 1994. In 2014 the highest number of casualties occurred in the maritime region South China, Indo China, Indonesia & the Philippines (*AGCS, 2015*). According to an analysis of time lost through injuries reported to the Maritime Authority in 2001, the rate of injury for vessels in the Danish Maritime Shipping Register was estimated to be 14.2 injuries per million working hours (Jensen et al., 2004).

The term that is used to assess maritime safety is total loss. The total loss of ships means “propelled merchant ships of not less than 100 GT which, as a result of being a marine casualty, have ceased to exist, either by the virtue of the fact the ships

are irrecoverable, or have been subsequently broken up” (AGCS, 2012). The number of world fleets will influence the amount or occurrence of maritime accidents, which is measured by the total loss number (Li & Zheng, 2008). The total loss rate can be calculated as follows:

$$Total\ loss\ rate = \frac{total\ loss\ number}{number\ of\ world\ trading\ fleet}$$

Figure 1 gives the total loss rate of ships between 1970 and 2003 (Li & Zheng, 2008).

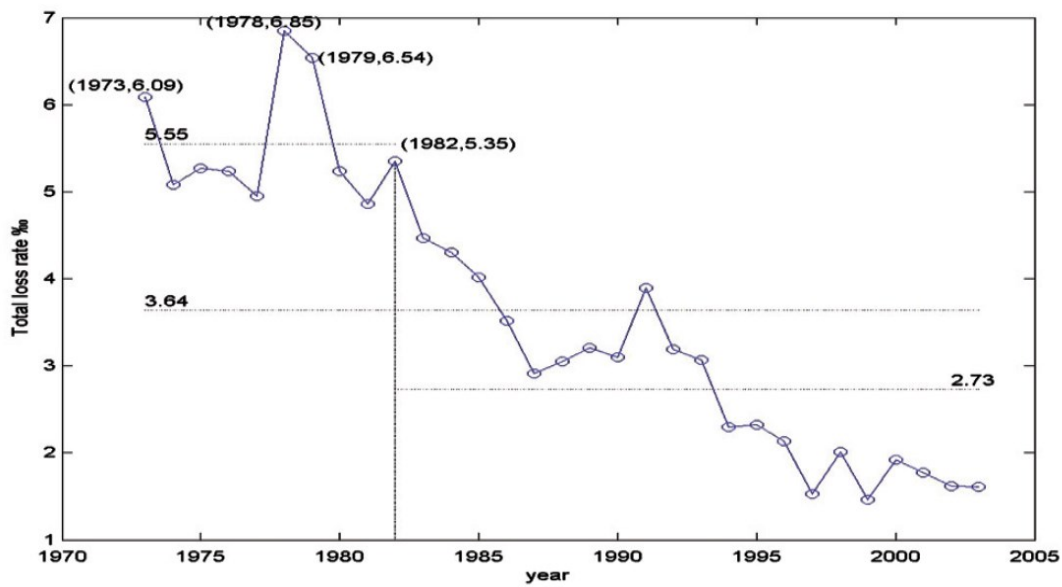


Figure 1 Total Loss Rate 1973-2003

Source: Li and Zheng (2008)

One third of maritime accidents happen in two maritime regions of the world, South China, Indo China, Indonesia & Philippines, and Japan, Korea and North China (AGCS, 2015). The number of total losses for ships over 500 GT was only 75 in

2014, which represents a 50 per cent decrease since 2005 (IUMI, 2014). Table 1 shows the number of total losses by ship type.

Table 1 Total losses by ship type (2005-2014)

Period	Barge	Bulk	Cargo	Chemical / Product	Container	Dredger	Fishery	LPG/LNG	Other	Passenger	Ro-ro	Supply / Offshore	Tanker	Tug	Unknown	
2005	5	6	61	6	2	4	34	1	3	12	7	3		5		149
2006	6	8	61	11	4	3	23		3	12	10	3	2	7	1	154
2007	6	12	70	6	3	2	33		7	8	5	5	1	11	1	170
2008	3	8	58	7	2	5	36	1	5	4	8	1	3	7	1	149
2009		10	51	8	4		29		5	5	6	3	2	5		128
2010	1	11	60	5	5	2	21		3	3	1	2	3	7		124
2011		13	36	2	3	2	14	1	5	7	3	1	2	2		91
2012		8	61	8	5	2	12	1	3	6	5	3	1	6		121
2013	3	15	40	10	4		13		6	8	2	2		7		110
2014	1	3	25	2	4	1	14		3	7	5	2	1	7		75
Total	25	94	523	65	36	21	229	4	43	72	52	25	15	64	3	1,271

Source: Lloyd’s List Intelligence Casualty Statistics

Hassel, Asbjørnslett, and Hole (2011) compared casualty data from IHS Fairplay from the period 1 January 2005 to 31 December 2009. The findings document that the estimated upper limit reporting performance for the flag states ranged from 14% to 74%, whilst the corresponding estimated average for IHS Fairplay ranged from 4% to 62%. The study shows that on average 50% of accidents are unreported in the maritime industry (Hassel et al., 2011).

In the following section, I will give an overview of the safety performance in aviation, rail, and road transport.

Aviation, Rail, and Road Transport

Aviation

Statistics suggest that only 1 out of 22.8 million flights will encounter a fatal

accident (Courtright, Stewart, & Ward, 2012). ICAO identified three high-risk categories based on a historical analysis of accident data. The high-risk occurrence categories are (ICAO, 2014):

- Run-way safety related events
- Loss of control in-flight (LOC-I)
- Controlled flight into terrain (CFIT)

An aircraft accident can be defined as “an occurrence associated with the operation of an aircraft that takes place between the time any person boards the plane with the intention of flight and such time as all such persons have disembarked, in which (Boeing, 2014):

- The aircraft sustains substantial damage
- The aircraft is missing or is completely inaccessible
- Death or serious injury results from
 - Being in the aircraft
 - Direct contact with the aircraft or anything attached thereto
 - Direct exposure to jet blast

Mortality Risk for Passenger flights is a measure that ignores the length and duration of flight, which are unrelated to risk, and weights each accident by the proportion of passengers killed (Barnett & Wang, 2000). One accident that kills every passenger on board is counted as one accident, whereas one accident that only kills a quarter of the passengers is counted as a quarter of a fatal accident (CAA, 2013, p.

33).

Table 2 shows the mortality risk for passenger flights expressed in three ways: 1) a pure probability, 2) the number of randomly chosen passenger flights that it would take, on average, to kill an aircraft occupant, and 3) the number of years that would pass if such as flight was taken every day (CAA, 2013, pp. 33-34).

Table 2 Mortality Risk for passenger flights for the ten-year period 2002 to 2011 broken down by aircraft class and operator region

	Per Flight	Number of Flights	Number of Years
All Passenger Flights	3.2×10^{-7}	3.1 million	8,505
Jet Passenger Flights	20×10^{-7}	5.0 million	13,573
Turboprop Passenger Flights	7.9×10^{-7}	1.3 million	3,466
African Operator Passenger Flights	2.0×10^{-6}	0.5 million	1,390
Asian and Middle Eastern Operator Passenger Flights	4.0×10^{-7}	2.5 million	6,784
Caribbean, Central and South American Operator Passenger Flights	8.1×10^{-7}	1.2 million	3,385
European Operator Passenger Flights	2.7×10^{-7}	3.8 million	10,285
(EU)	5.8×10^{-8}	17.2 million	47,215
North American Operator Passenger Flights	5.3×10^{-8}	19.0 million	51,982
Oceania Operator Passenger Flights	1.9×10^{-7}	5.3 million	14,655

Source: Adapted from CAA (2013, p. 34)

Rail

There are around 2400 significant accidents on the railways of EU member states annually. In 2013 two types of accidents, rolling stock in motion and level-crossing accidents, represented 83,5 % of the total amount of victims and 90,6 % of the fatalities. More than three quarters of railway accidents are caused by rolling stock in motion and level crossing accidents. 2 219 persons were killed or seriously injured in railway accidents in the EU-28 in 2013.

Figure 2 shows the relationship between significant accidents and resulting casualties for the EU-27 (2007-2011).

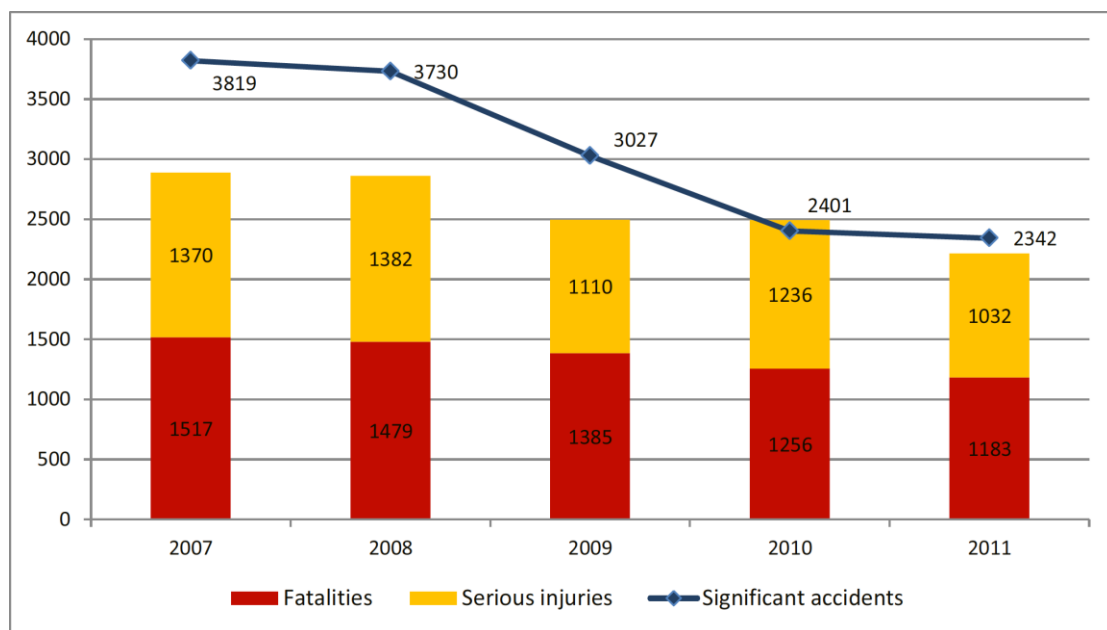


Figure 2 Significant accidents and resulting casualties for the EU-27 (2007-2011)

Source of data: EU transport in figures (Statistical Pocketbook 2012), DG MOVE 2012, European Commission

Road

There has been a substantial decrease in the fatality rates of the best performing countries in the period 1970-2005 (Hakkert & Gitelman, 2014). Until the

1960s and 1970s, decision-makers followed a mono-causal approach to road safety. However, some researchers started to realise that this approach was not helpful, and opted for a systems-approach to safety. One of the first thinkers was William Haddon, who developed a matrix concept, describing a short sequence of events before, during, and after the crash, wherein countermeasures can be sought applying to the human, vehicle, and road elements applying to such a crash (Hakkert & Gitelman, 2014, p. 142). Haddon sought an improvement in road safety analogous to industrial processes, whereby floors can be made more skid-resistant so that workers do not slip (instead of explaining to them to tread carefully), or making machines more fail-safe by introducing safety systems, for example operations by two hands before a press, or cutting knife, is activated (Hakkert & Gitelman, 2014). This was the underlying philosophy of vehicle safety regulations that improved safety performance in cars. However, this approach has its limitations, as it has not found ways to safety “package” vulnerable road-users such as motorcyclists, cyclists, and pedestrians (Hakkert & Gitelman, 2014). Figure 3 shows the development over time in the EU-28 since 2010.

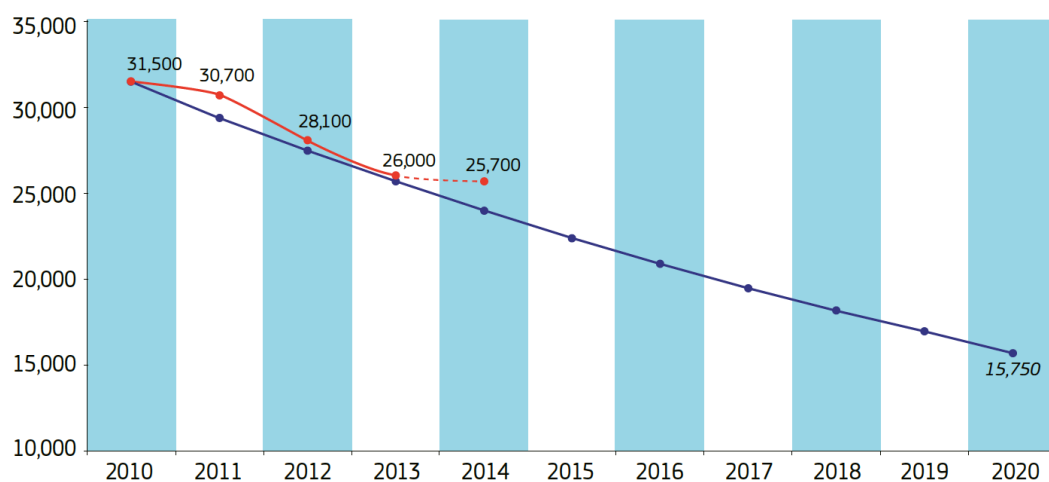


Figure 3 Road Fatalities in the EU-28 2001-2010

Source: European Commission (2015)

The overall trend shows a decrease in the number of road fatalities in the EU-28. However, the decrease rate has slowed down in 2014. The EU road fatality rate in 2014 was 51 deaths per million inhabitants (European Commission, 2015).

Globally the number of people killed on the world's roads was 1.24 million in 2010 (WHO, 2013). Eighty per cent of road traffic deaths occur in middle-income countries, which represent 72% of the world's registered vehicles. The overall global road traffic fatality rate is now 18 per 100 000 population (WHO, 2013). Pedestrians and cyclists account for twenty-seven per cent of all road traffic deaths (WHO, 2013).

Table 3 Reliability of Transport Systems

Source	Eurostat (2014)	Eurostat (2014)	Eurostat (2014)	European Commission (2014)	CAA (2013)	CAA (2013)	CAA (2013)	IHS Maritime (2014)	IHS Maritime (2014)	IHS Maritime (2014)
Metrics	Rail Number of fatalities EU-28	Rail Number of fatalities EU-15	Rail Fatality rate per billion pkm	Road Fatality rate per mill. inhabitants EU-28	Aviation Per Flight ^a	Aviation Fatal Accident Rate (per million flights flown)	Aviation Fatality Rate (per million flights flown)	Maritime Total Losses ^b	Maritime Loss Rate m.GT	Maritime Fatalities ^c
2008	1509	634						187	0,55	1 118
2009	1478	623						228	1,23	693
2010	1314	580		62				218	1,10	253
2011	1265	529						176	1,17	3214
2012	1174	523		55				158	0,84	641
2013	1184	601	0.24	52	3.2 x 10 ⁻⁷	0.6	22.0	138	0,86	290
2014				51						
Average	1320	581						184		1034

^aMortality Risk for passenger flights

^breported total losses of propelled, sea-going merchant ships of 100GT and above

^cThe number of persons reported killed or missing (lives lost) as a result of total losses

Maritime Regulations

The International Maritime Organisation

The International Maritime Organisation was established in 1959 as a permanent international body to promote maritime safety more effectively (Grech, Horberry, & Koester, 2008). Today the most important conventions are the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) and the International Convention for the Safety of Life at Sea, as amended in 1974 (SOLAS 74). International maritime conventions are often adopted as a response to major maritime accidents. This has been the case since the first iteration of SOLAS in 1914, two years after the loss of the Titanic in the Northern Atlantic.

IMO regulations are mandatory, but it is up to the flag state to implement and interpret them. IMO is rather slow at introducing new regulations that may impact safety performance, mainly because amendments to existing conventions need the ratification of 2/3rds of its 171 member states. However, the track record of the maritime industry with regard to safety has been rather lacklustre compared to other transport modes such as aviation and rail.

Safety Management System (ISM Code)

The ISM code was added as Chapter IX in SOLAS in 1994 and became mandatory for passenger and dangerous cargo ships in 1998, and for the rest of the fleet in 2002 (Chauvin et al., 2013). According to the International Safety Management (ISM) Code, ship owners must satisfy formal requirements that ascertain that the shipping company establishes and maintains procedures to control documents and data relevant to the safety management system (documents of compliance) (Lu & Tseng, 2012).

According to the ISM code, every company must develop maintain, and

implement a Safety Management System (SMS). The company must also assess and document the position of responsibility and individual competency of each crew member (IUMI, 2014). The SMS includes the following functional requirements (Chauvin, Lardjane, Morel, Clostermann, & Langard, 2013):

- (a) A safety and environmental protection policy
- (b) Instructions and procedures to ensure the safe operation of Ships and protection of the environment in compliance with relevant international and flag State legislation
- (c) Defined levels of authority and lines of communication between, and amongst, shore and shipboard personnel
- (d) Procedures to prepare for and respond to emergency situations
- (e) Procedures for international audits and management reviews

STCW

STCW (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978/1995/2010) established uniform standards of competence for seafarers. Maritime education and training now requires certificates of proficiency such as STCW 95. The maritime industry has taken several measures to improve its safety performance. However, the majority of the world's seafarers work on a ship that has a different flag state than their country of origin. This signifies that confidence in standards of competence is underpinned by the IMO Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW) (ICS, 2014).

Major Maritime Accidents that led to Maritime Safety Legislation

Maritime safety regulations can be traced back to the *Titanic* (Alderton, 2011)

Major maritime accidents in European waters include the Torrey Canyon and

the *Amoco Cadiz*. The *Torrey Canyon* ran aground on Pollard's Rock between Land's End and the Isles of Scilly on 18 March 1967. 119,328 tonnes of crude oil seeped into the Atlantic. The crude oil from the oil spill had devastating environmental consequences, and is still killing wildlife on a daily basis (Barkham, 2010). IMO and its member states ratified the MARPOL Act in 1973 as a response to the incident. It was later amended in 1978 following the *Amoco Cadiz* disaster. The *Amoco Cadiz* crashed into the Portsall rocks off the coast of Brittany on 16 March 1978. However, the MARPOL Convention did not enter into force before October 2, 1983.

Following the Exxon Valdez incident in 1989, MARPOL Annex I was amended in 1992. MARPOL Annex I required the phasing out of single-hull tankers. All category I tankers were to be phased out within 2015, whilst Category II and III tankers were to be phased out within 2015 (Håvold, 2010, p. 511).

After major accidents involving oil spills such as the *Torrey Canyon* in 1967 and the *Amoco Cadiz* in 1978, IMO member states ratified the International Convention for the Prevention of Pollution from Ships (MARPOL 1973) as modified by the Protocol 1978 relating thereto (MARPOL 73/78).

As a consequence of the *Exxon Valdez* incident in 1989, Congress passed the *Oil Pollution Act* (OPA 1990). OPA 1990 also included provisions with respect to safety at sea that are now mandatory for maritime organisations.

The *Costa Concordia* incident is a reminder that safety at sea requires continuous attention, and that even modern ships equipped with state-of-the-art technologies are vulnerable to human error.

The *Costa Concordia* incident, as many major accidents before it, prompted changes in maritime regulations on training that may impact safety performance. Recommendations from the accident investigation of the *Costa Concordia* included

provisions for revising the contents of instruments such as SOLAS, STCW and the ISM Code with regard to issues such as (Marine Casualties Investigative Body, 2013):

- a) *Bridge Resource Management* (a more flexible use of the resources and an emphasis on decision-making and “thinking aloud”)
- b) *Bridge Team Management* courses should be mandatory by 1. January 2015
- c) *Principles of Minimum Safety Manning* should be updated to be more suitable for larger passenger ships
- d) A *muster list* that documents that crew members have the proper certifications
- e) The inclusion of *inclinometer measurements* in the VDR.

Theory of Training

Training has been defined as “the systematic acquisition of attitudes, concepts, knowledge, rules, or skills that should result in improved performance (Goldstein, 1991)”.

CRM Training

Crew Resource Management was first introduced in 1979 as a training method aiming to improve non-technical skills among pilots in the cockpit. The training method was first named Cockpit Resource Management, but was extended to include cabin and maintenance personnel and renamed Crew Resource Management. The focus of most CRM training at this stage was on input factors, especially in the area of knowledge and attitudes (Helmreich & Foushee, 2010). J.K Lauber, a psychologist member of the National Transportation Safety Board (NTSB) defined CRM as “using all available resources – information, equipment and people – to achieve safe and efficient flight operations (Lauber, 1984, p. 20)”.

CRM training aims at developing the operator's non-technical skills, such as *s, communication, decision-making, leadership, management of stress & fatigue, Situational Awareness, and team-based coordination and cooperation*. Non-technical skills has been defined as “the cognitive, social and personal resource skills that complement technical skills, and contribute to safe and efficient task performance (Flin et al., 2008, p. 1)”. Non-technical skills are the decision-making and social skills that complement technical skills. Team decision-making refers to a process in which team members reach a common decision based on interdependent individuals to reach a common goal (Flin et al., 2008, p. 110). Disadvantages when developing a schema to assess non-technical skills can be that accident analysis may present only part of the complete picture (Hollnagel, 2004).

Cognitive skills can be defined as “the mental processes used for gaining and maintaining situational awareness, for solving problems, and for taking decisions (Royal Aeronautical Society, 1999)”. Situational Awareness can be defined by goals and tasks specified for a job. Level 1, *perception* of “cues” is an important element of SA. Without a basic perception of important information, the trainee may not be able to correctly assess the situation.

Level 2, *Comprehension* encompasses how people combine, store, interpret and retain information (Endsley, 2000). Level 3, *Projection* refers to the operator's ability to project from current events and dynamics to anticipate future events (and their implications) (Endsley, 2000).

CRM training does not necessarily strengthen any particular team, but it can improve the efficiency of individual team members' in whichever team they are working in (Flin et al., 2008, p. 93). CRM training involves communicating basic

knowledge of human factors that relate to maritime operations and provide the tools for applying these concepts operationally (Helmreich & Foushee, 2010).

Evaluation of CRM Training

The objective of CRM is to find out whether 1) CRM training makes any noticeable difference in the dependent variables and 2) the size of the training effect (Salas, Bowers, & Edens, 2001). Team-based coordination and cooperation and SA can for example influence decision-making. CRM Training can be measured using a standard rating scale. For example, airlines should be able to specify the criteria for standard performance on the basis of a job analysis (Holt, Boehm-Davis, & Beaubien, 2001, p. 198). Both technical and CRM performance ratings can be based on a 4-point rating scale covering the full range of possible crew performance (Holt et al., 2001): *unsatisfactory, satisfactory, standard, and above standard*.

Table 4 Four-Point Rating Scale With Labels and Their Meanings

<i>Rated Value</i>	<i>Label</i>	<i>Precise Meaning</i>
1	Unsatisfactory	Observed crew behavior did not meet minimum requirements
2	Satisfactory	Observed crew performance met FAA standards but not airline standards
3	Standard	Observed crew performance met airline standards
4	<i>Above Standard</i>	Observed crew behavior was markedly better than the <i>standard</i> performance in some important way

Source: Holt et al. (2001, p. 198)

Measurement of Training Effectiveness

Sensitivity can be defined as “the extent to which a measure can detect changes in the construct being assessed” (Holt et al., 2001, p. 174). For example, a sensitive measure of resource management should show higher scores for performance over average and lower scores for below average performance. Extreme examples of good or bad performance are easier to detect. To objectively index the sensitivity of measurement, the judgements of the evaluators should be compared with pre-established levels of resource management (Holt et al., 2001).

Reliability can be defined as the consistency or stability of measurement (Holt et al., 2001). Two methods of estimating and testing reliability were found to be relevant, each with its own advantages and disadvantages. *Test-retest reliability* is used to assess the stability of measurement over time. This form of assessment requires that evaluators assess the same set of performances at two different times and correlate these two sets of evaluations. In the method mentioned above, values of r near 0 indicates a lack of test-retest reliability, whereas values near 1 indicate near-perfect test-retest reliability (Holt et al., 2001). The assessment method is carried out by calculating the Pearson’s product-moment correlation and results in an index r that reflects reliability. Values of r near 0 indicates a lack of test-retest reliability, whereas values near 1 indicate near-perfect test-retest reliability (Holt et al., 2001, p. 175).

The other method that can be used to measure performance is *internal consistency reliability*. *Internal consistency reliability* refers to the internal coherence of a set of items that are all measuring the same thing (Nunnally, 1967). This method of measuring resource management requires distinct components, which each must have its own set of multiple items (Holt et al., 2001). Then the inter-correlations

among items in a set are summarized into a coefficient alpha index, which ranges from 0 (no internal consistency reliability) to 1 (perfect internal consistency reliability) (Holt et al., 2001, p. 176).

Validity refers to the extent of which a measure manages to measure its intended construct (Landy, 1986; Nunnally, 1967). From a resource management perspective, validity refers to the amount of variability in an evaluator's ratings that accurately reflects real-life variations in performance of the persons being evaluated. *Face validity* refers to the judgement of a group of experts that the items really measure the construct as intended (Holt et al., 2001, p. 177). As some judgements are subjective, it may not be easy to confirm that an item that measures a construct has predictive value. *Content validity* requires a specification of all the items that are relevant to the domain. Content validity can be achieved by showing that the evaluation items are a fair, representative and unbiased sample from the larger domain (Holt et al., 2001).

There are two basic principles that apply when examining the validity of a measure. *Convergent and discriminant validity* implies that measures that ought to be related to the construct should correlate or converge with the proposed measure (Holt et al., 2001). A construct is valid if it can show the expected relationships with plausible criteria (criterion validity) and predict expected outcomes of resource management (predictive validity). *Divergent reliability* implies that measures that ought to be distinct from resource management should diverge or not correlate with the proposed measure (Holt et al., 2001).

Network validity. To examine a construct for network validity, the nomological network of constructs that are theoretically associated with the construct need to be empirically assessed to determine whether it demonstrates the expected

pattern of relationships (Holt et al., 2001).

Simulation-based Training

Salas, Wildman, and Piccolo (2009, p. 560) defined simulation-based training as "... any synthetic practice environment that is created in order to impart these competencies (i.e. attitudes, concepts, knowledge, rules, or skills) that will improve a trainee's performance". In a simulated environment the learning curve occurs at an accelerating pace, as students who make decisions receive immediate feedback (Salas et al., 2009). According to Salas et al. (2009, p. 562), "immersion refers to the sense of realism that a simulation elicits". "The potential of immersion in SBT can ... prompt relevant emotional responses during training that may be critical to the gaining of new competencies" (Lane, 1995).

Simulation fidelity should be matched to simulation requirements. Research has shown that low-fidelity PC-based simulations can be used to train complex individual and teamwork skills (Salas & Burke, 2002). "Simulation in aviation, maritime and other environments suggests that realistic role play is essential for acquisition of new skills, and that recurrent practice is essential for skills maintenance" (Musson & Helmreich, 2004, p. 34).

The best way to train maritime personnel in technical and non-technical skills is to use specially designed simulators that simulate complex shipboard conditions (Schröder-Hinrichs et al., 2012). Full mission bridge simulators emulate the real shipboard environment through the use of virtual reality (VR). Simulators can also be used to train the trainee's non-technical skills such as communication, decision-making and leadership.

The advantages of using Simulator-Based Training are many. It is possible to evaluate the effectiveness of training in a controlled environment. SBT can be more

effective than classroom instruction. SBT is particularly adapted to the training of practical skills that are needed in a complex socio-technical environment such as a bridge. Advanced simulators also have the possibility to introduce stressors, so that the trainee also receives training in handling abnormal situations, if those should occur. A disadvantage of using SBT is cost. A full mission simulator can cost several million dollars.

Team Knowledge

Team knowledge can be defined as the collection of task- and team-related knowledge held by teammates and their collective understanding of the current situation (Cooke, Salas, Cannon-Bowers, & Stout, 2000, p. 154).

Edmondson (1999) conducted an examination of team learning in a field setting. Her findings show that team members exhibited more team-learning behaviours that were related to higher team performance when the team context supported experimentation and risk-taking (S. W. J. Kozlowski, Chao, & Jensen, 2010, p. 376). Her model postulated psychological safety as a key contextual construct, based on a perception of safety among team members, that promoted interpersonal risk taking in a psychologically safe setting (S. W. J. Kozlowski et al., 2010, p. 376): “Teams that perceived more psychological safety were engaged in more learning behaviours, such as sharing information, requesting assistance, seeking feedback, and discussing mistakes” (S. W. J. Kozlowski et al., 2010, p. 376).

Tuckman’s classic model of team development consists of the stages forming, storming, norming, and performing. In the forming stage, team members experience uncertainty about the group, their goals and roles, and how they will work together (S. W. J. Kozlowski et al., 2010, p. 379). The team then enters a storming stage in which they formulate ideas and compete to shape a social structure to reduce uncertainty (S.

W. J. Kozlowski et al., 2010, p. 379). After some time, the team enters a norming stage when team members develop norms to guide interactions, resolve their differences, and reduce social uncertainty. When the social structure is in place, the different team members enter the performing stage, and are able to focus on the tasks that they are given.

Knowledge, Skills and Attitudes (KSA)

J.A. Cannon-Bowers, Tannenbaum, Salas, and Volpe (1995) argued that three competencies are required for effective teamwork: knowledge, skills, and attitudes (KSAs). Knowledge refers to the team members' ability to predict and plan performance in future situations, along with their own roles and responsibilities (J.A. Cannon-Bowers et al., 1995). Table 5 gives a summary of teamwork competencies (KSAs) (Rosen et al., 2013).

Table 5 Summary of Teamwork Competencies (KSAs)

KSAs	Description	Example Behavioural Markers	Example Citations
KNOWLEDGE			
Accurate and shared mental models (knowledge about team members and role structure, team task, and environment)	Organised knowledge structures of the relationships among task and team members	<ul style="list-style-type: none"> • Team members can recognise when other team members need information they have. • Team members anticipate and predict the needs of others. • Team member have compatible explanations of task information. 	<p>Blickensderfer, Cannon-Bowers, and Salas (1997)</p> <p>Cooke et al. (2000)</p> <p>Smith-Jentsch, Campbell, Milanovich, and Reynolds (2001)</p>
Team Mission, objective, norms, and resources	An understanding of the purpose, vision, and available means to meet team goals	<ul style="list-style-type: none"> • Team members make compatible task prioritisations. • Team members agree on the methods adopted to reach their shared goals. 	<p>J.A. Cannon-Bowers et al. (1995)</p> <p>Marks, Mathieu, and Zaccaro (2001)</p>

SKILLS

KSAs	Description	Example Behavioural Markers	Example Citations
Closed-loop communication	A pattern of information exchange characterised by three steps: a sender initiates a message, the receiver acknowledges the message, and the sender follows up to confirm that it was appropriately interpreted	<ul style="list-style-type: none"> • Team members crosscheck information with each other. • Team members give “big picture” updates to one another. • Team members proactively pass critical information to those that need it in a timely fashion. 	<p>Bowers, Jentsch, Salas, and Braun (1998)</p> <p>McIntyre and Salas (1995)</p> <p>Smith-Jentsch, Johnston, and Payne (1998)</p>
Mutual Performance monitoring	Team members ability to track what others on the team are doing while carrying out their own tasks	<ul style="list-style-type: none"> • Team members have an accurate understanding of their teammates’ workload. 	Dickinson and McIntyre (1997)
Backup/supportive behaviour	The ability to shift and balance workload among team members during high-workload or high-pressure periods	<ul style="list-style-type: none"> • Team members communicate the need for task assistance. • Team members promptly offer and accept task assistance. 	McIntyre and Salas (1995)
Adaptability	The team’s ability to shift and balance strategies to changing situations	<ul style="list-style-type: none"> • Team members replace or modify routines when the task changes. • Team members detect changes in their environment quickly. 	S. W. Kozlowski, Gully, Nason, and Smith (1999)

KSAs	Description	Example Behavioural Markers	Example Citations
Team Leadership	Dynamic process of social problem solving involving information search and structuring, information use in problem solving, managing personnel resources, and managing material resources	<ul style="list-style-type: none"> Team members accurately assess the causes of important changes. Team members appropriately identify the person with the most appropriate skill set for leadership in a specific situation. Team members shift leadership roles in response to task demands. Leaders develop plans and communicate them to the team. 	Burke et al. (2006) Salas et al. (2008)
ATTITUDES			
Mutual trust	The shared belief among team members that everyone will perform their roles and protect the interests of fellow team members	<ul style="list-style-type: none"> Team members are willing to admit mistakes. Team members share a belief that team members will perform their tasks and roles. 	Driskell and Salas (1992)
Team/collective efficacy	The team members' sense of collective competence and their ability to achieve their goals	<ul style="list-style-type: none"> Team members share positive evaluations about the team's capacity to perform its tasks and meet its goals 	Bandura (1986)
Team/collective orientation		<ul style="list-style-type: none"> Team members have high levels of task involvement and participatory goal setting. 	

KSAs	Description	Example Behavioural Markers	Example Citations
		<ul style="list-style-type: none"> • Team members value team goals over individual goals. 	
Psychological safety	The team members' shared belief that it is safe to take interpersonal risks	<ul style="list-style-type: none"> • Team members believe others on the team have positive intentions 	Edmondson (1999)

Source: Adapted from Rosen et al. (2013)

Shared Mental Model

Smith-Jentsch et al. (2001) investigated mental models as a possible mediator of task performance in individuals. Shared knowledge refers to similar knowledge (i.e. homogeneous), or to knowledge that is distributed among team members (i.e. heterogeneous) (Cooke et al., 2000). Effective teams may not share knowledge that is similar or common among them. Instead, team members might hold *compatible* or *complementary* knowledge in addition to common knowledge (J. A. Cannon-Bowers & Salas, 2014).

According to Rouse and Morris (1986, p. 351), “mental models are the mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states.” Efforts to develop taxonomies of mental models tend to produce attribute-oriented characterisations for particular tasks (Rouse & Morris, 1986).

According to Salas, Rosen, Burke, Nicholson, and Howse (2007), shared mental models consist in knowledge that allows a closed-loop communication, mutual performance monitoring, and adaptive and supportive behaviour.

Team Mental Model

Recent research has emphasised team processes such as task coordination and performance. There has been a shift from individual mental models to team mental models (Ford, Kraiger, & Merritt, 2010). Smith-Jentsch, Mathieu, and Kraiger (2005) and Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000) have investigated the pre- and post-training effects of mental models on team performance and /or team process.

Marks, Zaccaro, and Mathieu (2000) studied the pre- and post-training effects of mental models on team performance, more specifically how team interaction training influences team members' knowledge structures (measured by a modified form of concept mapping). They found that team interaction training (cross-training) as well as leader

briefings led to enhanced levels of mental model similarity (sharedness) and accuracy. The enhanced level of knowledge facilitated communication between team members and increased overall team performance.

A mental model is similar to the one of Situational Awareness (SA). SA theories in general make the assumption that mental models enables SA by directing the operator's attention and by providing a means of integrating information and acting as mechanism for projection of future system states (Endsley, 2000).

Stanton, Salmon, Walker, and Jenkins (2008) suggested that there is a similar relationship between genotype (stereotypical) and phenotype (local- and individual-specific) schemata, as between mental models and SA. Genotype schemata are triggered by task-relevant information and operator behaviours, whilst phenotype schemata are constructed and updated based on genotype data during task performance (Stanton et al., 2008).

Method

Research Design

The literature search for this review was conducted by using different databases. The articles were chosen based on their relevance to CRM training in the maritime, aviation and healthcare domains. Keywords used in the search process included “training”, “Crew Resource Management”, “Maritime Resource Management”, and “non-technical skills”.

Search Engines and databases that have been used in the literature search include Academic Search Premier (EBSCOhost), Google Scholar, European PubMed Central, Oria, ProQuest, PsycARTICLES, PsychINFO, ScienceDirect (Elsevier), Scopus, Springer Link and Web of Science.

Ship accident data has been obtained from IHS Maritime's *World Casualty Statistics - 2013*. Reports on maritime casualties & incidents have been retrieved from the European Maritime Safety Agency and the UK's MAIB. Aviation accident data have been retrieved

from IATA, ICAO, and CAA. Railway accident data has been retrieved from ERA and Eurostat. Road accident data have been retrieved from the CARE database.

Inclusion and exclusion criteria

Research articles in the literature review have been selected on the basis of their relevance for the topic, maritime training and assessment. However, there is a paucity of research on the effectiveness of training on maritime safety. The literature search is therefore based on purposeful sampling. The articles were selected on the basis of relevance with respect to training and assessment and safety performance. Some of the articles are not about training and assessment. This is due to two reasons: a) there is a paucity of articles on CRM training that measure training effectiveness in the maritime domain b) the chosen articles are relevant with regard to maritime safety.

Theory on teamwork that has been used to gain an understanding of the subject include Holt et al. (2001); S. W. J. Kozlowski and Salas (2010).

Evaluation of Training Effectiveness

The evaluation of training effectiveness is based on Level 1 (Reactions), Level 2 (Learning) and Level 3 (Behaviour) of Kirkpatrick's four levels of training evaluation.

Table 2 Kirkpatrick's typology

Level 1	Reaction	How do the trainees react to the training? Level 2 (reactions) is the equivalent of measuring customer satisfaction.
Level 2	Learning	What have the trainees learned? Did they modify their attitudes and belief after training?
Level 3	Behaviour	Has the training resulted in changes in trainees' behaviour (transfer of training)?

Level 4	Organisation	Tangible evidence from training. How does the training impact the organisation's safety performance?
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Source: Kirkpatrick and Kirkpatrick (2006)

The first step in implementing this training evaluation model is to understand the guidelines of level 1 and applying them in every programme (Kirkpatrick & Kirkpatrick, 2006). Level 1 is the starting point, and one should proceed to the other levels as time and opportunity allow (Kirkpatrick & Kirkpatrick, 2006). Level 1 refers to the content of the training. The training should be comfortable, relevant and interesting. Level 2 (learning outcomes) measures what the trainee has learned during training. Has the trainee achieved the intended objectives? Level 3 (transfer of training) is related to training effectiveness, whilst Level 4 is related to safety performance at the organisational level.

Level 3 (transfer of training) represents a challenge. We do not know whether Level 1 and Level 2 actually transfer to changes in behaviour. Level 4 (results of training) ought to document that the training has produced tangible results, i.e. a reduction in total losses of ships.

Training evaluation is based on whether they have been effective, and whether it is quantifiable and measurable in improved team performance or improved safety in the working environment. Kirkpatrick's typology is a useful method to evaluate whether training programmes have been successful, i.e. improved team performance. Training effectiveness is a construct that can be difficult to assess. In the literature review I have focused on Level 3 (transfer of training). Transfer of training is related to safety behaviour.

Findings

Table 3 Training and Assessment

Source	Content	Type of Study/Method	Transfer of Training (Level 3)	Results of Training (Level 4)
Bloor, Sampson, and Gekara (2013)	The article reflects on the issues of the training double bind. The training double bind refers to the contradictory influences employers exercise on education and training providers.	Literature review of the computer-based assessments		Enforced self-regulation has been proposed to address the situation.
Brun et al. (2001)	Four teams consisting of 6 members each	Pilot study/experiment with 22 male and 2 female cadets Experimental group and control group Simulator task: Sail from "Brekstad Harbour" to "Stokkesund"	Medium degree of <i>shared team understanding</i> in the equipment domain (from 38 to 52 percent across the teams) <i>Shared task understanding</i> : 74,5 percent agreement on the choices on average.	There were no systematic differences in degree of shared mental understanding in the pre- and post-test administration of the SMM questionnaire regarding which tasks to prioritise in a critical situation.

	Measure team decision-making under stressful conditions and develop a method that could be used to measure “shared mental models” (SMM)	Pre-post design	<p><i>Team interaction model:</i> Average scores between the teams in the control group varied between 83 to 85 percent (Team 1 and Team 2).</p> <p><i>Team model:</i> Only small (and not systematic) differences between the teams on the degree of shared mental models across the domains.</p>	
Chauvin, Clostermann, and Hoc (2009)	Analysis of the performance of trainee watch officers with regard to decision-making in collision avoidance situations	<p>Multiple correspondence analysis</p> <p>Experimental group and control group (both groups were made up of 81 students)</p>	<p>Students who have experience of navigating on board car ferries perceive correctly the vessel’s relative speed, anticipating that the give-way merchant vessel will keep her course</p> <p>Only 1 of the 13 subjects who have experience of navigating on board ferries performed a late manoeuver to port</p>	

Chauvin & al. (2013)	Analysis of 27 recent collisions	Multifactorial analysis of collisions at sea using HFAC-Coll		Skill-based errors are absent and violations are exceptional. Unsafe acts are mainly related to decision-making (85%).
Devitt and Holford (2010)	20 interviewees Selection based on purposeful sampling	Qualitative interviews Assessment of criteria for leadership and its associated behavioral markers		Effective leadership, an open working culture, and strong teamwork can make the difference between a crew performing safely and efficiently, and one that fails to achieve the potential of the team members on board
Goeters (2002)	Evaluation of training needs	Experiment Pre-post design		A training need for decision-making can be observed. After the post-test a massive improvement in non-technical skills in situational awareness and decision-making can be observed.

<p>Fonne et al. (1995)</p>		<p>Questionnaire</p> <p>Pre-post design</p>		<p>The results of this study show a positive change in attitudes and increased individual awareness and knowledge of team processes.</p> <p>The follow-up study 6 months after the training showed that the attitude change was not as pronounced as directly after the training</p>
<p>Hetherington, Flin, and Mearns (2006)</p>		<p>Literature review of 20 articles on maritime safety</p>		<p>Human factors issues prevalent in the maritime industry, such as CRM, BRM and ERM, are subject to a number of methodological problems or "gaps".</p>

Bloor et al. (2013) explores some of the challenges faced by those attempting to standardise maritime education and training across globalised markets. Bloor et al. (2013) examines how specialist crewing agencies operating in new labour supply countries have problematised the assessment of seafarer training and how effectively international regulations on training standards are enforced.

The training double bind refers to the contradictory influences employers exercise on education and training providers, on the one hand demanding the urgent provision of more recruits, and on the other complaining about the poor quality of recruits received (Bloor et al., 2013, p. 1). The shipping industry is one of the industries that has been the most transformed by globalising economic processes (Sampson, 2013). There is now a single global market for seafarers, the majority of whom come from the transitional states of Eastern Europe and from developing countries. Nine nations supply two-thirds of the million seafarers in the international fleet: the Philippines, Russia, Ukraine, China, India, Poland, Indonesia, Turkey, and Myanmar (Sampson & Wu, 2004).

Seafarers are frequently employed by specialist international crewing agencies. Ship operators have transferred the costs of training their outsourced labor to seafarers themselves and seafarers' families in the developing world (Bloor et al., 2013, p. 2). There are (were) concerns that maritime education and training institutions do not meet the training standards of STCW. Those concerns led the IMO to set up the "white list" system in 2003 (Bloor et al., 2013, p. 2). There is little evidence that the overall quality of new training improved following the introduction of the white list.

Governance of globalisation is highly problematic. Shipping is a prime example of the problems of governance in globalised industries (the nation states translate regulations by IMO into their national shipping regulations; and all vessels must be registered with a ship registry that complies with these national shipping regulations, which are enforced through a

jurisdiction called “Flag State Control” (Bloor et al., 2013). Today there is even a Mongolian registry, despite the fact that Mongolia lies 850 miles from the sea (Bloor et al., 2013, p. 4). The shipping industry has a “polycentric” governance structure, meaning that it is fragmentary, complex, multi-level, and overlapping in character (Black, 2008).

Enforced self-regulation, such as deletion from the white list of states that do not comply with seafarer training standards, has been proposed to address the situation. However, deletion from the white list is only practicable for small nations that are small-scale suppliers of maritime labour (Bloor et al., 2013, p. 4).

Chauvin et al. (2009) presents an analysis the performance of trainee watch officers with regard to decision-making in collision avoidance situations. Collision avoidance manoeuvres are frequent in the Dover Straits. In some of these situations observed behavior is in violation with existing rules and regulations. These violations occur in situations when the COLREGS (COLision avoidance REG-ulations) recommend that the give way vessel should alter her course to starboard so as to cross astern of the stand-on vessel (Chauvin et al., 2009). Informal rules can also exist side by side with formal regulations and shape the actors’ behaviour.

In situations where different goals or rules are contradictory, experts are able to make a compromise between three types of requirements (Chauvin et al., 2009) : *The (control) requirements of the task, the requirements of regulations, and the requirements of performance.*

Flin (2006) defines the notion of resilience as the ability to manage conflicts between production and safety goals. Experts are better than novices to assess their own strengths and weaknesses. Experts are also able tot take in more information than beginners, and call upon patterns, which enable them to develop precise mental models of the situation and make an appropriate decision (Lipshitz & Shaul, 1997).

In an analysis of car officers' activity on board car ferries (Hockey, Healey, Crawshaw, Wastell, & Sauer, 2003), the watch officer onboard the stand-on vessel has to anticipate the 'give-way' vessel's actions and carefully monitor the situation. Rule 17 (COLREGS) generates a lot of workload upon the officer. However, officers manage to follow the rules and control the situation. If the give-way vessel will not take action, officers change course very early, before rules begin to apply (Chauvin et al., 2009).

Two groups of fifth-year students took part in the experiment (both groups were made up of 81 students). The students were presented with two decision-making exercises in collision avoidance manoeuvres in the in the Dover Straits traffic separation scheme. The experiment was carried out in a bridge simulator. The simulator reproduces the bridge layout of a modern vessel.

The aim of the experiment was the following (Chauvin et al., 2009, p. 1126):

- (a) Compare the results obtained by students who went through the training programme and by students who did not.
- (b) Assess the effect of the type of navigation experienced during on-the-job training on the cognitive process and performance of trainees

The method that was chosen was multiple correspondence analysis. The experimental situation reproduced a typical situation observed in the Dover Straits. The experiment lasted 43 minutes. After a ten-minute presentation of the experiment, followed by a five-minute period to become familiar with the situation under scrutiny, the simulation began.

Two hypotheses were formed with regard to this experiment (Chauvin et al., 2009, p. 1227):

- (a) The decision-training programme will lead to a greater improvement in the experimental group's performance than the control group

- (b) Students who already have already performed on-the-job-training, will adopt an expert strategy aimed at controlling the situation

The article mentions that only 1 of the 13 subjects who have experience of navigating on board ferries performed a late manoeuvre to port (7%, as opposed to 28% for the other subjects). Students who have experience of navigating on board car ferries perceive correctly the vessel's relative speed, anticipating that the give-way merchant vessel will keep her course (Chauvin et al., 2009). There is a tendency in the results for the experimental group that they pay greater attention to the situation's features than students in the control group. A possible outcome of the study is that the decision-making games can be used to familiarise trainees with specific situations

Chauvin et al. (2013) conducted a systemic and multifactorial analysis of collisions at sea using HFAC-Coll. The study is an analysis of 27 recent collisions using HFACS-Coll, and is based on investigation reports from MAIB and TSB. The analysis relies on a tool based on Reason's model, the Human Factor Analysis and Classification System (HFACS). The HFACS describes human error at each of four levels of failure:

- (a) Unsafe acts of operators
- (b) Preconditions for unsafe acts
- (c) Unsafe supervision
- (d) Organisational influences

Chauvin et al. (2013) found that skill-based errors were absent and violations are exceptional. Unsafe acts are mainly related to decision-making (85%). The study confirms the importance of BRM for navigation and stresses the need to investigate the masters' decisions with regard to bridge manning and vessel speed. Bridge resource mismanagement includes problems of coordination and problems of communication between crewmembers.

BRM failures can be linked to poor shared mental models and shared situational awareness in the bridge team.

Fonne et al. (1995) conducted a training evaluation of attitude change among Norwegian HSV-navigators. The aim of the evaluation was to assess the usefulness of CRM and its potential for increasing safety and anticipating change of behaviour (Fonne et al., 1995). The course concept was based on two models. The SHELL model emphasises the human-machine interphases. The COORDINATION model emphasises the Liveware-Liveware interphases (communication, workload, social atmosphere, and culture).

The method was a questionnaire modified for use by maritime navigators. The questionnaire was completed on three different occasions (Fonne et al., 1995, p. 587):

- (a) Before attending the seminar
- (b) Directly following completion of the seminar
- (c) As a follow-up study 6 months after completing the seminar

The study shows that there is an attitude change in the captains' preference regarding subservient or self-assured first officers. Ratings after the seminar show that only 41% of the captains prefer the self-assured type, compared to 54% in the pre-seminar. Fonne et al. (1995) observed a significant change in the respondents' attitude to the statement "Navigators should feel obliged to inform the rest of the crew about one's own psychological stress, before and during the assignment (Fonne et al., 1995, p. 588)". Before the seminar 39% of the respondents prefer keeping personal stress as private matter. After the seminar the response was significantly reduced to 25%. With regard to the statement "I have reduced visibility. I reduce the vessel's speed with Y%", 29% of the participants answered that they hardly reduce speed in conditions of low visibility (Fonne et al., 1995). The follow-up study 6 months after the training showed that the attitude change was not as pronounced as directly after the training.

Goeters (2002) conducted a training evaluation of 17 pilots in an A320 simulator. Step 1 (pre-phase) consisted of a Line Oriented Flight Training (LOFT) scenario to be flown in an A320 simulator equipped with dual channel audio and night vision video recording. Step 2 (training phase) covered the standard training goals with respect to communication, cooperation, leadership/management and situational awareness (Goeters, 2002). Step 3 (post-phase), consisted of a LOFT mission that intended to evaluate the effects of CRM training. Step 3 could only be undertaken after some time had elapsed since the training. The NOTECHS systems was used to assess the training.

The results show that for there is a training need for decision-making. Both captains and first officers score low on decision-making. The distribution of scores for participating pilots displayed a large spread in their performance level of non-technical skills (Goeters, 2002). With the pre-post design it is possible to identify the influence of certain treatments on performance and behaviour. The treatment in this study is the customised CRM training with a stabilisation duty time of three months (Goeters, 2002). After the post-test a massive improvement in non-technical skills was observed both at the elementary level and the categorical level in *situational awareness* and *decision making*.

Hetherington et al. (2006) did a literature review of 20 studies on human factors in the maritime industry. The article mentions the relationship between safety climate and safety performance. The article presented many human factors elements that can be contributory to accidents, such as fatigue, automation, teamwork, and health. The article makes an assessment of the current status of attempts to face address these human factors issues, such as CRM, BRM and ERM. (Hetherington et al., 2006) mentions that the methodological problems within the shipping literature seems to be consistent and are based around five themes (Hetherington et al., 2006, p. 410):

- (a) There are questions about the ecological validity of earlier conducted research (Hockey et al., 2003)
- (b) Sample sizes are small (Ek, 2003; Koester, 2003)
- (c) A large proportion of the work in the maritime domain is retrospective
- (d) Issues of validity with research administered to individuals in their second language
- (e) Lack of performance measures that can assess human behaviours or conditions (e.g. fatigue)

Technological advances have contributed to decreased manning on board merchant vessels. VLCCs typically have crews of 22 seafarers (Hetherington et al., 2006, p. 402). This development is due to two factors: technological advances in navigation aids and ship design has reduced the frequency and severity of shipping accidents; the reduction of technological failures have revealed the influence of human error in accident causation (Hetherington et al., 2006). The incidents of the last 20 years represent 83 per cent of the total. Human factors was cited as the cause in 16 percent of all port accidents (Hetherington et al., 2006).

Hetherington et al. (2006) mentions that CRM training may reduce human factors related causes of incidents and in turn incidents themselves. Hetherington et al. (2006) concludes that the human factors issues prevalent in the maritime industry, such as CRM, BRM and ERM, are subject to a number of methodological problems or “gaps”:

Brun et al. (2001) conducted a pilot study/experiment with a community of 22 male and 2 female cadets. The research design was a survey/questionnaire. The study is based on Janis A. Cannon-Bowers, Salas, and Converse (1993). The community consisted of four teams consisting of 6 members each. These were divided into two groups, one experimental group and one control group.

The research design was a pilot study/experiment with *22 male and 2 female cadets*. The method chosen for the research design is a quantitative survey/questionnaire. The aim of the study was to measure team decision-making under stressful conditions and develop a method that could be used to measure “shared mental models” (SMM). There were four types of mental models: equipment model, task model, team interaction model, team model (Cannon-Bowers et al., 1993). There was a medium degree of *shared team understanding* in the equipment domain (from 38 to 52 percent across the teams). *Shared task understanding*: On average there was a 74,5 percent agreement on the choices. The most popular task to choose was to turn on the lights (nine subjects ticked this option). There were no systematic differences in degree of shared mental understanding in the pre- and post-test administration of the SMM questionnaire regarding which tasks to prioritise in a critical situation. *Team interaction model*: Average scores between the teams in the control group varied between 83 to 85 percent (team 1 and Team 2). There was a very high degree of agreement among the team members on what was considered relevant information sources. *Team model*: There were only small (and not systematic) differences between the teams on the degree of shared mental models across the domains. Hence, they cannot conclude that one of their teams is systematically “better”.

Devitt and Holford (2010) identified whether the broad competence criteria described in the STCW amendments would be consistently interpreted by maritime stakeholders. The interviewees include P&I Clubs, ship owners, and ship managers based in the UK. The aim of the study was to develop a behavioural marker system specific to the maritime industry that would enable resource management and leadership competencies to be evaluated against the framework of STCW (Devitt & Holford, 2010) .

The impact of positive and negative behaviours around teamwork was clearly identified. Some respondents made a link between effective leadership behavior and effective

team performance (Devitt & Holford, 2010, p. 11). Both positive and negative behaviours were identified for situation and risk assessment aspects of decision-making (Devitt & Holford, 2010, p. 13). Questions were raised whether some team members' competence reflected formal qualifications (Devitt & Holford, 2010, p. 17). Other key factors were communication of the task and the ability of the team to clarify tasks and identify potential risk issues.

Effective leadership, an open working culture, and strong teamwork can make the difference between a crew performing safely and efficiently, and one that fails to achieve the potential of the team members on board (Devitt & Holford, 2010, p. 22). Behavioral markers pertaining to evaluation criteria in STCW are less tangible to identify. The next stage of the research will be to propose behavioral markers that can be validated in a simulated environment.

Analysis

Training and assessment in the maritime sector differs from that in high-reliability organisations for a number of reasons. One of them is that the maritime industry is atypical from companies in high-reliability industries such as aviation and railway. The shipping industry is increasingly organised along global value chains, and ship owners have transferred the costs of training and assessment of their outsourced labour to seafarers themselves and seafarers' families in the developing world (Bloor et al., 2013, p. 2).

In the maritime industry, the charter party (i.e. the contract) confers considerable authority on the cargo owner, thereby reducing the cargo owner's liability in terms of safety (Molland, 2008, p. 787). Shipping companies worldwide need only comply with the mandatory minimum requirements of the STCW Code (IMO, 2011).

Training and assessment of maritime personnel may reduce the probability of human error, and thus reduce the risks of an accident. The most common accidents attributed to

human error on board ships are collisions. Common accidents that occur during the navigational watch are running aground in inshore waterways or even during maritime operations in a port. In addition to the navigational watch, maritime personnel should also have adequate training in other areas that are vital to the safety on board a ship, such as proper maintenance of the hull & machinery, training in how to use fire extinguishing equipment, cargo safety procedures, and safety procedures when loading/unloading cargo

CRM Training

CRM training was introduced as a means to improve teamwork coordination and cooperation in the cockpit. It has since then been introduced in many high-reliability industries as a means to improve team effectiveness and reduce the occurrence of human error. According to Reason's (1997) "Swiss cheese" of accident causation, humans are prone to make human error.

CRM can help improve team cohesion on the bridge. In a complex technical environment as a bridge, team coordination and cooperation is important. This is particularly the case for large cruise ships. Cruise ships are complex socio-technical systems that depend on the service of functional teams. Creating a safety culture in which each team member is knowledgeable of her role and how to react to abnormal situations is an important precondition for improving safety. In this respect, CRM can be used as a means to increase SA and decision-making skills. Decision-making skills are very important in collision avoidance situations (Chauvin et al., 2009). CRM can also be used to create a community of practice. But this may not be achievable on ships that have a high degree of turnover.

Teamwork is an important component in the day-to-day operations of a ship. Teamwork is especially important during nautical tasks like navigating, manoeuvring, and berthing. Resource Management training now make extensive use of simulators as a means to improve team performance. The task performance of the individual seafarer depends on

his/her ability to act as a member of a team. The master, the first mate, the second mate, and other members of the Crew are all part of a team that need to solve problems in the day-to-day activities of a ship. The OOW depends on accurate information from fellow team members and from the Integrated Bridge system. BRM may help improve communication between the OOW and other team members.

Training in non-technical skills may also increase the trainees' situational awareness. SA is especially important in navigation. Maintaining a proper lookout on the bridge, and being able to take correct decisions at the right moment, as well as anticipating future events, can be important for handling unanticipated situations (e.g. collision avoidance).

Regularly seafarers are exposed to environmental and physical factors at sea that require an effective response. Navigation requires both technical skills and non-technical skills such as situational awareness and decision-making. The officer in charge of the navigational watch will often experience situations at sea requiring immediate attention and action. Bridge Resource Management has changed how captains work on board ships. Now the captain is more of a resource and manages the bridge team to which he assigns roles. A key to success is "thinking aloud" (Marine Casualties Investigative Body, 2013)

Lack of situational awareness has been mentioned as a cause of maritime accidents (Hartel, Smith, & Prince, 1991). Officers should have compatible and complementary knowledge when they are performing their tasks (J. A. Cannon-Bowers & Salas, 2014).

Training that aims at developing non-technical skills such as CRM may increase the trainees' ability to cope with abnormal situations. On the flight deck, CRM training has been used to train the non-technical skills of aircrews in civil aviation since 1979. Numerous studies have attempted to evaluate the effect of training on team performance (Salas, Burke, et al., 2001; Salas, Wilson, Burke, & Wightman, 2006). Training in team coordination and cooperation may have an effect on how individuals perform in a team (S. W. J. Kozlowski,

Grand, Baard, & Pearce, 2015). Training in non-technical skills such as decision-making, leadership and situational awareness can facilitate teamwork and reduce the occurrence of human error.

Effective teams may not share similar knowledge, but compatible knowledge (heterogeneous knowledge) (Marks et al., 2000). Shared mental model and situational awareness are comparable elements, and some researchers have depicted them as representing the same things (Stanton et al., 2008). Team training such as CRM training can improve shared mental model similarity (and accuracy) (Marks et al., 2000).

Training of non-technical skills such as situational awareness can facilitate the development of a shared mental model on the bridge, and thereby facilitate teamwork. The aim is to develop a common understanding/knowledge and increase team efficiency.

Training effectiveness will depend on a number of constructs, such as time spent on training, personal motivation, cognitive ability, and competencies (KSAs). The effectiveness of a training programme depends to a large degree on the transfer of competencies (KSAs) to the trainee.

There are many other variables that can impact safety than just the training of non-technical skills. In the past decades we have seen a development where the maritime industry has improved its safety performance. However, it seems that maritime regulations and automation has had a more direct effect on safety performance than training. Amendments in SOLAS 74 and the STCW Code have a direct impact on safety. Port State Control (Paris MoU and Tokyo MoU) and ship detentions also have a positive impact on safety performance.

Automation has been introduced on board ships as a barrier to human error. The master needs to be aware of both technological and human factors elements, and overreliance on navigational instruments such as ECDIS can contribute to accidents.

There has been a substantial improvement in safety performance in aviation, rail, road, and maritime. The maritime industry has a higher variability in fatality rates than the other transport systems.

IMO

International Conventions such as IMO play an important role in ensuring safety at sea. STCW 1978/95/2010 and the introduction of mandatory certificates of competencies for seafarers have greatly improved safety. The problem with IMO with regard to training and assessment is that the organisation does not have any enforcement capacity. It is up to the national authorities, the flag state, to implement the STCW Code. IMO consists of 171 different member states, and the implementation of the STCW Code may vary between these. IMO strives to make the maritime certifications of competency transparent. However, globalisation of the seafaring working force and the fact that many shipowners register their ship(s) in foreign ship registers such as Panama, Liberia, or the Marshall Islands, does not contribute to maritime safety.

Maritime transport compared to other transport modes

The fatality rates in transport modes such as aviation and railroad have decreased significantly since the 1990s. There has been a continual improvement in safety performance and the occurrence of human error in these industries is very rare. The fatality rate for aviation is now 22.0 per million flights flown (CAA, 2013). Road is the leading cause of death in the age group 25 to 44 (Cooper, Burke, & Clarke, 2011). The most vulnerable transport modes are Powered Two-Wheelers (P2W), cyclists, and pedestrians. Maritime transport is the fourth safest transport mode, after aviation, rail, and bus.

Maritime Safety

Maritime safety has improved continuously in the last four decades (DNV, 2013). However, attitudes regarding safety vary a lot depending on what part of the world one is

operating. In shipping the competition can also be very intense, and some ship owners may think that they can get away with spending less on training.

The safety culture in the maritime industry may vary widely geographically, depending on the rules and regulations that are customary in some parts of the world. National cultures vary with respect to power distance and the degree of human inequality, uncertainty avoidance and how they adapt to unstructured situations. Values, risk perception and safety standards are known to differ between nationalities (Hofstede, 2001).

Most training and assessment programmes in the maritime domain are linked to regulations that have been adopted by IMO member states and implemented into national legislation. However, given the global dimension of shipping, the organisational structure of a maritime organisation may vary a lot. There is not a single shipping company that has the same organisational structure with respect to manning and how to promote a safety culture on board.

Simulation-Based Training

The maritime industry has invested billions of dollars in advanced simulators that can mimic the conditions that are present in a rough and hazardous sea environment. Since it was first introduced in the 1980s, Simulation-Based Training has been used as a training method for maritime trainees. SBT can only be considered to be effective if the learning in the simulator transfers to a real-world setting. As a simulator is a tool in the learning process, there are requirements to assess the training effectiveness of SBT (Cross, 2011). In order to assess the performance of a trainee, one has to compare the trainee's performance against a criterion or a standard. Methods of evaluation and measurement have been developed to assess the trainee's training outcome. The elements required for evaluating SBT are the following (Reay, 1994):

- Methodology (how to evaluate and with which tools)
- Criteria (which outcome is required)
- Objectivity (outcome not influenced)
- Reliability (measurement consistency)
- Validity (measures what is intended)
- Fidelity (accuracy in reproduction of simulated process)
- Reality (impression has physical and behavioural realism)

The bridge of a ship can be compared to a command and control centre. The maritime industry differs from aviation in that it is a highly hierarchical system. The bridge system depends on the interaction of the master, the first mate, the second mate, and the officer of the watch. A bridge team can consist of up to 10 members (Øvergård, Sorensen, Martinsen, & Nazir, 2014).

Safety performance

Safety performance has become a very important issue for organisations in various domains, including the maritime industry. In the maritime industry, there is a lack of knowledge on the effect of training and assessment on safety performance at the sharp end. However, there is some research on the effect of training and assessment on human performance from other industries. In the literature review I will give an overview of some results that have been achieved by other industries with respect to the effect of training and assessment on safety performance at the sharp end.

Most research on the effect of training and assessment on safety performance have been conducted in the aviation industry, which pioneered research in the area of Crew Resource Management. Aviation has also been one of the most successful industries in terms

of safety performance. The number of accidents in the aviation industry was relatively stable from 2009 to 2012, resulting in an accident rate of approximately 4 accidents per million departures (ICAO, 2014, p. 27). However, the number of accidents dropped to 3.2 accidents per million departures in 2012. There has also been a sharp decrease in the number of fatalities from 2009 to 2013.

Industries such as health-care (anaesthesia), road, rail, nuclear power plants, and maritime have adapted CRM to their own communities of practice. The aviation industry was the first to implement Crew Resource Management as a training and assessment method.

The military domain has extensive experience with training and assessment. Concepts such as distributed or shared situational awareness were first used in a military setting.

Maritime organisations now have to comply with the new regulations on training and assessment mentioned in the amendments. Bridge Resource Management, or Bridge Team Management, is a training and assessment method that aims at developing Crew members' non-technical skills.

The challenge here is how we measure safety performance. Safety performance in high reliability industries such as aviation, health care and rail is measured by looking at passenger safety. Passenger safety can be measured by calculating the number of fatalities per billion km. Safety Performance in road is measured by calculating the number of fatalities per billion vehicle km.

The maritime industry has used the term total loss to describe maritime casualties (very serious casualties). The total loss rate can be calculated by dividing the total loss number with the number of world trading fleet. Another indicator for measuring safety performance is the total incident number per 1,000 shipyears (a shipyear is defined as one ship operating for one year).

Team Mental Models is a part of the mandatory training and assessment of seafarers.

Some higher end segments of the shipping industry, such as *Mærsk*, have implemented simulator-based training as a measure to improve team effectiveness across their maritime operations. For example, Mærsk uses simulator-based training to create scenarios with high level of realism to increase competencies and job performance. The aim of the CRM training at Maersk is to enhance team performance through the training of no-technical skills such as decision-making, communication. The purpose of CRM training at Mærsk is to establish a no-excuse performance culture based on a high level of personal responsibility, strong operational teams, and clear cross-departmental communication (Mærsk Training, 2013).

Teamwork

Effective teamwork may have an impact on safety performance at the sharp end. Teams are generally more adept at finding solutions to problems than individuals who perform on their own. Salas, Sims, and Burke (2005) point out that it is important to make a distinction between team performance and team effectiveness. Team performance refers to the outcome of the team's actions regardless of how the team may have completed the task. Team effectiveness takes also into consideration how the team interacted (i.e. team processes, teamwork) to achieve the team outcome (Salas et al., 2005, p. 557).

Efficient teams are made up of team members who are aware of team functioning and manage to monitor and catch the mistakes, slips and lapses of fellow team members before or shortly after they have occurred (Salas et al., 2005).

Bridge Resource Management

Bridge Resource Management policy and procedures include situational awareness, communication skills, managing stress, management of workload, etc. Bridge Resource Management now also includes mandatory training of non-technical skills such as *maritime resource management* and *security awareness*. The maritime industry has also invested billions of dollars in advanced simulators that can realistically mimic reality (Virtual Reality).

Navigation now requires competence in mastering advanced navigational instruments such as *Advanced Radar Plotting Aid*, *Electronic Chart Display & Information System*, and *Automatic Identification System*. It has become increasingly important for the OOW to master non-technical skills such as situational awareness, decision-making, and communication in addition to technical skills in navigation or in maritime engineering.

Following the lead of the aviation industry, Crew Resource Management training is now implemented in many industries, including the maritime industry, e.g. *MaErsk*. Breakdown of CRM was a causal factor in 60% of Navy and Marine Corps accidents between 1991 and 2000 (Salas, Wilson, Burke, & Wightman, 2006, p. 393).

Teamwork on the bridge also requires the Officer of the Deck to maintain a proper lookout. Management of workload, stress & fatigue are factors that may impact the safety performance of the OOW. This comes in addition to the technical skills that are needed for navigation.

On the bridge safety performance will depend on cooperation and interaction between team members and on the inter-personal skills of the Crew. Maritime training should focus on improving inter-personal skills (leadership, communication, and teamwork) and cognitive skills (decision-making and situational awareness) (Flin et al., 2008).

Technical proficiency and non-technical Team coordination can be important for effective decision-making. In the maritime industry, situational awareness is the single most important cause of accidents. The majority of accidents at sea are a result of human error, where the Officer of the Watch either fails to understand warning signals from the environment, or a result of poor communication and decision-making.

Does training and assessment affect safety at the sharp end?

Training effectiveness will depend on a number of constructs, such as time spent on training, personal motivation, cognitive ability, and competencies (KSAs). The effectiveness

of a training programme depends to a large degree on the transfer of competencies (KSAs) to the trainee.

So has the investment in training and assessment had a noticeable effect on safety performance? Some higher end segments of the shipping industry already use CRM as a training method throughout their operations. Resource Management has been used with satisfactory results in shipping companies such as Maersk. However, the maritime industry does not, to my knowledge, have a safety culture that is comparable to that of high-reliability industries such as aviation and rail. Since the introduction of CRM training in the aviation industry, there has been a continuous improvement in safety performance at the sharp end. This has not been the case with the maritime industry. Although the maritime industry has improved its safety performance significantly since the 1980s, the relative safety performance of the maritime industry has lagged somewhat behind that of other transport modes (see table 3).

Road transport has also made significant progress with regard to safety performance, at least in Western Europe. Road remains, however, one of the most hazardous transport modes, with a fatality rate of 18 per 100 000 people globally (WHO, 2013).

Accident reporting has only recently become mandatory in the maritime industry. Accident reporting (the reporting of slips and lapses) is important in order to take preventive action. This has been somewhat lacking in the maritime industry. There is no reason why the maritime industry shouldn't learn from the other industries with regard to incident reporting. The introduction of a mandatory safety management system on board ships has to some degree improved safety performance, but this cannot be attributed to training.

However, a maritime organisation can implement measures that aim at reducing the probability of human error during complex maritime operations, such as navigating through

the Strait of Malacca or manoeuvring a large container ship out of port in congested waterways.

Maritime Accidents

The *MV Sewol* tragedy in South Korea in 2014 is an example of substandard shipping. Over 200 lives went lost in this disaster, and the cause of the accident may be attributed to human error. The underlying cause of the accident was in this case the management of the ship at the blunt end, and not so much at the sharp end. But when the accident happened, the captain and his crew were not prepared for the situation and gave the wrong order. Telling the passenger to stay in their cabins. In this example we see that decision-making skills are paramount for keeping safety at sea. In the event of an accident the most important task is to get the passengers out of harm's way. To achieve this one has to give the correct information at the right time and have the right procedures. Such accidents highlight the need for training non-technical skills.

Loss of structural hull integrity and liquefaction are often mentioned as the causes of total losses in the dry bulk carrier segment (Committee II.1, 1997; Gard AS, 2014).

Human-machine interaction is an important aspect of safety performance in complex systems. Safety performance on the bridge of a ship depends on coordination and a shared mental model. To ensure operational safety on board a complex socio-technical system as a ship, there are many things that are important. Team coordination, leadership and decision-making are some of the most important skills that need to training.

In the maritime industry, there are procedures that should be followed rigorously. One of these is when the ship is entering shallow waters and needs the assistance of a pilot. Many accidents at the sharp end in shipping happen in coastal waters or in the vicinity of a port. The *World Fleet Statistics* (IHS Maritime, 2014) show that the number of accidents are more

frequent in waterways with heavy traffic. Most accidents happen (IUMI, 2015) in the South China, Indo China, Indonesia & Philippines, and Japan, Korea and North China.

Lack of communication between team members on board the ship and/or with the Vessel Traffic Services has also been contributory to maritime accidents. However, the literature mentions loss of situational awareness as the most frequent cause of accidents.

Recently in 2014 the *Norman Atlantic* ferry fire in the Mediterranean showed that safety on board in a fire situation requires prompt teamwork and cooperation between members of the Crew. It shows that it is important to have people trained in non-technical skills such as situational awareness. When a fire breaks out, it is necessary to react as fast as possible and keep calm.

Resource management, which means using all available resources, means making use of both non-technical and technical skills in an emergency situation. Training of non-technical skills may prepare the seafarer for situations such as a fire or a man over board situation, but it is important to practice the non-technical skills as memory usually is short.

Many accidents that have occurred at sea would have occurred anyway. What the seafarer can do is to prepare for situations that will demand a firm reaction.

The question of automation and its impact on safety is also important. From aviation we know that accidents happen in situations where the pilot or the co-pilot does not follow the correct procedures. In the maritime world the procedures are different. The safety culture is also very different from aviation. Training of non-technical skills may have had an impact on safety in the aviation industry. We see that the safety performance in the aviation industry also varies a lot across the world, with Africa coming last with regard to safety (see table 2).

From the literature review, we also see that decision-making and situational awareness are some of the most important technical skills with respect to safety in a maritime environment. Modern socio-technical systems such as a ship use automation to a large degree.

The more advanced the systems on board a ship, the more important it is to train non-technical skills of seafarers. We cannot say for sure that CRM training has an effect on safety performance, but if we look at the improvements in overall year on year safety in different transport modes we have to ask ourselves what is the reason behind such an improvement in safety performance: We can then go into what we think is most likely. The most likely reason for the improvement of safety performance in socio-technical systems is automation. In an aircraft, the use of the autopilot has changed both in-flight and landing procedures. In terms of safety we see that shipping has been highly successful. The numbers witness that there are some regions in the world where there are more casualties than others, for example in the dry cargo ship/break bulk segment. If we look at statistics over how many total losses there are every year, we see that there is a huge variability in the number of total losses in shipping. This distinguishes the shipping industry from other transport modes. This can also be due to the unpredictability of shipping. In the container ship segment the ships are getting ever larger, now with container ships that have as size of over 19,000 TEU. Shipping is one of the most important transport modes with regard to the volume of trade. Training and assessment of maritime personnel is very important to ascertain that no life goes lost. But we should be aware that human error is the main cause of accidents. Training of non-technical skills such as CRM is perhaps the way to go in order to reduce the likelihood of human error.

Conclusion

Does CRM training work? There is certainly some ambiguity with regard to the effectiveness of CRM training on safety performance in the maritime industry.

Safety at sea depends on Performance of all individual team members. The safety performance of a ship and of its master and crew are inter-linked and are part of a complex system. When a complex system involves both technology and humans, it can best be described as a socio-technical system (Reason, 1990)

Maritime organisations need to comply with regulations set out by the International Maritime Organisation with regard to training and assessment of seafarers.

Training and assessment may have a very high impact on safety performance in a maritime organisation. The introduction of new technology and automation are developments that may affect safety performance on board ships.

Billions of dollars have been invested in the development of advanced simulators that can realistically mimic real-world scenarios that take place on board ships. Training and assessment of seafarers have become ever more important to mitigate the risk of human error.

Maritime training of non-technical skills may help reduce the risk of human error. Trained maritime personnel are more prepared to react in case of an emergency situation.

Human Factors Skilled-Based Training Programmes in the Maritime Industry
However, some shipping companies, such as A.P. Møller - Mærsk A/S, have implemented Crew Resource Management as part of their compulsory training.

Training and assessment of management should focus on better communication between the master and his crew. Some sectors in the maritime industry, such as container shipping, and larger and more complex ships, have changed how shipping companies operate.

The shipping industry now consists of many specialised sectors, with some large companies that operate on a global scale in different market segments, such as A.P. Møller - Mærsk A/S. Many different actors in an industry operating in a number of different shipping markets, is a challenge when it comes to implementing safety measures. Large container ships usually have a small crew, but each individual crew member must satisfy formal requirements with respect to maritime education and training. This also applies to training with regard to improving safety performance.

The leading industry in terms of safety performance over time is aviation.

Although CRM training is now in use in many industries, it has been necessary to adapt the contents of CRM to the specific job environment of the industry.

Training and practicing for safety is very important in order to maintain a proper safety culture on board. Preventive measures to improve safety, such as changes in the STCW Code, are often introduced after major maritime catastrophes.

The Costa Concordia incident highlights the need for training and coordination of teamwork in complex sociotechnical environments. Navigation is a technical skill that may require training in non-technical skills such as situational awareness, management of workload, and control of fatigue and stress. A maritime organisation can implement measures that aim at reducing the probability of human error during complex maritime operations, such as navigating through the Strait of Malacca or manoeuvring a large container ship out of port in congested waterways. Since 1912, when the Titanic sank in the Northern Atlantic after hitting an iceberg, the maritime industry has vastly improved its safety performance (IUMI, 2015). Risk is inherent to shipping, and there are great geographical variations with respect to safety culture.

Acknowledgements

I would like to acknowledge the invaluable assistance of Professor Kjell Ivar Øvergård.

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