11-3-2019

Improving simulation-based training to better serve the maritime community: a comparative research between the aviation and maritime domains

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IMPROVING SIMULATION-BASED TRAINING TO BETTER SERVE THE MARITIME COMMUNITY: A COMPARATIVE RESEARCH BETWEEN THE AVIATION AND MARITIME DOMAINS

By

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A dissertation submitted to the World Maritime University in partial fulfilment of the requirement for the award of the degree of

MASTER OF SCIENCE
In
MARITIME AFFAIRS

(MARITIME SAFETY & ENVIRONMENTAL ADMINISTRATION)

2019

Declaration

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

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

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Acknowledgements

First and foremost, I would like to express my deep gratitude to my sponsor, IMO – Republic of Korea fund for the great opportunity they provided to me to study in this university.

I want to express my sincere appreciation to Professor Dimitrios Dalaklis for his guidance and his advice directed my thesis. I am so grateful for all MSEA professors for their support, constructive criticism and the knowledge they shared during the year.

Finally, I would like to express my gratitude towards my beloved wife, Hien who always encourage and support me to make this study; and my lovable daughter: Linh Linh.

Abstract

Title of Dissertation: Improving simulation-based training to better serve the maritime community: a comparative research between the aviation and maritime domains.
Degree: Master of Science

The shipping industry is one of the most international sectors in its nature. Besides, it is still a high-risk industry with potential hazards. After centuries of development, the industry has reached quite good practices in technological, economic and scientific aspects. However, there is one thing that has not changed, that is the percentage of maritime accidents caused by the human factor, regardless the level of technology applied on ship structure and operation. To deal with the problem, maritime education and training (MET) is recognized as an initiative method that has potential ability to save more lives at sea. One of the most powerful tool in the MET section is simulation-based training, which is an effective tool for enhancing competency of seafarers. Nevertheless, the use of simulation-based training in the maritime sector is implemented poorly, which cannot catch up its potential value. Meanwhile, the use of that tool in the aviation sector is recognized as an indispensable as it is a substitute of actual flight training. It is utilized heavily in the aviation sector.
This thesis presents a literature review and comparative analysis of the utilization of simulators for training in the aviation and the maritime sectors. The aim is to find the limitation of simulation use in the maritime sectors, and pinpoint the best practice of that in the aviation sector that can be learned to improve the practice.
An important conclusion is made after analyzing the data collected from literature for simulation-based training usage in those domains. The limitations and possible features were discussed. It is hoped that the result of this study might help the practice of simulation-based training will improve in the future, then it may have positive impacts on the safety practice of the maritime community.

KEYWORDS: Simulation-based training, Simulation-based assessment, Maritime education and training, Maritime policy

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List of Abbreviations

ARPA	Automatic Radar Plotting Aid
DNV GL	Det Norske Veritas and Germanischer Lloyd
DP	Dynamic Positioning
FAA	Federal Aviation Administration
FFT	Full Flight Training
FSTSC	Flight Simulator Technical Sub-Committee
FTD	Flight Training Device
GA	General Aviation
ICAO	International Civil Aviation Organization
IMO	International Maritime Organization
IMSF	International Maritime Simulator Forum
MARSIM	International Conference on Marine Simulation and Ship Manoeuvrability
MPL	Multi-crew Pilot License
NYK	Nippon Kaiji Kyokai
SBT	Simulation-based training
STCW	International Convention on Standards of Training, Certification and Watch Keeping for Seafarers
USCG	United States Coast Guard
VTS	Vessel Traffic Services

Chapter 1. INTRODUCTION

1. Broad background

According to the Britannica Encyclopedia (2019), simulation can be defined as “a research or teaching technique that reproduces actual events and processes under test conditions”. A simulation is “a working representation of reality which may be abstracted, simplified or an accelerated model of the process”, which enables students to learn in a safe environment, discovering skills, integrating knowledge, experiencing success and committing errors, without the significant consequences that would result if these errors were committed ‘in the field’ (Jillian, 2015). Simulation techniques can be very useful in experimentation when it provides researchers a “*simulated lab”* for demonstrating without consuming any expensive equipment or special rare-to-find materials. Other cost-saving functions of simulation technology is time compression. It can simulate any long hours, days even years happening events in a few minutes (Britannica, 2019).

Moreover, the simulator is a “replica of system operations” over time (Bhoopathy, 2018). In the book, “Human Factors in Simulation and Training” by Hancock, Vincenzi, Wise, & Mouloua (2008), the main reason simulator training has prevailed as a training and educational tool is identified as “cost effectiveness” compared to real life training, or on the job training. It is considered as a very effective means to train, to provide an experience, to help a student grow and gain confidence in a given field, or to assess competence. Simulation can range from very basic paper based exercises to sophisticated computerized tools (Jillian, 2015). Furthermore, simulator facilities can be available 24/7. Therefore, it can offer a more flexible timeframe and quite often do not even require any physical presence of participants.

2. Simulation-based training utilization in transportation

Simulations are recognized as an important training tool for complex and advanced technological tasks in high-risk fields. Simulations have been practiced for a significant period of time for improving training skills, judgement and problem solving. In the recent years, they have been extensively used for instruction in various transportation methods, such as aviation, shipping and rail. Some indicative examples within the training and study purpose, include training pilots, navigators and drivers in public transport sectors (Baldauf, Dalaklis, & Kataria, 2016; Lützhöft, Brown, Dunham, & van Leeuwen, 2017). Simulators enable trainees to face probable dangerous situations in a risk-free environment (Oliveira, 2013), to enhance decision making and to develop hands-on and fault-treat abilities. (McGregor, 2012).

2.1. Simulation-based training in commercial aviation

It is interesting to note that the aviation industry as a whole moved from a "risky" level of safety in the early 1960s to a "safer" one within few decades. This safety improvement may be attributed to the increased aircraft reliability; a higher standard for training by simulation should also be considered a contributing factor (Bilotta, 2013). As a result of safety improvements, simulation-based training is mandated and culturally accepted for pilot training as a reliable educational tool (Cook, 1998). In the aviation industry, flight simulators have been used as the integral part since the 1960s, and training in an real aircraft is no longer practical. After this, there has been a continuous development of flight simulators, resulting in aviation simulation becoming a large industry. According to Stratistics MRC (2016), the Global Flight Simulator market was worth about $5.89 billion in 2015, and it is forecasted to go up to $8.03 billion by 2022 with a compound annual growth rate of 4.5%, covering all three type of flight simulators,ie rotary wing, fixed wing and even unmanned aircraft.

2.2. Simulation-based training in the maritime domain

In the shipping industry, simulators are used for training towards several purposes, such as offshore, onshore operation, vessel traffic services (VTS), search and rescue and offering opportunities for specialized training in educational settings (Crichton 2016). In these maritime training courses, traditional methods of training have been largely adopted; however, with the current fast pace of technology development and the reduction of costs, other alternative methods have also been implemented, including the use of simulators (IMO, 2012). The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) with the 2010 Manila Amendments has already incorporated simulation-based training to assess the utilization of simulators for marine expert improvement and certification (IMO, 2011).Currently, in the maritime sector, there were 19 education institutions certified by ClassNK (ClassNK's registered book, 2019); 4 approved by Lloyd's Register (List of Lloyd's Register, 2019); over 30 institutions certified by DNV GL for simulation-based training.

Different types of maritime simulation-based training are used by maritime experts to ensure safety and security with diverse systems. These simulators are recognized as beneficial tools which are developed to deliver specific required learning outcomes. Many researchers have demonstrated the significant effectiveness of simulation-based training. However, achieving the intended training outcomes does not automatically translate into an increase of maritime safety (Rashed, 2017). While there were other studies which highlight that there were no sufficient evidence recorded to support that simulators have improved seafarer performance by the U.S Coast Guard, a few others put forward the notion that simulator training can replace real time at sea, and that the experience in achieving the competency levels had been demonstrated over time with the use of simulators (Salman, 2013).

3. Problem Statement

While simulation has already been established as an extremely important part of aviation for training and become a well developed industry, its application in the maritime sector is often viewed with skepticism. Although there are many factors affecting the highest goal of maritime safety, there is no doubt that maritime education and training plays a certain important role. According to many studies, simulation have several benefits on training seafarers (Trodden, Kobylinski, & Short, 2011; Jillian, 2015). Besides, only simulation can provide some specific types of training that there is no alternative method for that. The types of training lead directly to mitigate safety risks. Although the aviation and maritime industry are different in terms of its type, their objectives and ways of operation can be quite similar in the safety and security domains. According to Francis and Alexander (2012), the aircraft industry is one outstanding example of simulation utilization for training. Hence, the maritime sector will gain benefit from their experience in that field by using their learning tools and learning outcomes. In summary, it is necessary to gain a better understanding of simulation-based training in these sectors and pinpoint the best practices of simulation in aviation training which can be transferred to the maritime domain, in order to improve practical use of simulation based training (SBT).

4. Objectives

The main objectives of this research are the following:

- to summarize the history of development of simulation and its role in aviation and maritime training;

- to review current industry practices and research via developing a comparative approach;

- to discuss the effects of simulation based team training to the maritime industry, especially in relation to safety;

- to define limitations of maritime simulation based training;

- to develop recommendations to overcome these limitations and improve simulation based training performances;

5. Research questions

More specifically, the following research questions are addressed:

- What is the current situation of simulation based training in the maritime and aviation sectors and what exactly are the current levels of utilization?

- Which limitations can be identified in relation to simulation based training within the maritime sector?

- What are "the best practices" from aviation that can be "transferred" to the maritime sector?

- How to overcome these limitations and improve the performance of simulation based training in the maritime domain from what has been learned from aviation?

6. Research Methodology

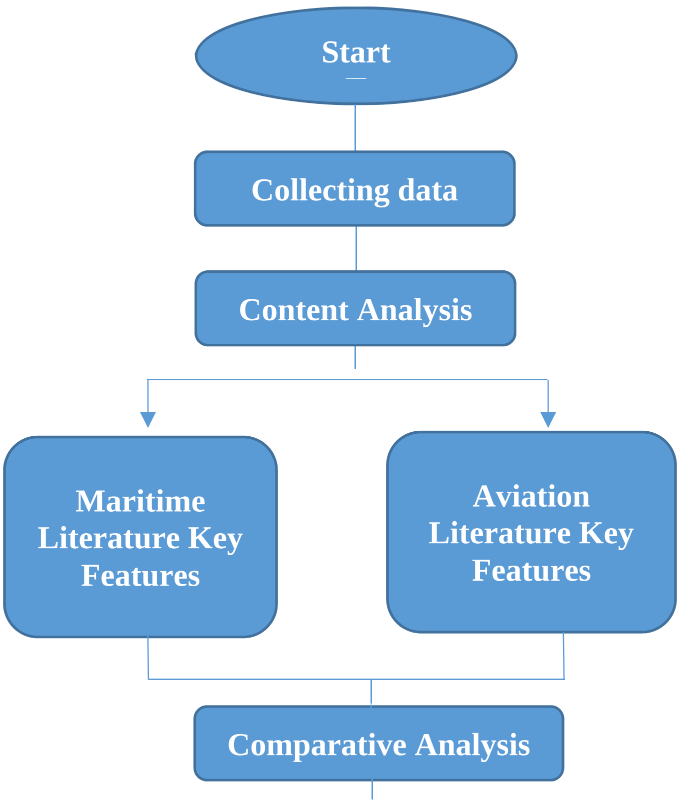
A considerable number of studies have been conducted to evaluate the utilization of simulation based training in those sectors. This research effort is using a literature study in combination with a comparative analysis in order to effectively address the research questions put forward above.

6.1. Literature study

The literature study is presented in chapter 2. It is the base for the background, which provides a big picture about simulation based training used in both the aviation and maritime domains. Afterwards, the results of the literature study are implemented to the comparative analysis. It is noted that the use of simulation based training in the military is excluded in this research effort; only commercial sectors are discussed.

6.2. Comparative analysis

When the database is completely collected, the researcher categorized all literature-based database according to different aspects. Afterwards, the differences and similarities between studies in those sector will be found. The aim is to discover the limitation of simulation use in the maritime sectors, and pinpoint the best practice of that in the aviation sector that can be learned to improve the practice.



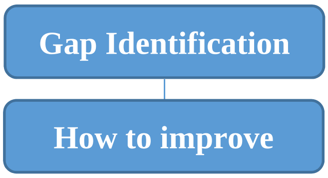


Figure 1. Research Methodology

7. Limitation

- The time limit put pressure on the researcher that may limit the scope of the research.
- One of the biggest limitations is in data collecting. Despite the fact that the researcher has permission to access many different databases (including Ebsco – a database containing the full text of over 6,000 scholarly and trade journals), there may still be articles about simulation based training that have not been published on any of the databases, for instance, the academic studies on the implementation, effectiveness and legislative perspectives that were conducted and published by simulation forum such as Flight Simulation Conference (aviation) and International Conference on Marine Simulation and Modelling (maritime). The researcher suffered limited access to these studies due to membership issue. Some of them were used in this thesis, which may lead to some difficulties for finding the latest practices.
- In the context of the digital era and the rapid technological developments, the maritime community is heading towards more artificial intelligence in ship design and less man power. The future challenges for simulation based training have also been highlighted in this research.

8. Structure of the study

This research consists of 4 different chapters. Chapter 1 provides an introduction of simulation based training, problem and objective of this research. The research methodology also be explained in chapter 1. Chapter 2 provides a literature review on the utilization of simulation based training in both aviation and maritime sectors.. Chapter 3 delivers the analysis of the collected data and further discussion on the basis of the analysis results. Finally, chapter 4 includes the conclusion and recommends measures to embrace the use of simulation based training in the maritime industry.

Chapter II. Literature review

In this disertation, the focus is on the differences and similarities of simulation based training usage between the aviation and maritime domains. The aim is to identify current drawbacks of its utilization in the maritime sector, pinpoint the effective characteristics in the aviation sector, which may possibly transfer and adapt to the maritime sector. This chapter briefly introduces the history of simulation based training, its current practices and regulatory aspects in the aviation and maritime domains. It concludes with a comprehensive literature review to demonstrate different studies on perspectives within the aviation and maritime domains, from pedagogic features, training theory, regulations, implementations to practical simulation based training exercises.

1. Simulation

Simulations have been applied for practicing training skills, problem solving and judgement for centuries (Homlong, Pan, Vederhus, & Hildre, 2016). Since the early years in India around the 6th century AD, the board game *Chturanga* was invented as a battle simulation, until modern day with computer based simulator facilities. However, in the history timeline, simulation only became very popular after being used in the aviation sector with the inventory of the Link trainer for flight pilot training in the 1930s (Kluge, Sauer, Schüler, & Burkolter, 2009). Simulation has been implemented for training as well as study purposes. However, the inclusion of this dissertation is only for training, other kinds of implementation of simulation are considered as not relevant.

Simulation based training is recognized as the more effective method in comparison with the traditional method, which is class teaching with casual lectures. According to a study by Magennis, & Farrell (2005), people tend to remember better when they interact with what they learn by doing in practice, than only by reading or hearing. The best way to gain more knowledge effectively is a combination between audio, visual and actions.

Table 1: Relative weightings given to activities in the learning pyramid

Activity	Average Retention Rate
Lecture	5
Reading	10
Audio-Visual	20
Demonstration	30
Discussion Group	50
Practice by doing	75
Teach others / Immedate use of learning	90

Source: Magennis, & Farrell (2005)

According to Lützhöft, Brown, Dunham and van Leeuwen (2017), a simulation consists of three components which are human participants (trainees), models and scenarios. Many studies showed the effectiveness of simulation based training to deliver the best intended learning outcomes, as it provides a realistic, immersive experience in the context of appointed role in training (Muirhead, 2003; Baldauf, Dalaklis, & Kataria, 2016; Nazir, & Jungefeldt, 2017). As an example of the impact of simulation based training, in 2019, the Formula E champion was actually beaten by a simulation racer, who is a gamer who had never tried a real race before (Nazvi, 2019). According to Baríc (2018), simulations are effective educational tools used to acquire knowledge, skills and attitudes needed for performing jobs in different industries outside aviation, such as shipping and health(Baldauf, Dalaklis, & Kataria, 2016; Homlong, Pan, Vederhus, & Hildre, 2016).

2. Aviation

Simulation is recognized as a credible method of training in the aviation sector (Nählinder, Oskarsson, Lindahl, Hedström, & Berggren, 2009; Kozuba, & Bondaruk, 2014; Nowakowski, & Makarewicz, 2018). It is accepted widely by the whole industry (Dahlström, 2008). Furthermore, to aviation practice, training on an actual aircraft is very dangerous, with potential hazards. Hence, simulation has been implemented heavily for many years (Page, 2000). Especially, the Multi-crew Pilot License (MPL) is a global license for pilots, who can obtain simulation flight hours, instead of traditional actual flight time. Because of that, the MPL is easier to obtain than the old license (PPL); therefore, MPL has now become popular around the world (Wikander,

& Dahlström, 2014). The simulation flight hours are also regulated clearly in the guideline “Doc 9868” (ICAO, 2006).

To gain an understanding of simulation based training (SBT) in the aviation industry, historical, regulatory and practice aspects will be explored. In this dissertation, the term ‘flight simulator’ refers to simulation facilities used for training in the aviation domain.

2.1. Flight simulator history

The origin of modern flight simulators can be traced back to 1929 when Edward A. Link patented an air actuated plane model, which demonstrated and made control movements apparent for instructors. At an early time, pilots were trained mainly by real aeroplanes, but only running on the ground (Page, 2000).

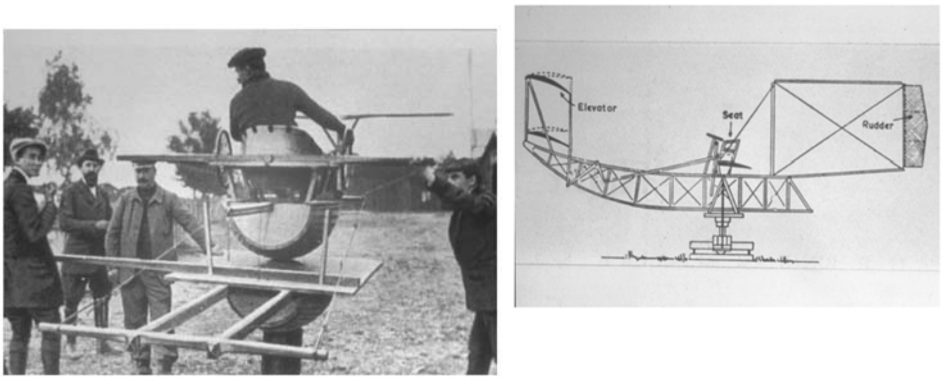


Figure 2. Origin of modern flight simulators

Source: Page (2000)

The very high demand of training during the World War I had affected the principle of pilot training. According to Utrilla (2017), many new training devices were invented, but the most successful one was the Link Trainer device made by Ed Link with an automatic electronic driver. However, due to the technological limit, simulation based training had not been accepted as a substitute for actual flight yet

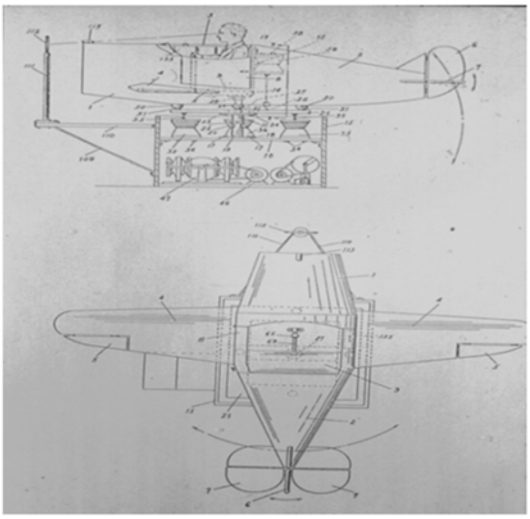


Figure 3. The first Link Trainer device

Source: Page (2000)

From the late 1930's onwards, however, the majority of advances in flight simulation technology were based on the application of electrical and electronic methods. When the Second World War started, there was an increase in the need for the training of a very large numbers of pilots. At that time, the developments in aircraft design such as variable pitch propellers, retractable undercarriages and higher speeds made sound training in cockpit drill essential (Page, 2000).

In 1939, at the request of England, Ed Link cooperated with aerial navigation expert P. Weems to design a massive trainer suitable for use by an entire bomber crew. During the war time, the most technological success was the design of synthetic radar trainers. It was one of the additional features adding to the basic link trainer model in order to build other designs for specific training purpose. The benefits of simulation had been proven during this time.

During the Second World War, the US military utilized ten thousand units based on this system for pilot training. Computers have been introduced into flight simulation since the 1960s. After this, there has been a continuous development of flight simulators, resulting in aviation simulation becoming a large industry. Page (2000) explained the evolution of the flight simulation during the last century, and he also mentioned the difficulties of achieving consensus between simulator manufacturers about standards. Therefore, these had negative impacts on the utilizations of flight simulation in the sector at the beginning as the airlines found they had considerable difficulty in maintaining some standards. To deal with the issue, the International Air Transport Association (IATA) formed a subordinate body named Flight Simulator Technical Sub-Committee (FSTSC). The sub-committee developed standards that helped simulation move forward, and then gained credibility with the authorities as well as the airline pilots.

According to Weber (2016), simulation based training became an indispensable part for training of all commercial airline companies in the 1960's. Until now, training in the actual airplane is no longer done anymore because of both safety and training effectiveness (Page, 2000).

2.2. Flight simulator standards and regulations

In the beginning of 21st century, aviation policy changes pushed the issues of effectiveness and affordability of flight simulators for use by U.S. airlines to the forefront (Burki-Cohen, Go, & Longridge, 2001). The appearance of the Multi-crew Pilot License helps the route becoming pilot shortened. In fact, it is the fastest way to become a pilot (Wikander, & Dahlström, 2014). It is well regulated in the Doc 9868 (ICAO, 2016) that the standards for the multi-crew pilot license specify the minimum number of actual and simulated flight hours (240) but do not specify the breakdown between simulated and actual flights. Thus, it is allowed that the training can be done in a flight simulator, instead of the traditional method on an airplane. In commercial aviation, the airline pilots receive extensive training in simulation for instrumentation procedures, emergencies and grading, flying their assigned aircraft type in a simulator before moving on to the actual plane. Every six months, they must return to the simulator to practice such scenarios and assess their overall competence. Failure to meet the required standards may result in the revocation or suspension of their licenses.This intensive use of simulators has a positive impact on commercial aviation safety and subsequently is accepted by the operators, flight crews, unions, and regulators (Allerton, 2002)

At present, in most countries, it is mandatory to undergo a minimum number of training hours in the simulator before the sortie can be carried out on the aircraft (Shashidhara et al., 2018). The ICAO Standards for the Multi-crew Pilot License require 240 actual and simulated flight hours as minimum standards but do not specify the time ratio between actual and simulated hours. This enables part of the training can now be done in flight simulators, while in the past it was only accommodated in an airplane (ICAO, 2006). FAA proposed a rule that would mandate the use of simulators for all air carrier training and qualification, limiting the use of the aircraft itself as a training option even for small regional airlines (Go et al., 2000). In Europe, EASA, FAA or the NAA are used as certification types of simulator.

Table 2: Civil Aviation Authority (CAA) Definition of Each of the Three Main Levels of Simulator Used for Flight Training

Simulator Description	*Definition According to CAA, CAP 804, Section 1, Part B*
Basic instrument training device (BITD)	Ground-based training device which represents the student pilot's station of a class of aeroplane . . . providing a training platform for at least the procedural aspects of instrument flight.
Flight training device (FTD)	Full-size replica of a specific aircraft type's instruments, equipment, panels and controls in an open flight deck area or an enclosed aircraft flight deck . . . to represent the aircraft in ground and flight conditions . . . . It does not require a force cueing motion or visual system.
Full flight simulator (FFS)	Full-size replica of a specific type or make, model and series aircraft flight deck . . . to represent the aircraft in ground and flight operations, a visual system providing an out-of-the-flight-deck view and a force cueing motion system.

Source: Taylor, Dixon-Hardy, & Wright (2014)

Basically, classification of flight simulator is shown in Table 2. In comparison with the maritime industry, this classification systems are fewer and more tidy to regulate (Muirhead, 2003). That is the reason the aviation industry could set the international standards easily from the beginning of the simulator industry.

2.3. Training theory of flight simulator/ Industry's perception

In both civil aviation and military training, simulation based training has become widely accepted. Simulation technology has a vital role in aviation to improve safety and training (Koblen, 2012).

Aside from an entertainment experience, flight simulators are currently used for training and improving for the aviation domain. Reliable flight simulators are used to train military and commercial pilots in the simulated backgrounds from normal operation to severe conditions that is impossible to facilitate safely in the real flights. Simulators in commercial aviation are also the most used method of assessing, qualifying and certifying pilots and aircrew in different skills. The simulation enables crews to face dangerous situations; therefore, they can be improved by using their devices and specialization in front of situations that cannot be performed in real flights, such as radar systems failure, engine failure, problems with landing gear, extreme weather, and much more. This helps to enhance the effectiveness of the reaction of the pilot in case the failure actually happens. (Martinez, 2017). Furthermore, the simulation of these unpredicted dangerous situations will contribute effectively to studying accidents. The constant repetition with exact environment and the same factors can makes possible a trustable reconstruction of the actual facts, which can improve the parameters of the flight in order to prevent the repetition of that type of simulation in the future. Therefore, flight simulators also has a vital role in aircraft design.

2.4. Fidelity and Motion

The need for the use of motion systems for flight simulation has over the years generated quite some controversy; however, many of the experiments used to argue the case against motion systems have used very early motion systems, which without a doubt, provided many false cues and certainly may have even provided some negative training. While it is well understood that motion systems may be ineffective in the simulation of highly maneuverable military fighters, there is little doubt in the view of the training captains from the world airlines and the world regulatory authorities that motion systems are essential for commercial aircraft flight simulation.

There have been many other developments such as domes and area of interest visual systems; however, these have specific applications and have not been part of the mainstream development for the flight simulator which has provided the credibility for the use of simulation for training (Page, 2000)

3. Simulation based training in the maritime sector

Simulators are regarded beneficial tools for maritime training as training tools are developed to produce particular learning outcomes. Research in the service and training institutions consistently claimed the significant training results provided by simulation training. However, the learning outcomes appear to be intermediate outcomes which do not necessarily become conclusive to increase sea safety (Rashed, 2017). While there were studies which indicated that there was no sufficient evidence to support that simulators have improved seafarer performance by the U.S Coast Guard, a few others showed that simulator training can replace sea service, as the use of simulators over time had shown experience in producing the levels of competency (Salman, 2013)

3.1. Historical background

The maritime industry has also been using marine simulation in limited ways since the late 1950s, but its acceptability has been somewhat tardy and its use for assessment purposes even less well accepted (Muirhead, 2003). The late 1960s saw the pioneering development of simulation based training in the maritime sector. The first marine simulators were operated by SSPA Sweden (a ship research and development facility), the Netherlands Organisation for Applied Scientific Research and the Netherlands Ship Model Basin (Lützhöft, Brown, Dunham, & van Leeuwen (2017). The use of maritime computer based simulators has expanded along with advancements in computer technology, and is now considered the method of choice in maritime education for risk reduction (Sauss et al., 2010). According to Baric (2018), simulation based training has a role in studying and researching, to find solutions that address team working problems.

The International Marine Simulator Forum (IMSF) was established in 1978 and is an organisation for professionals in education, training, research and development in simulation (Lützhöft, Brown, Dunham, & van Leeuwen (2017). IMSF's efforts to establish a system of standardization or classification for marine simulators aresimilar to the system of classification which had been implemented in the airline training. However, little progress was made due to the great diversity of systems, different technical designs and other interests of the members involved (Nordholm, & Cross, 2018). Today, most maritime simulators equipped by training institutions in the world are likely supplied by Kongsberg, Transas or VSTEP (Ecdisorg, 2017). For approved simulators information, IMO has built a database called "Global Integrated Shipping Information System (GISIS)" (IMO, 2019)

3.2. Regulations and standards

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) mandate was noted to require simulation training in 2012 in Regulation l/12 Use of Simulators. The Convention makes simulator training an important means to train and demonstrate competence in passage planning, navigation, use of navigational aids and bridge resource management (BRM, non-technical skills), emergency response, engine room resource management (ERM, nontechnical skills), etc. For radar, ARPA (Automatic radar plotting aid), and electronic chart display (ECDIS) skills, simulation assessment is mandatory. In all other instances, demanding training and assessment such as bridge resource management, GMDSS (Global maritime distress safety system) communication, ship handling and cargo handling, the use of simulator is not mandatory, but accepted as a method (IMO, 2012). The IMO has built the GISIS database, which can be accessed to check approved simulators all over the world.

In 2010, the STCW - Manila amended regulated the mandatory training requirement for the use of simulators for training in electronic chart display and information systems (ECDIS). Before that, only the use of radar and ARPA was mandated under STCW. In other parts of training, the use of simulation is just optional. It is recognized by the Convention as one of the methods for training and assessment. These parts include GMDSS communication, cargo handling, navigation and ship handling, propulsion and auxiliary machinery.

Simulators are needed to conform with STCW provisions and certified by international classification societies, such as Lloyd, DNV or Class NK. In terms of guidelines for simulators, IMO has published the IMO model course 6.10 Train the simulator trainer and assessor (IMO, 2012b).

The International Maritime Organization (IMO) is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships. The IMO provides and maintains a regulatory framework. These include the International Convention on Standards of Training, Certification and Watch keeping for Seafarers (STCW). IMO has the authority to vet the training, examination and certification procedures of Contracting Parties to the STCW Convention.

The STCW Convention sees simulator training as one of the methods for training and demonstrating competence. The use of simulators is equally acceptable as in-service experience or training ship experience.

In the world, there are some examples as a practice for simulation based training, including the Netherlands and the USCG as they employ the simulator as a substitute for on board training (Uitterhoeve, Heel, Werner, & Ende, 2018)

3.3. Simulator classification

In the maritime domain, Simulation based training was classified under STCW into the following categories:
Category 1 – Full mission
Category 2 – Multitask
Category 3 – Limited task
Category 4 – Special task
According to Lützhöft, Brown, Dunham and van Leeuwen (2017), a simulation consists of three components which are human participants (trainees), models and scenarios.
Ship handling and cargo handling simulators, communication aids simulators are the most popular ones for the navigator training (Aizinov, & Orekhov, 2009). Engine room simulators, cargo handling simulators and other mechanisms are used for the mechanic training. For the other specialists, the crane simulators and simulators for maintenance and repair of various ship and coastal systems should be noted.

3.4. Why do we need simulation-based training?

A ship is a giant and complex machine; therefore, it is not reasonable for training institutions to equip a ship only for training purposes. Furthermore, for some specific type of situation, it is hard for crews to experience that in the real ship due to working position and other factors.

While some people argue that experience only come from the real life exposure, others opine that simulation-based training may prepare working experiences for crews. They believe that no one can experience all workplace situations, and simulation-based training can provide them with opportunities in the risk free environment (Muirhead, 2006).

Table 2. Pros and Cons of simulator and on-board training

Benefits of simulator training	Benefits of on-board learning
• Possibility to make mistakes without damage consequences • Training of irregularly occurring situations plus dangerous situations • The simulator guarantees a controlled condition and repeatability • Learning content is given in a structured way • Learning content matches individual capabilities • The organisation of the learning process is more efficient • Coaching and performance monitoring by professional trainers	• Experience the real life on board: o long period away from home o International crew, different cultures o Social structures forced by limited environment. • Exposure to routine and day-to-day situations • Experience all the additional tasks of the job of a watch officer • Experience the effects of stress, fatigue and boredom during watch schedules • Experience the effects of working conditions: e.g. motion, noise and temperature

• Assessment by professional simulator instructor using agreed/validated criteria • Possibility to train team performance • Possibility to train on a large variety of vessel types • The trainee has a more active role and can exercise situations that would normally be dealt with by more senior officers	• Experience the true delays involved with working on a large ship • Maintain and repair machinery
	Cons of on board learning
	• Difficult situations are dealt by more senior personnel • Dangerous situations are avoided • No validated performance criteria • Assessments are dependent on the individual mentor • On-board the level and amount of learning content can be too high or too low

(Source: Uitterhoeve, Heel, Werner, & Ende, 2018)

3.5. Is simulation-based training worth it?

It has been said the value of one life saved is greater than any cost as long as it is affordable. Simulation based training is worth using because it is one of the initiatives having potential to save life at sea, or improve maritime safety. However, there are others that also have the benefits but at a lower cost. The question is whether in comparison with others, can simulation based training actually save money through a reduction in accident related costs or performance issues?

Cross (2009, p. 3) conducted a study to evaluate the training cost with the potential money saved from accidents. He mentioned:

> If simulator training can improve safety of operations, this would result in fewer accidents, which in turn will save funds, which could be used to afford the additional training efforts.

Additionally, if the amount of the increased costs of training is compared to the funds spent presently on damages from accidents, a simple cost benefit analysis could show if such training efforts are worthwhile.

Table 3. Percentage reduction of accidents

	Percentage	Absolute
Total number of accidents occurring	**100%**	**1.00 x**
Percentage (of 1.00x) of accidents which can be related to human error (see 4.1)	**80%**	**0.80 x**
Percentage (of 0.80x) of training related accidents within human error category (see 4.4)	**65%**	**0.52 x**
Percentage (of 0.52x) of competences in training related to simulators (see 4.5)	**58%**	**0.30 x**
Percentage (of 0.30x) of competence improvement through simulator training (see 6.3)	**45%**	**0.14 x**
Resulting percentage of accident reduction	**14%**	

Source: Cross (2009).

His analysis estimated that through the appropriate application of simulator training, 14% of maritime accidents could be avoided. That means only for the damages claimed for accidents from the IOPC Fund in the period 1980-2008, the money saved can allow for a simulation training course for each seafarer all around the world. This showed that simulation based training has the effect of both reducing costs and improving safety.

3.5. Limitations of simulation-based training

Marine simulators in existence usually use plane projection techniques to structure visual scenes and the mariners control the virtual ship by a spacious room. Obviously, today's marine simulators have some disadvantages. The high price and large-spacerequirements impede the installation, meanwhile the one-by-one training model fails to meet the training demand of large group of trainees is also a problem. (Ma, Zhang, Chen, & Liu, 2018)

In research conducted by a variety of authors, some other limitations are pointed out, namely simulation training is not mandatory but merely an option (STCW, Section B-I/12, 67). There are no guidelines for simulation training to respond to imminent danger, such as collision and fire situations (IMO, 2012). Simulation training is assessed by instructors, trainers, or so called 'subjective assessment'. Complaints have been made that there is a lack of standardization and reliability, compared with 'objective assessment', which uses simulator data for assessment (Sitkov, 2015). The application of different simulator types that are designed with a specific education task in mind can provide a better and more effective solution than when trying to build more and more complex simulators that can fulfil virtually any educational task and the importance of checklists were also discussed by Kluj (2003).

According to Muirhead (2006), the simulation-based assessment in the airline industry is made easier than that in maritime sector due to the limited number of aircraft types on the market.

Saus et al. (2010) indicated the importance of designing simulator training regarding the level of seafarer experience, which is recognized as the omission of simulation-based training in the maritime sector.

4. Literature review

The success of the simulation industry is that it has gained the credibility of the aviation sector, which led to grant training credits for simulation based training in training and licensing aircrew by legislative authorities (Page, 2000). Apart from the enormous cost savings so generated, training aircraft accidents were eliminated and today, the task to instill in crew members the instinctive and correct reaction to failures as well as emergencies, has passed beyond the economic and practical use of the aircraft for training. With current development of technology, there is no doubt that simulators can provide realistic and cost effective training that should be supplemented by sea time (Ecdisorg, 2017). According Muirhead (2003), making marine simulator training mandatory for seafarers has always been a troublesome issue. Despite many perceived benefits of simulator training, delegates revising the STCW 1978 Convention (STCW 95) were unwilling to extend the mandatory requirements beyond radar and ARPA training, a situation unchanged in 2003. IMO's work on simulation based training has been conducted mostly by the Sub-Committee on Human Element, Training and Watchkeeping (HTW). There are not many efforts in technology development, strategy building of utilization of simulation based training in the maritime sector, apart from some model courses. Instead of adopting mandatory technical specifications, introducing the standard, managed by a Ship Classification Society has enabled the requirements for simulators to follow the same path as development and implementation of real equipment on ships. Otherwise, it may artificially restrict the simulator manufacturers' option for solving technical problems (Nordholm, & Cross, 2018). The greatest danger lies in simulation technology being used for training and assessment purposes and tasks for which the simulator is clearly not suitable or capable. A second problem is a lack of instructor experience in designing, running and evaluating simulator programs and exercises where reliability and validity of training and assessment outcomes have become much more important (Muirhead, 2003). Sandhåland, Oltedal, and Eid (2015) stressed that it is necessary for seafarers to be provided sufficient on board training in addition to training on navigation simulators. It is proven that some competences can be trained better in simulators than in practice e.g. emergency manoeuvres and human resource training (Uitterhoeve, Heel, Werner, & Ende, 2018). Kobayashi (2005) concluded that simulators are compatible for training and assessment only when they are implemented properly.

The study conducted by the Maritime Institute Willem Barentsz into the 'Effectivity of simulator training' in 2012 concluded that the time to reach the same performance level was 7.25 times shorter using simulator training compared to the time it took during the sea time (Uitterhoeve, Heel, Werner, & Ende, 2018). These studies contributed to the time shortening in maritime education in the Netherlands

It is proven through studies of Emad and Roth (2018) that the current implementation of SBT in the maritime domain is not effective although simulation is a training tool with potential advantages to assessment and training. Therefore, it causes a potential safety hazards for the maritime industry (Gekara, 2011). However, according to Fisher and Muirhead (2016), critics stated that it is no substitute for real hands-on experience onboard a ship, a view one cannot disagree with when taken at face value. However, research shows that many watchkeepers and senior officers are not getting the opportunity to acquire key practical skills at sea for good safety and operational reasons. The simulator, if used effectively, provides an alternative medium in which to acquire these operational skills in a risk free environment. A common criticism is that most simulators only represent one manufacturer (and thus, only a limited number of workplace(s) – ships) and will not provide generalised training (Lützhöft, Brown, Dunham, & van Leeuwen, 2017). In the research aspect, the study of Sellberg (2017) shows that it has been a lack of empirical studies on SBT in the maritime sector. The industry needs to explore evidence based practice to enhance the training and assessment quality. In addition, cost of validity, fidelity and simulator sickness were determined as the drawbacks of simulation based training research (Lützhöft, Brown, Dunham, & van Leeuwen, 2017).

CHAPTER III. DATA ANALYSIS

After reviewing research on SBT usage in chapter II, this chapter conducts collection of data based literature searches in both chapters. It is known that the use for simulators have three different areas: for technical development, for education and training and for experiments and research (Lützhöft, Brown, Dunham, & van Leeuwen, 2017). This thesis includes

1. Data collecting

The inclusion criterion for data collecting is that articles should study the use of simulators as a training tool in the aviation and maritime domains; therefore, simulators as an engineering tool or for experiments are not included. Moreover, the studies should be searchable in major academic databases, peer-reviewed journal articles, available in English and published between the years 2000 and 2019. Thus, the primary data collection is used in this dissertation, which included the databases as studies searched on:

- Google Scholar, which include only credible, scholarly material
- Springer, which publishes peer-reviewed academic journals
- Ebscohost is an intuitive online research platform used by thousands of institutions
- Researchgate, which is a social networking site for scientists

To expand further the collection of data, there are additional sources used, such as conferences papers of the International Marine Simulator Forum proceedings (MARSIM conference).

The keywords consisted of three components. The first component contained the words used to the mentioned sectors: “aviation”, “maritime”, “marine”, “flight”, “ship”. The second component contained the words in relation to the usage of simulation for training including: “simulat*” (for all possible related results), “simulation-based”, “simulation”, “simulator”. The last component was related to training purpose: “education”, “training”, “assess”; and extensions: “training practices”, “training effectiveness”, “training technique”, “training limitations”.

The initial searches identified 3256 hits, whereof 147 papers were considered relevant and examined in full text. Since the objectives of this dissertation is to discover the limitations of SBT usage in the maritime sector and adapt compatible features from the aviation sector that may possibly deal with limitations. Furthermore, flight and marine simulators are different in machinery, so the researcher mainly chose the articles which relate to regulation, training effectiveness, technical and research aspects and not to be too specific in machinery. Of these, 71 were suitable for the inclusion, of which 42 were from the maritime domain and 29 from the aviation sector. A further search into the references of these papers resulted in 21 additional relevant papers. They are all peer-reviewed journal articles. In all, 92 articles were included in this data (see Annex A).

2. Analyzing the results

After collecting data from studies in both the aviation and maritime sectors based on the above criteria, the database was analyzed according to different categories from quantity, authors' background, sources, content relevance, study's subjects and research methodologies in the effort to record the similarities and differences in the research aspect. The content of those studies are discussed simultaneously.

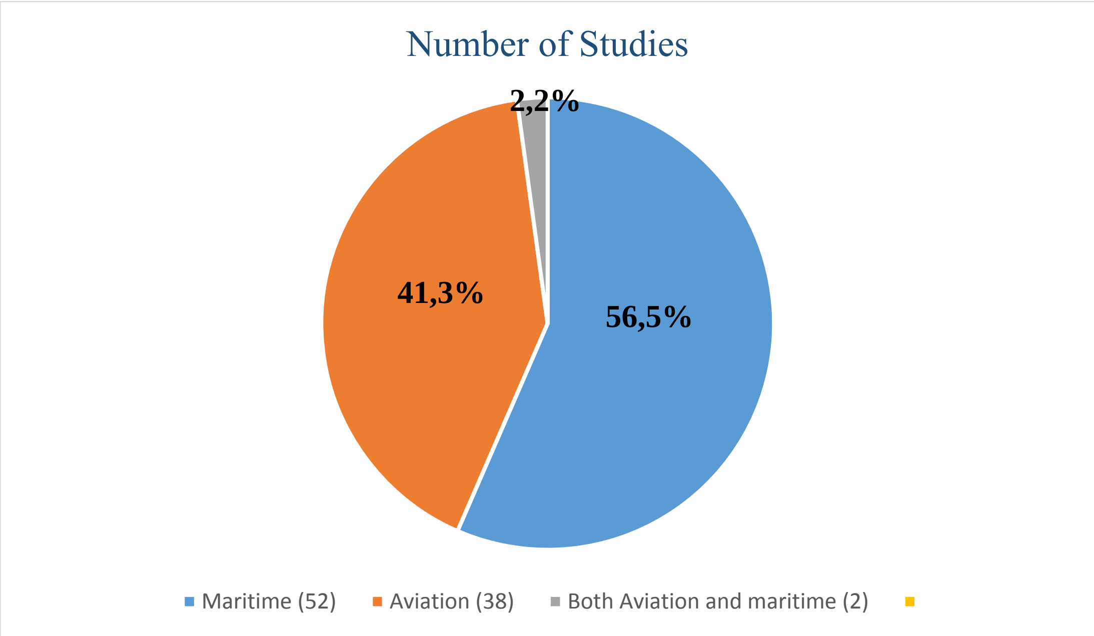


Figure 4. Distribution of studies according to sector

As can be seen in Figure 5, a number of studies have differences between the two domains. In the progress in collecting data, there were more studies of maritime simulation based training that were excluded by the researcher, due to its relevance, or its specific machinery content, while in the aviation domain, many studies were published a very long time ago before 2000.

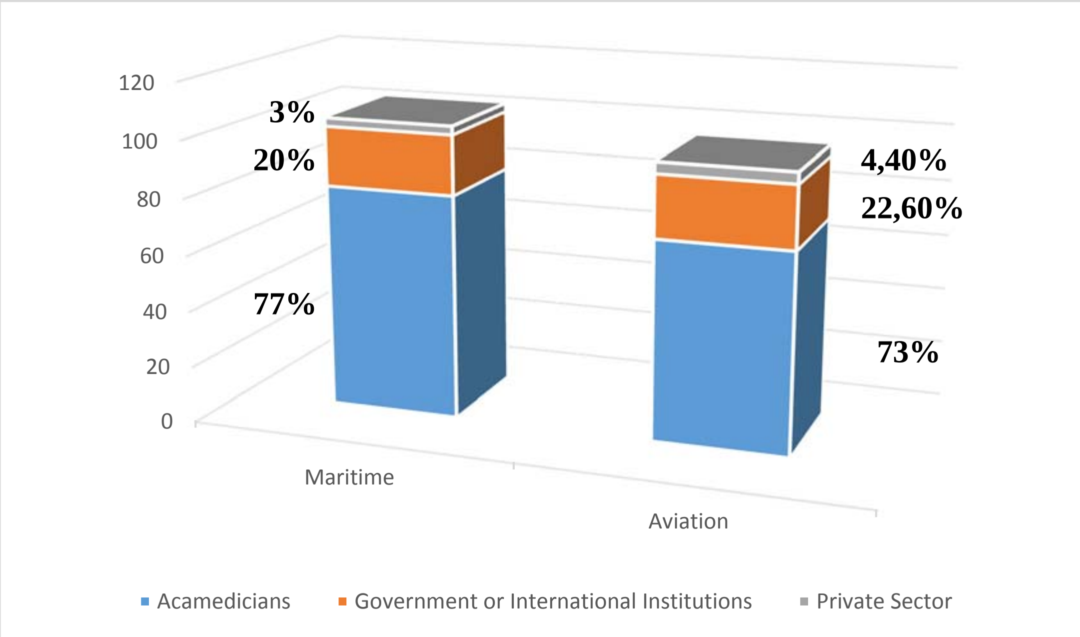


Figure 5. Authors' professional background

Once the 92 studies, which include simulation based training in both the aviation and maritime sectors, the authors' background should be discussed. It is seen that in Figure 6, the proportion of authors' professions was almost the same in both the sectors. There were approximately 77% and 73% of authors as academicians, in the maritime and aviation research respectively. The studies conducted by these authors have also provided information tremendously with discriminating evidence based discussion. On the contrary, only a minority of authors work for private sectors.

No.	Origin	Number of items (Maritime)	Number of items (Aviation)
1	Google Scholar	26	27
2	Researchgate	9	10
3	Ebscohost	6	3
4	Springer	7	0

5	MARSIM conference papers	6	0
	Total	54	40

Table 4. Data statistics by source

The distribution of papers database sources in which they were found is given in Table 4. It can be easily noticed that the data wascollected mainly on Google Scholar and Researchgate databases. As mentioned above, due to the membership issue, only six MARSIM conference papers were collected.

No	Geographical region	Quantity of maritime SBT studies	Quantity of aviation SBT studies
1	Europe	76 (76%)	56 (66,67%)
2	America	9 (9%)	26 (30, 95%)
3	Asia	10 (10%)	0
4	Australia	0	1 (1,19%)
5	Africa	1 (1%)	0
6	None	4 (4%)	1 (1,19%)
Total		**100**	**84**

Table 5. Geographical regional of the authors

Distribution of geographical regions of the authors is classified by continent. The information in Table 5 is extracted from Table 5, which is the distribution of authors' countries. It is obvious that the studies were mostly conducted by authors in Europe, which represents for 76%, and 56% for the maritime and aviation sectors, respectively. Following Europe is Asia (10 authors) within studies in the maritime sector and America (26 authors) within studies in the aviation sector. This shows that researchers in the U.S are interested in studying simulation based training in aviation, in comparison with other countries.

No.	Country	Maritime sector		Aviation sector	
		Quantity	%	Quantity	%
1	Australia			1	1,2%
2	Austria	3	3%	1	1,2%
3	China	4	4%		
4	Czech Republic			13	15,5%
5	Egypt	1	1%		
6	Finland	1	1%	1	1,2%
7	France			5	6,0%
8	Germany	9	9%		

9	Kuwait	1	1%		
10	Malaysia	3	3%		
11	Norway	14	14%		
12	The Netherlands	4	4%	9	10,7%
13	Philippines	2	2%		
14	Poland	1	1%	4	4,8%
15	Portugal	2	2%		
16	Romania	6	6%		
17	Russia	2	2%		
18	Slovakia			9	10,7%
19	Slovenia	4	4%		
20	Spain	1	1%	3	3,6%
21	Sweden	17	17%	4	4,8%
22	Turkey	7	7%	1	1,2%
23	United Kingdom	5	5%	6	7,1%
24	United States	9	9%	26	31,0%
25	None	4	4%	1	1,2%
Total		**100**	**100%**	**84**	**100%**

Table 6. Countries of the authors

Table 6 shows the classification of 24 countries and one unspecified category (authors come from non-govermental organizations) of the authors. These countries are the places that the authors work in, rather than the birthplace. It is found that Sweden and Norway have more authors than other countries among maritime SBT studies, representing 17 and 16 researchers, respectively. Meanwhile, for aviation SBT studies, authors from the United States represent 31% of the total, which is 26, followed by the proportion of authors from the Czech Republic representing 15,5% (13 authors). Obviously, authors from the United States contribute considerably to SBT research in the aviation sector.

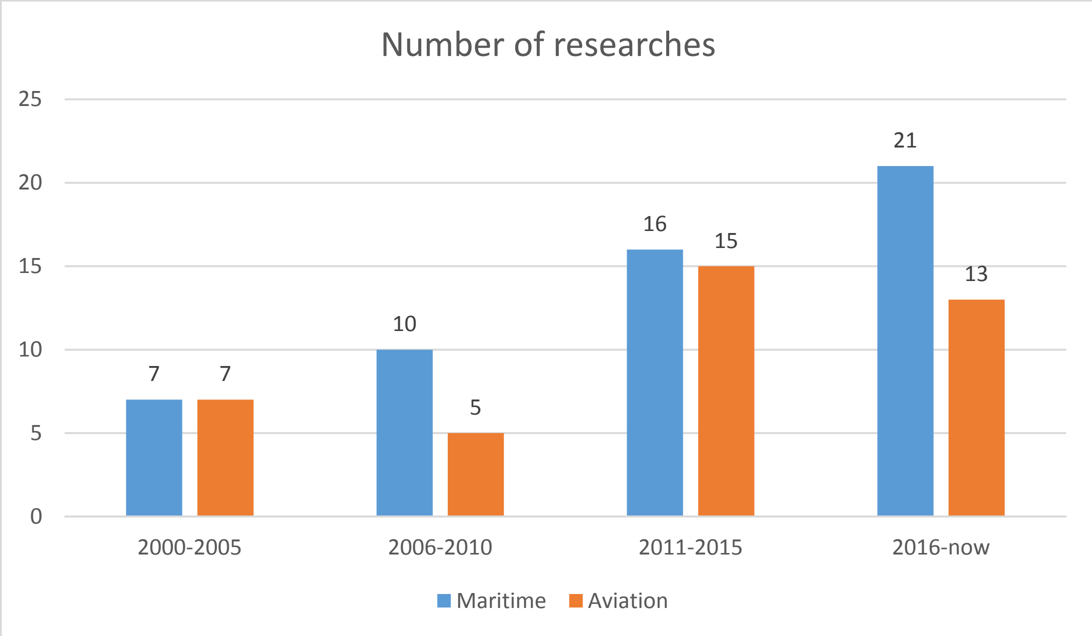


Figure 6: Distribution of researches according to the time frame of publication

Reviewed articles have been analyzed in terms of author numbers in the articles and the publishing time frame. Distribution of studies on simulation based training according to the sectors and the time frame of publication is given in Figure 7. According to Figure 7, articles were mostly published in the period from 2016 until now for maritime studies; in the period from 2011 to 2015 for aviation studies.

	Quantity	Percentage
1 Author	32	34,04%
2 Authors	19	20,21%
3 Authors	25	26,59%
4 Authors	9	9,57%
5 Authors	4	4,25%
6 Authors	2	2,12%
7 Authors	2	2,12%
13 Authors	1	1,06%
Total	94	100%

Table 7: Articles distribution according to the number of authors

The distribution of articles according to the number of authors is illustrated in Table 7. According to Table 7, it can be seen that the number of authors is approximately 2.55 in average and more than 80 % of all articles were published by three or less authors.

Methodology	Quantity	Percentage
Experience based	9	16,67%
Analysis of maritime regulations	8	14,81%
Literature-based	7	12,96%
Survey	7	12,96%
Review and analysis different studies	6	11,11%
Experiment	6	11,11%
Video-based research	4	7,4%
Case Study	3	5,55%
Technical development	2	3,7%
Software development	2	3,7%
Total	54	100%

Table 8: Research methodologies distribution in the maritime studies

Table 8 shows the distribution of studies about simulation based training in the maritime sector according to types of research methodology. It can be seen that the most popular methodology followed in the studies is “experience based methodology” within 9 articles. Following that “Analysis of maritime regulations”, “Literature-based”, “Survey”, “Review and analysis different studies”, “Experiment” with 8, 7, 7, 6, 6 articles, respectively. This distribution seems to be similar to the statement of Sellberg (2017) that several of the simulator based maritime training studies found lack of empirical data as a basis for analysis. There are 9 articles based on experience, which account for 16,67% of the total number of studies. The methodology is also the most popular among studies in marine SBT.

Methodologies of the SBT studies in the aviation are examined separately. The aim of this separation is to find the difference between methodology usage in both domains. The distribution table is given in Table 8. While there is not a big difference among the usage of methodology in the maritime simulation based training studies, “Experiment” is the most popular one as the methodology used in studies in aviation, accounting for 32,5% of the total, with 13 articles. Following that, “review and analysis of different studies" with 10 articles. Studies in SBT aviation seems more experiment based than that in the maritime field. Most of the experiments are conducted to find the impacts of technical and pedagogical aspects on the performance of crews (De Winter, Dodou, & Mulder, 2012; Burki-Cohen, Sparko, & Bellman, 2011; Myers III, Starr, & Mullins, 2018)

Methodology	Quantity	Percentage
Experiment	13	32,5%
Review and analysis different studies	10	25%
Experience based	4	10%
Literature-based	4	10%
Analysis of aviation regulations	3	7,5%
Survey	3	7,5%
Software development	2	5%
Analysis of accident data	1	2,5%
Total	40	100%

Table 9: Research methodologies distribution in the aviation studies

After reviewing and examining the collected data, all articles have been labelled under specific terms, based on their contents. It includes: "Regulation", "technical", "training effectiveness", or "research".

- "Regulation" type articles related to studies which review or analysis the maritime policies in terms of simulation based training
- "Technical" subject relates to articles that explore the role of technical in simulation. It may be hardware, software or some specific features of facilities.
- "Training effectiveness" is used for papers that study the impact of simulation usage on crew training
- "Research" subject is for studies involving the use of simulation for research (experiment, exercise, case study).

No.	Subject	Maritime		Aviation	
		Quantity	Percentage	Quantity	Percentage
1	Regulation	13	24%	5	12,5%
2	Training effectiveness	18	33,33%	17	42,5%
3	Technical	19	35,18%	17	42,5%
4	Research	4	7,4%	1	2,5%
	Total	54	100%	40	100%

Table 10: Subject of the researches

Table 10 shows the distribution of studies according to subjects. As can be seen, there are some points:

- While technical and training effectiveness aspects of SBT are more interested by researchers in the maritime sector, the studies in the aviation domain focus mainly on the effectiveness of training and technical matters.
- Regulation is highly noticed in the maritime studies, with 13 articles (24%); however, that subject in the other sector was not too concentrated, with only 5 articles.
- Technical and training effectiveness was the most attractive subjects to the researcher in both domains, with 18 articles for maritime SBT and 17 articles for aviation SBT.

Domain	Period	Regulation	Training effectiveness	Technical	Research	Total
Maritime	2000 - 2005	2	3	2		7
	2006 - 2010	2	4	4		10
	2011 - 2015	4	5	5	2	16
	2016 - now	5	6	8	2	21
Aviation	2000 – 2005		1	5	1	7
	2006 – 2010		4	1		5
	2011 – 2015	3	6	6		15
	2016 – now	2	6	5		13
	Total	18	35	36	5	94

Table 11: Subjects of study sorts by time

Table 11 was an expanded version of Table 10, in that the researcher classifies subjects of studies over the time in four periods since 2000 until now. Table 11 shows the research trends over time of the entire study in both domains. It is easy to see that "Technical" and "Training effectiveness" are the hottest subjects in both sectors over the periods. The "Technical", "training effectiveness" and "Regulation" subjects have been becoming more popular in maritime studies as the number of studies has increased steadily over the periods. The same event happened to the "training effectiveness" in the aviation studies.

3. Discussion

As can be seen, comparison between the studies in the two domains in Appendix A, studies in the maritime sector still need to consider many aspects including regulatory (Muirhead, 2003; Ziarati, Demirel, & Albayrak, 2010; Nazir, Jungefeldt, & Sharma, 2019), cost effective (Cross, 2009), and technical matters (Kuzu, 2016) The studies in the aviation domain focus only on how to improve the training effectiveness by training techniques and technical matters. The reason may be that the simulation based training has been implemented heavily in the aviation sector since the war time (Page, 2000). It is made mandatory for every pilot in the industry because simulation based training is the substitute training method of actual flight training that has been accepted by the whole industry for many years (Homlong, Pan, Vederhus, & Hildre, 2016).

One important factor is that the shortage in the aviation sector currently demands airlines to produce pilots faster and properly. The application of Multi-crew Pilot License was also a huge motivation for more intense implementation of simulation based training (Wikander, & Dahlström, 2014)

In the maritime sector, simulation based training has reached the highest practice over time, after the adoption of the STCW Manila amendment. At present, for some countries, simulation based training has been used as a substitute for the traditional on board training methods, for instance the Netherlands and the USCG (Uitterhoeve, Heel, Werner, & Ende, 2018). However, according to Emad and Roth (2018), the current implementation of SBT in the maritime domain is not effective although simulation is a training tool with potential advantages to assessment and training. Therefore, it causes a potential safety hazards for the maritime industry (Gekara, 2011).

According to Muirhead (2006), the simulation based assessment in the airline industry is made easier than that in maritime sector due to the limited number of aircraft types on the market. IMSF made efforts to establish a system of standardization or classification for marine simulators, similar to the system of classification which had been implemented in the airline training. However, little progress was made due to the great diversity of systems, different technical designs and other interests of the members involved (Nordholm, & Cross, 2018). After many efforts, currently, marine simulator facilities are certified by DNV GL under the standards. In fact, for the aviation, in the beginning, there was no common standards for flight simulators, and this caused great difficulty to the airlines. However, after the form of FSTSC of IATA, the standards were set and accepted by simulation suppliers. Until now, simulation has moved in advance to achieve credibility with the legislative authorities as well as the airline pilots. However, there is still the difference in standardizing maritime simulation classification, which needs an open discussion of issues which the maritime industry are facing in simulation usage for training.

Technical factors are also focused on and studied in a great deal of research in both the aviation and maritime sectors. Many studies were conducted to prove the unnecessary fidelity based development of simulation training. For instance Go, Bürki-Cohen, & Soja (2000) indicated that the motion provided during flight simulator training does not affect training performance which includes training progress and transfer of training, regardless which type of simulator it is. Experiments in 2007 conducted by Robinson and Mania (2007) showed that perceptual fidelity is not necessarily induced by exact physical simulation. Therefore, it is not required to simulate the physics or reality. It sometimes may raise the burden of cost. Kluj (2003) stated that simulators need to be considered in other aspects aside from fidelity for being an effective and usable training tool. To be specific, there needs to be a well compatible relationship between the simulation type and intended outcomes.

The experiment conducted by Håvold, Nistad, Skiri and Ødegård (2015) showed that the training content, team membership stability and team size can explain more than 30% of the variance of a team's performance. This exercise also proved that the debriefing process is important. Sellberg (2017) conducted a video based research that stresses the importance of instruction in SBT. It is required to be specific and suitable for the process. Elashkar (2016) stated that simulation can offer non-technical skills training for seafarers. The use of simulation based training in the maritime sector was motivated from the aviation industry. These studies highlighted that the simulator itself offers little in terms of learning, emphasizing that what is simulated is far more important than the simulator (Sellberg, 2018).

Burke and Clott (2016) mentioned the reason that in the aviation industry, pilots can gain a commercial pilot's certificate only in four and a half months, which is the intensification of the training course. Basically, the simulation training facilities in the maritime sector also have the quality as high as the flight simulator in the aviation. However, the use of marine simulators is not seen as an effective substitute for sea service. The study indicated that a novice can reach a satisfactory level of competence within a similar period of time if the training is of high intensity, similar to the way of training in the aviation industry.

In the paper written by Valentino, Christian and Joelianto (2017), virtual reality has been implemented into training in the aviation sector. Although it is in progress of development, it promises a semi-portable devices to give the trainee a real experience in the future. That means pilots may be trained anywhere, leading to overcoming the current physical difficulty of flight simulators.

Simulation facilities have potentially improved maritime safety and security (Felsenstein, Benedict, & Baldauf, 2010). Research has shown that the use of simulation based training combined with actual training in the aviation sector enhances the performance in real aircraft than aircraft-only training (De Winter, Dodou, & Mulder,2012). In a study conducted by Landman, van Oorschot, van Paassen, Groen, Bronkhorst, and Mulder (2018), the impact of unexpected event pilot training was demonstrated. It can be an effective way to improve skills andprepare students for unexpected and novel conditions. Walker (2015) stated that it is useful to emphasize the learning context, as an aid to the design of aviation training in a way that is based on logical awareness. Flight simulation has been proven, and will continue to prove itself irreplaceable in pilot training. Their potential is primarily to provide accurate flight habits, eliminate bugs, teach flight procedures and provide crisis management.

According to Lützhöft, Brown, Dunham, and van Leeuwen (2017), research in marine simulations was inevitable. Future researchers should attempt to track pilot performance during in-flight activity in an effort to correlate performance in the simulator with performance in flight (Walker, 2015). However, in the maritime sector, Sellberg (2018) has done very well research into performance recording for evaluation. These studies have become the basis for further research, which can improve training effectiveness in the maritime sector. Therefore, in terms of research, aviation has gone more advanced than the maritime sector. This can be explained by the condition of simulation based training in the maritime sector. It is not implemented as heavily as in the aviation counterpart. The usage limit raises arguments about its effectiveness, regulation and technical aspects. It is also notable that these articles are based on knowledge of the field and experiences rather than empirical data. At times, surveys are used, but mainly in order to collect the experience and opinions of maritime professionals in a wider sense.

In the future, ship design is moving forwards with more artificial intelligence and less manpower, which is important information for marine simulators to pay attention to. As the unmanned ships and remote-control ships are coming into use, marine simulators should be changed to meet the new demands of these driving modes. To design a new type of marine simulator, functions like remote control, remote monitoring, enhance control and safety alarm should be considered. Based on function modularization and information fusion, multi-degree motion platform and Virtual Reality equipment are integrated to develop the marine simulator for the future needs of smart ships on marine simulators (Ma, Zhang, Chen, & Liu, 2018).Therefore, the use of autonomous ships is already progressing with high speed. The grade of autonomy will depend on ship type, service area and cargo types. Regardless of the stages from remotely controlled to full autonomy will require personnel to handle the operations. Thus, the future captain and chief engineer will obviously have a totally different knowledge of mode of operation than today. To what extend is yet to be discovered (Nordholm, & Cross, 2018).

CHAPTER IV. SUMMARY AND CONCLUSION

4.1. Summary

The aim of this dissertation was to analyze literature based data for simulation based training usage in the aviation and maritime sectors. Then limitations of SBT implementation in the maritime sectors was imposed as lack of empirical based research; the weak regulations for simulation based training usage.

The research examined the importance of simulation based training for the industry to maintain safety. It is an initiative to save people's lives at sea. However, it is not implemented properly in the industry due to different reasons. After reviewing the practice of simulation based training in the aviation sector, some practices possibly useful to the maritime sector were pinpointed.

4.2. Challenges

These challenges can be categorized into the following areas:

- Regulation: In comparison with the aviation sector, maritime policies do not require standards of simulation strictly. It based on performance standards, and according to IMO, it will not hamper the simulation development. The maritime sector also has diverse types of simulators, so it is the difficult to unite the standards.

- Research: Simulation research is not popular in the maritime sector. The quality of research is also not too credible. While in the aviation sector, researchers prefer experiment as the methodology research, in the maritime domain, it lacks empirical research.

- Technical: There are a future challenges for simulation due to the development of autonomous ships and other types of technology. Marine simulator facilities need to be studied with new features to catch that development.

4.3. Recommendations

- Regulations: A growth of the international maritime policies is needed; STCW needs to be revised in 2020. The regulations need to be considered to the example in the Netherlands and the USCG. IMO should set simulation based training matters on the agenda at the next related conference. There a need for open discussion between stakeholders including manufacturers, trainees, maritime institutions about the best way to implement that valuable tool.
- Implementation: Maritime institutions should study to set a proper curriculum that serves trainees effectively and efficiently in accordance with STCW regulations and IMO Model Courses.
- Technical: Simulators should be made more flexible as it may be easier in the future with software and displays.

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Appendix A

Table 12. Detailed results of content analysis for simulation-based training in the maritime sector

Articles	Author	Source	Country	Keyword	Method	Main results
A review for evaluation of marine simulator training performance	Kuzu (2016)	researchgate	Turkey (1)	training effectiveness	Literature review	There is a need for standardizing evaluation system for all seafarers in scope of STCW
Applications of simulation and adoption of new function areas to the DNV GL Standard for Certification of Maritime Simulator Systems	Nordholm, & Cross (2018)	MARSIM	UK (1), DNV GL	regulations	Analysis of maritime policy	IMO's argument on simulation standards. The role of Ship Classification Societies on introducing and managing the standard
Azipilot - Review of existing training facilities and capacities	Trodden, Kobylinski, & Short (2011)	Google Scholar	UK (3)	Technical	Review and analysis different studies	A comprehensive review of simulation usage in the maritime sector
Broadband technology and marine simulation: why not simulator training anywhere, anytime	Muirhead (2003)	MARSIM	Sweden (1)	regulation	Experienced base	Technological development
Crew resource management training in the maritime industry- a literature review	Wahl, & Kongsvik (2018)	Google Scholar	Norway (2)	training effectiveness	literature review	The complexity and magnitude of BRM training programmes in the maritime industry. BRM programmes should aim to train crews that usually work together,

						and consider to give assessment not only on individual, but team performance
Crew Resource Management- What aviation can learn from the application of CRM in other domains	Jimenez, Kasper, Rivera, Talone, & Jentsch (2015)	Researchgate	United States (5)	training effectiveness	literature review	CRM implementations in the maritime domain are successful with the standardization of training. Simulation-based training methods, assessment methods, trainee's certification
Demonstrating professional intersubjectivity- The instructor's work in simulator-based learning environments	Sellberg, Lundin (2017)	Google Scholar	Sweden (2)	teaching technique/ instructor	experimental	The gap between learning objectives and on job activities can be identified by instructor's ability in the simulator
Development of a simulation environment for training and research in maritime safety and security	Felsenstein, Benedict, & Baldauf (2010)	Google Scholar	Germany (2), Sweden (1)	training effectiveness	Case Study	Simulation facilities have potentially improved maritime safety and security
Design and Application of Multi-function Marine Simulators for the Future	Ma, Zhang, Chen, & Liu (2018)	MARSIM	China (4)	technical	Technical development	Future technology for simulation-based training, which applies multi-funtional marine simulators into training
Effectiveness of Kongsberg simulations thru maritime education technology	Francis, & Alexander (2012)	Google scholar	Philippines (2)	training effectiveness	Survey	The current practices of training by Kongsberg simulation facilities
Error without consequences	Jillian (2015)	Google Scholar	UK (1)	training effectiveness	Experienced base	Beyond its role as a training aid, a simulator can be an effective tool in evaluation and assessment. To do that, it is required the skill to using a simulator to assess the outcome of learning activity

Filling the gaps the need to use simulators effectively	Barber (2003)	MARSIM	United Kingdom (1)	traing effectivene ss	Experienced base	The effectiveness of the overall training programme is the key to the successful use of simulation training.
From briefng, through scenario, to debriefng- the maritime instructor's work during simulator-based training	Sellberg (2018)	Springer	Sweden	technical	Literature review and empirical case	The simulator itself ofer little in terms of learning, emphasizing that what is simulated as far moreimportant that the simulator. The instructor's role is very important during simulator-based training
Future trends in maritime training simulator systems	Yildiz, Kacmaz, & Kara (2016)	Google Scholar	Turkey (3)	technical	Literature review	New technologies will affect the potential of simulators as a training tool. 3D visualization realism is the most important of the future trends on maritime simulation training.
Higher Performance in Maritime Education Through Better Trained Lecturers	Hanzu-Pazara, Arsenie, & Hanzu-Pazara (2010)	google scholar	Romania	technical	Experienced base	Instructors and lectures need to catch up with contemporary technologies for simulation based training
Integrated maritime simulation complex management, quality and training effectiveness from the perspective of modeling and simulation in the state of Florida, USA	Sendi (2015)	Google Scholar	United States (1)	technical	Case Study	The collaboration between instructors and trainees are the key for the success of simulation-based training
Interactive 3D desktop ship simulator for testing and training offloading manoeuvres	Varela, & Soares (2015)	Ebscohost	Portugal (2)	technical	Visual and software developement	A 3D integrated system can be used to test operations and find defects which parts that can be improved or eliminated

Intra-connected bridge and engine simulators and their use in training	SÖDERSTRÖM, & SJÖGREN (2017)	Google scholar	Sweden (2)	technical	Survey	Intra-connected simulators can be an effective tool for improving the teamwork onboard the vessels. It increases the understanding between the bridge and the engine room
Innovation in maritime education and training	Ziarati, Demirel, & Albayrak (2010)	Google Scholar	Turkey (3)	regulation	Analysis of maritime policy	The content of maritime training need to be improved. Automation should be included in the syllabus.
Innovative Fast Time Simulation Tools for Briefing/ Debriefing in Advanced Ship Handling Simulator Training and Ship Operation	Benedict, Fischer, Gluch, Kirchhoff, Schaub, Baldauf & Müller (2017)	Google Scholar	Germany (6); Sweden (1)	technical	Software development	The fast time manoeuvring simulation is beneficial to training, also efficiency and safety of real ship manoeuvring
Learning to navigate - the centrality of instructions and assessments for developing students' professional competencies in simulator-based training	Sellberg, Lindmark, & Rystedt (2018)	Springer	Sweden (3)	technical	Video-based research	Simulation-based training should not replace periods of on board training for new seafarers
Maritime Safety and Security Challenges – 3D Simulation Based Training	Felsenstein, Benedict, & Baldauf (2013)	Google Scholar	Sweden (1), Germany (2)	technical	Experiment	Explore maritime safety and security training in a 3D training simulator and show the complexity of simulator-based training
Maritime Simulator Training Across Europe: a comparative study	Nazir, Jungefeldt, & Sharma (2019)	Springer	Norway (3)	regulation	Interview and literature review	Due to the regulation limit, the implementations of similar proceedings can create dissimilarities within European institutions

Maritime research	Lützhöft, Brown, Dunham, & van Leeuwen (2017)	Researchgat e	Sweden (4)	research	Analysis of maritime policy	Simulation is not implemented properly in maritime research
Perceived learning outcome- the relationship between experience, realism, and situation awareness during simulator training	Saus, Johnsen, Saus, & Eid (2010)	Google Scholar	Norway	effectivene ss	Experiment	In order to enhance the learning outcomes from simulator training it is necessary to design training procedures and scenarios that enable students to achieve functional fidelity and to generate and maintain SA during training
Practical teaching skills for maritime instructors	Fisher, & Muirhead (2013)	Ebscohost	Sweden (2)	regulation	analysis of maritiem policy	Current practice of simulation training in the maritime sector
Quantifying the Physiological Stress Response to Simulated Maritime Pilotage Tasks	Main, Wolkow & Chambers (2017)	Google Scholar	Australia (3)	training technique	Experiment	Task difficulty and expertise have dependently impact on the stress response
Reducing of maritime accidents caused by human factors using simulators	Hanzu-Pazara, Barsan, Arsenie, Chiotoroiu, & Raicu (2008)	Google Scholar	Romania (5)	effectivene ss	Experienced base	Training in simulators shows promising results of reducing human error caused by improving the crisis management capability of maritime crews
Reducing Risks of Arctic Operations with Ice Simulation	Koponen (2015)	Google Scholar	Finland (1)	research	Experienced base	Simulation-based training is the most cost-effective way to improve specific skills needed in Polar waters. There is the lack of extensive studies about the need for a simulator and its influence to maritime navigator.
Role and importance of the simulator instructor	Ali (2006)	google scholar	sweden (1)	training technique	Survey	Highlights the importance of the instructor as well as the need for technologies to be augmented with new measures to ensure the quality of training

The application of high quality maritime simulator training to improve safety and economy in shipping operations	Cross (2009)	MARSIM	UK (1)	training effectivene ss	Analysis other studies	The increased application of well structured maritime simulator training seems to be one method of overcoming the contradiction between safety and cost: the overall costs decrease and the safety is improved
Sea service equivalency for full mission simulators training	Barsan (2013)	Google Scholar	Romania (1)	regulation	Analysis of maritime policy	Developed the Bsea service equivalency ratio concept to inform IMO and STCW on simulation-based training standards for training and certification
Simulation-Based Learning- Comparative Review between Maritime Simulation and Other Domains	Homlong, Pan, Vederhus, & Hildre (2016)	Google Scholar	Norway (4)	regulations , standards	Literature review	Simulation-based training can be a strong alternative for on the job training in both the aviation and maritime domains. However, there is a need for more refined research of skill transfer in these domain. It takes vital role in discovering hidden risk factors.
Simulation-based team training for maritime safety and security	Baldauf, Schröder-Hinrichs, Benedict, & Tuschling (2012)	Researchgat e	Sweden (2); Germany (2)	training effectivene ss	Experiment	Simulators show great potential in meeting the requirements of training of technical and non-technical skills formulated in STCW
simulator instructor -STCW requirements and reality	Ali (2006)	ebscohost	Sweden (1)	regulation	Analysis of maritime policy	There is a strong need to have a IMO Model Course for the simulator instructors
Simulators in bridge operations training and assessment- a	Sellberg (2017)	Springer	Sweden (1)	research	Literature review	address the pedagogical use and benefits of simulator-based training in the maritime sector. simulator-based

systematic review and qualitative synthesis						maritime training seems to be a rather small and quite diverse field of research, and several of the studies found lack empirical data as a basis for analysis. there is potential advantages of simulator-based training and assessment, but that they are currently being poorly implemented, which poses possible safety hazards for the shipping industry.
stcw and assessment of competence by simulator-ten year on - why no global acceptance of the practice	Muirhead (2003)	Ebscohost	Sweden (1)	regulation	Analysis other studies	There is a clear omission in STCW implementation processes for seafarer assessment. The performance measurements of competency and ongoing proficiency by the use of marine simulators have still not been seen as reliable and valid yet.
Simulator-Based training for maritime operations: A Comparative study	Nazir, & Jungefeldt (2017)	Springer	Norway (2)	training effectiveness	Interview	There is an existing variation between different institutions due to the regulation limit
Simulation-Based Training-Applying lessons learned in aviation to surface transportation modes	Blickensderfer, Liu, & Hernandez (2005)	Researchgate	United States (3)	training effectiveness	Analysis other studies	Lesson learned in simulation-based training of the aviation
Simulator training for the high technology ship crews	Aizinov, & Orekhov (2009)	Springer	Russia (2)	technical	Literature review	The following trends can be seen in the development of simulator systems for the ship crews: improvement of the mathematical models, improvement of ship

						environment interaction models and development of interaction between various simulators
Team training in safety and security via simulation - a practical dimension of maritime education and training	Baldauf, Dalaklis, & Kataria (2016)	google Scholar	Sweden (3)	traing effectiveness	Experiment	Navigation experience and comfort level of seafarers may cause risk of collision.
Temporal and Material Conditions for Instruction in Simulation-Based Maritime Training	Sellberg, & Rystedt (2015)	Researchgate	sweden	implementation, regulations	Video-based research	Systematic professional guidance and feedback is very important for simulation-based training
The Effects of Marine Simulators on Training	Shahin (2017)	Researchgate	Kuwait (1)	simulation exercise	Analysis and review other studies	Simulation is a valuable tool but need to be researched more carefully
The human factor and simulator training for offshore anchor handling operators	Håvold, Nistad, Skiri, & Ødegård (2015)	ebscohost	Norway (4)	training effectiveness	Questionnaire	"tailor-made" exercises is needed to support for both critical and routine operations
The Dutch perspective on the use of simulators and sea time reduction in Maritime Education and Training	Uitterhoeve, Heel, Werner, & Ende (2018)	MARSIM	The Netherlands (4)	regulation	Analysis of maritime policy	Organisational and educational aspects of training development should be focused in the future to use simulation properly
The use of integrated maritime simulation for education in real time	Perkovic, Harsch, Suban, Vidmar, Nemec, Muellenhoff, & Delgado (2013)	Researchgate	Slovenia (4), Euro Commission (2), Transas (1)	training theory, regulation, implementation	Case Study	There is a need to set up a preparedness and response system via simulation-based training to handle crisis in the future

The use of simulation techniques in the development of non-technical skills for marine officers	Elashkar (2016)	ebscohost	Egypt (1)	training effectivene ss	Analysis and review other studies	Simulation can offers non-technical skills training.
Training skills and assessing performance in simulator-based learning	Sellberg, Lindmark, & Rystedt (2017)	Researchgat e	Sweden (3)	regulation	video-based research	Timing of instructions is crucial; providing specific instructions to student, debriefing phase is decisive for further analysis and research
Training to become a master mariner in a simulator-based environment	Sellberg (2017)	Google Scholar	Sweden (1)	training technique	Empirical case and video-based research	Stressing the importance of both in-scenario instruction and post-simulation debriefing
Training-onboard and simulation based familiarisation and skill enhancement to improve the performance of seagoing crew	Albayrak, & Ziarati (2010)	Google Scholar	Turkey (2)	training technique	Analysis of maritime policy	Two problem of the automation are initiatives and expensive; simulation needed to be regulated better
Usability criteria for simulators applied in the maritime engineering education	Kluj (2003)	Google Scholar	Poland (1)	technical	Experienced base	Maritime engineering education need to set other criterion aside with fidelity
Use of Simulators in Assessment, Learning and Teaching of Mariners	Kobayashi (2005)	Springer	Sweden (1)	training effectivene ss	Survey	Simulators are well suited for training and assessing the competencies involved in safe navigation. The application of appropriate assessment methods makes it possible to measure the mariner's
Use of Simulators in e-Navigation Training and Demonstration Report	Schmidt (2015)	Google scholar	Germany (1)	practice of simulation	Experienced base	Describe the use of maritime simulators within the ACCSEAS project after the 2010 amendment.

Utilization of Simulation for Training Enhancement	Sulaiman, Saharuddin, & Kader (2011)	Google Scholar	Malaysia (3)	research	Experienced base	Simulation bring considerable benefits to competency based education. However, it has reached to its litmit that only overcome by extending current research methods and taking further progress on simulation based education development

Table 13. Detailed results of the content analysis for simulation-based training studies in the aviation domain

	Author	Source	Country	Method	Keyword	Main results
A comparison study of simulation of simulation versus multimedia presentation instruction on flight students' decision-making skills	Weber (2016)	Ebscohost	United States (1)	Survey	training effectiveness	Simulation can enhance decision making skill during a practical application of training
A novel classification method for driving simulators based on existing flight simulator classification standards	Eryilmaz, Tokmak, Cagiltay, Isler, & Eryilmaz (2014)	Researchgate	Turkey (5)	experiment	technical	Classification approach should reconcile the specific need for simulators
A Quantitative Study Evaluating the Impact of Training Context on Performance in Simulator-Based Aviation Training	Walker (2014)	researchgate	United States (1)	experiment	training effectiveness	Aviation trainers should consider the use of higher fidelity simulator in training, for instance: motion
Aviation simulation training in the czech air force	Boril, Leuchter, Smrz, & Blasch (2015)	Google Scholar	Czech Republic (3), United State (1)	experience based	regulation	Regulation of simulation implementation in the Czech air force

Brief History of Flight Simulation	Page (2000)	Google Scholar	Australia (1)	literature-based	Technical	The standards of flight simulator is set until now. The use of flight simulator is at very high level in the aviation sector
Crew resource management (CRM) - what aviation can learn from the application of CRM in other domains	Jimenez, Kasper, Rivera, Talone, & Jentsch (2015(	Researchgate	United States (3)	Review	training effectiveness	CRM implementations in the maritime domain are successful with the standardization of training. Simulation-based training methods, assessment methods, trainee's certification
Educational simulation in practice -a teaching experience using a flight simulator	Ruiz, Aguado, & Moreno (2014)	google Scholar	Spain (3)	experiment	training effectiveness	Trainees may learn and assimilate the pursued concepts of fight commanding and navigaton with a very high success rate
Effects of Simulator Training - Motivating factors	Nählinder, Oskarsson, Lindahl, Hedström, & Berggren (2009)	google Scholar	Sweden (5)	analysis of other studies	training effectiveness	Motivation and fun are important factors in training
Employing Flight Simulation in the Classroom to Improve the Understanding of the Fundamentals of Instruction among Flight Instructor Applicants	Byrnes (2017)	Google Scholar	United States (1)	experiment	technical	The enlargement of the current enclosure by removing the wall panel of the laboratory should be considered.
Facilitation and Debriefing in Aviation training and operations	Dismukes, & Smith (2017)	Google Scholar	United States (2)	experience based	Technical	The importance of facilitation and debriefing was proved.
Flight Simulation: Research Challenges and Flight Crew Assessments of Fidelity	Robinson, & Mania (2004)	google Scholar	UK (2)	Analysis of other studies	research	Perceptual fidelity is not necessarily as the same as physical simulation

Flight simulator fidelity considerations for total airline pilot training and evaluation	Burki-Cohen, Go, & Longridge (2001)	google Scholar	United States (3)	Analysis of other studies	Technical	In the future scenario, two research areas with high pay-off potential are realistic radio communications and platform motion.
Flight simulator as an essential device supporting the process of shaping pilot's situational awareness	Kozuba, & Bondaruk (2014)	google Scholar	Poland (2)	Literature review	training effectiveness	The use of flight simulators for forming and consolidating the pilot capabilities necessary, among others, for the efficient execution of the situational awareness process should be considered as justified.
Flight simulator development with safety system implementation	Utrilla (2017)	google Scholar	Finland (1)	Analysis of other studies; experience-based	regulation	The importance of ergonomics consideration in simulation model
Flight Simulator Training: Assessing the Potential	Magnusson Nählinder (2009)	google Scholar	Sweden (1)	Analysis of other studies	training effectiveness	Modern flight simulators lack the possibility of providing pedagogical feedback; Higher mental workload does not necessarily lead to higher training effectiveness
Flight simulation devices in pilot air training	Nowakowski, & Makarewicz, (2018)	google Scholar	Poland (2)	Analysis of aviation regulations	Technical	Using simulation training in aviation is legitimate. Simulation has several benefits that increase safety, however, main obstacle lies on the high cost
Flight Simulator Fidelity, Training Transfer, and the Role of Instructors in Optimizing Learning	Myers III, Starr, & Mullins(2018)	google Scholar	United States (3)	Analysis of other studies; Case study	Technical	Instructional design practices will ensure simulator instructors are provided with the most current and appropriate teaching tools

Flight Simulator Motion Literature Pertinent to Airline-Pilot Recurrent Training and Evaluation	Burki-Cohen, Sparko, & Bellman (2011)	google scholar	United States (3)	Analysis of other studies	Technical	Motion of simulation
Helicopter Flight Training Through Serious Aviation Gaming	Proctor, Bauer, & Lucario (2007)	researchgate	United States (3)	experiment	training effectiveness	Simulation takes a vital part in helicopter flight training nowadays
Pilot training in our time - use of flight training devices and simulators	Dahlström (2008)	ebscohost	Sweden (1)	Survey	technical	initio flight training can be accomplished successfully with early and extensive involvement of flight instructors in planning, preparation and mitigation of the impact this will have on the training.
Positive effects of combined aircraft and simulator training on the acquisition of visual flight skills	Koglbauer, Riesel, & Braunsting(2016)	researchgate	Austria (3)	experiment	training effectiveness	The trainees improved their performance despite training with different simulators.
Real-time Flight Model for Embedded Simulator	Frantis, & Cuzzolin (2014)	researchgate	Czech Republic (1), France (1)	Software developme nt	Technical	The model used to describe aerodynamic forces and moments
Selected information on flight simulators - main requirements, categories and their development, production and using for flight crew training in the both Slovak Republic and Czech Republic conditions	Koblen, & Kovácová (2012)	Researchgate	Slovakia (2)	Analysis of aviation regulations	regulation	The using of simulation technologies for the flight training have the high importance from the training, air safety, financial and other aspects.

Simulation Training in U.K. General Aviation- An Undervalued Aid to Reducing Loss of Control Accidents	Taylor, Dixon-Hardy, & Wright (2014)	google Scholar	UK (3)	Analysis of accident data	training effectiveness	Landing has been shown to be a particular problem; Restrictive regulations reduce investment in simualtion
Simulator training improves pilots' procedural memory and generalization of behavior in critical flight situations	Koglbauer (2016)	researchgate	Austria (1)	Analysis of aviation regulations , literature review	training effectiveness	LOC - experiment
Simulator Training Improves the Estimation of Collision Parameters and the Performance of Student Pilots	Koglbauer (2015)	google Scholar	Austria (1)	experiment	training effectiveness	Feedback-based training in the flight simulator significantly improved the accuracy of time to collision estimations of student pilots.
Simulation-Based Learning-Comparative Review between Maritime Simulation and Other Domains	Homlong, Pan, Vederhus, & Hildre (2016)	Google Scholar	Norway (4)	Literature review	regulation	Simulation-based training can be a strong alternative for on the job training in both the aviation and maritime domains. However, there is a need for more refined research of skill transfer in these domain. It takes vital role in discovering hidden risk factors.
The complexity of team training-what we have learned from aviation and its applications to medicine	Hamman (2004)	google Scholar	United States (1)	Literature based	Technical	Team training is a wonderful effective tool to improve operational performance in aviation
The Education of Attention as Explanation of Variability of Practice Effects- Learning the Final Approach Phase in a Flight Simulator	Huet, Jacobs, Camachon, Missenard, Gray, & Montagne (2011)	researchgate	France (4), Spain (1), UK (1)	Experiment	Technical	Variability of practice is beneficial for the learning of the final approach phase

The possibility of increasing air transport security via simulation training	Volner (2017)	google Scholar	Czech Republic (1)	experience based	training effectiveness	Safety Management System concept and Simulator Trainings are helping pilots with improving safety and stress mitigation
The effect of simulator motion on pilot training and evaluation	Go, Bürki-Cohen, & Soja (2000)	google Scholar	United States (3)	experiment	Technical	The motion does not affect training performance
Training Effectiveness of Whole Body Flight Simulator Motion- A Comprehensive Meta-Analysis	De Winter, Dodou, & Mulder (2012)	ebscohost	The Netherlands (3)	analysis of other studies	technical	Whole body motion in simulation-based training may not be important to experts, but for novices in specific disturbance tasks, it is really important.
Training Pilots for Unexpected Events - A Simulator Study on the advantage of unpredictable and variable scenarios	Landman, van Oorschot, van Paassen, Groen, Bronkhorst, & Mulder (2018)	google Scholar	The Netherlands (6)	experiment	training effectiveness	The impact of unexpected event pilot training was proved. It can be an effective way to improve skills, which can prepare trainees for unexpected and novel conditions.
Technological trends in simulation technology in aviation & pilot training	Janícek, & Pistek (2004)	google Scholar	Czech (2)	experience based	Technical	The problems of integration of the simulation technology systems into complex training systems for development of multi-level skills mainly in pilot training
The Impact of Training Context on Performance in Simulator-Based Aviation Training	Walker (2015)	google Scholar	United States (1)	analysis of other studies	training effectiveness	It is useful to emphasis on learning context, as an aid for designing aviation training in a logical cognitive-based manner.
Training of Pilots Using Flight Simulator and its Impact on Piloting Precision	Socha, Socha, Szabo, Hanak, Gazda	Google Scholar	Czech Republic (6),	experiment	training effectiveness	Flight simulators already have proven, and will continue to prove themselves irreplaceable in pilot trainings. Their

	Kimlickova & Puskas (2016)		Slovakia (7)			potential is mainly in providing correct flying habits, eliminating errors, teaching flight procedures, offering crisis management etc.
The Role of Aircraft Simulation in Improving Flight Safety Through Control Training (NASA)	Shy, Hageman, & Le (2002)	google scholar	United States (3)	experiment	training effectiveness	By taking advantage of existing technologies and resources, the training configurations require less cost and time to develop, while greatly expanding the capabilities.
Technological research challenges of flight simulation and flight instructor assessments of perceived fidelity	Robinson, & Mania (2007)	google Scholar	none	experiment	Technical	It is vital that simulation keeps up to date with advancements in flight technology
The Multi Crew Pilot Licence - Revolution, Evolution or not even a Solution	Wikander, & Dahlström (2014)	google scholar	Sweden (2)	literature, interviews	Regulation	Several challenges with the MPL which will need to be addressed.
Virtual reality flight simulator	Valentino, Christian, & Joelianto (2017)	researchgate	Indonesia (3)	Software developme nt	Technical	The flexibility that makes virtual reality an effective tool should have been considered in future development of infrastructures.