University of South-Eastern Norway

# **Ship Domain in Open waters-** the size and shape of the navigator's declarative ship domain.

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## Abstract

This master thesis presents the outcome of the declarative ship domain from Norwegian seafarers, in open waters. A ship domain is a psychological phenomenon when on board a ship the navigator will have a distinct feeling of when targeted vessels come to close in the surrounding area of the ship. Expert's knowledge and expertise found the basis for the resulting domains. The purpose of this quantitative, quasi-experimental, questionnaire-based study was to examine Norwegian seafarer`s perception of the shape of ship domain in open waters, hence examine whether there were any similarities to findings in existing literature. The collected data were analysed in IBM SPSS 24. The results presented support the theory and illustrated how the ship domain from Norwegian navigators increases in size as the ship size increases. Additionally how the domain shape appears to be larger forward than aft of own ship and that port and starboard side seems equal in size and shape. The research conducted within this study can be seen as a contribution to the maritime field of ship domain. This study recommends future research within the field of ship domain both using same and expanded data collection procedures.

*Keywords*: declarative ship domain, ship domain in open waters, Norwegian seafarers, maritime field.

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## Foreword

A research team formed by Professor Kjell Ivar Øvergård, consisting of the master students Johan Øen Strand and Mari Starup for the study of ship domain in open- and restricted waters. The research team cooperated firmly in the first months of the study, during data collection and when receiving supervision on the development of the questionnaire, the method part as well as most of the statistical analysis performed. Associated Professor Jarle Løwe Sørensen and Professor Kjell Ivar Øvergård supervised us individually and as a research team.

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# CHAPTER 1. INTRODUCTION

*"A ship domain is not a fixed boundary around the central vessel but is a water area adopted by the Officer of the Watch based on the varied circumstances."*

- Zhao et al., 1993, p. 425

## 1.1 Background

With the shipping industry, growing ever larger, global trade is making the world smaller in the sense that goods and commodities are freighted seaborne through established trade routes. The world`s shipping lanes are more congested than ever and- with the high density of ships the risk of an accident increases. Even with state- of- the- art instruments on the bridge. The need for humans still exists for supervising and reacting to operations. With the human factor involved, accidents can and will occur.

When Titanic sunk in 1912, it led to the implementation of Safety of Life At Sea (SOLAS). The loss of M/S Herald of Free Enterprise led to the enactment of the international safety and management code (ISM). Oil tankers were built with a double hull to prevent leakage of cargo in accidents after the  Exxon Valdez disaster (Andersen, 2017). Tragedies like these and several more incidents are the cause of many rules and regulations at sea, which originally is the background for the United Nations (UN) founding the International Maritime Organization (IMO) in 1948. For Imo to be able to do promote safety they adopted several acts, one of their first was Safety of Life At Sea (SOLAS) in the 1960s. Then in 1972 IMO adopted The Convention on the International Regulations for Preventing Collisions at Sea (COLREGS). The COLREGS is still in use by all seafarers worldwide today.

COLREGS compromises Part A- general rules, Part B- steering and sailing rules (in the vicinity of each other and restricted visibility), part C- lights and shapes, part D- sound and light signals and, part E- exemptions. The rules advise seafarers how to proceed when at sea and/ when encountering other seagoing crafts. Simply explained, when you meet another vessel head on, you will pass it, so you have the other vessels on your port side. Nevertheless, you have to give way to any ship that is heading towards you from the starboard side. Thus situations are often more complicated than this (COLREG 1972; Davis, Dove and Stockel, 1980, p 215).

With complex situations, COLREGS leaves a lot of room for seafarers to interpret. For instance, the COLREGS does not mention anything about how close is too close to pass or overtake another ship or obstacle (IMO, 2018). Thus, the ISM will include limits on how close to pass other vessels meeting vessel in open or closed waters; the restrictions are set as a general-, more than a specific distance. The passing limits written in the ISM are company rules on safe distances to other vessels or objects. Further, a navigator would also have the Master`s standing orders to accompany the ISM. The standing orders are orders on navigation and can include passing limits to targeted ships or objects. The navigator has to sign the Master standing orders, which are in force at all times. The Signing makes the navigator held responsible if the orders are not followed. The Master`s standing orders are guidelines to ensure safe navigation at all times. To accompany the Master`s standing orders, the master has the Masters Night order book. The Night orders is a handwritten supplement to the Standing Orders that can include instructions that are more detailed for current night’s sailing.

The ISM or Master’s standing orders will still not take into account the human factor of the navigator. Any responsible navigator will have a feeling of the “ship`s personal space” or ship domain, as the feeling of one`s personal space. This feeling is the same as the feeling you have for your personal space, just prolonged to also include the ship (Zhao, Wu & Wang, 1993). In 1971, Fuji and Tanaka as a first introduced the term ship domain to ensure safer navigation when traffic capacity was high in a waterway. The term has been further research by several other researchers over the years.

### 1.2 Problem statement

Ship domain is perceived to improve navigational safety and prevent accidents (Fuji & Tanaka, 1971; Goodwin, 1975; Zhao et al., 1993; Szlapczynski & Szlapczynzka, 2017). The individual ship`s domain should ideally help to improve navigational safety, to prevent ship accidents from occurring. As human error statistically is a substantial reason for ship collisions, the focus on ship domain and its boundaries may be an additional help to prevail accidents from occurring (Pieterzykowski & Uriaz, 2009). However, the problem is that the term ship domain is a foreign word among practitioners, thus widely used within research (Rawson, Rogers, Foster & Phillips, 2014; Wang & Chin, 2016**).**

Sources to date are conflicting as to why the concept of ship domain is not widely used amongst practitioners. But reasons cited range from the difference in navigational situations resulting from regulations and those from navigator`s knowledge and experience (Peterzygowski & Uriaz, 2009, p. 93). The gap between theory and practice has rarely been filled, nor have theory been adopted by the average navigator (Andrew et al., 2014; Wang & Chin, 2016). Further, there is no standardisation of the term ship domain, which makes it harder for seafarers to apply it (Goodwin, 1975; Peterzygowski & Uriaz, 2009). There are multiple models of ship domain, and some different parameters affecting the size of the domain surrounding the ship. Like open- or restricted waters wherein open waters, the vessel would have a larger domain than in restricted waters (Zhao et al., 1993; Pieterzcykowski & Uriaz, 2009; Wang & Chin, 2016; Szlapczynski & Szlapczynzka, 2017). Other parameters as high traffic density make the size of the domain decrease (Goodwin, 1975; Zhao et al., 1993, p. 428). Good visibility will increase the domain, and reduced visibility will decrease the domain. (Goodwin, 1975). The speed of own ship or target ship will also influence the domain size. And a high speed will make the ship domain more extensive, and low speed will decrease your ship domain (Zhao et al., 1993, p. 427). The need exists for a clearly stated ship domain (Goodwin, 1975; Pietrzykowski& Uriaz, 2009; Wang & Chin, 2016; Szlapczynski & Szlapczynzka, 2017).

There is a necessity for further research within the concept of ship domain though minor research work is executed on the practical use of this. "*The cases where ship domains are used, not just mentioned, are relatively rare*" (Szlapczynski & Szlapczynzka, 2017). In particular, there is a need to examine the appliance of ship domains in open waters, as increased knowledge may lead to increased safety and a better estimation of navigational risk (Pietrzykowski& Uriaz, 2009).

### 1.3 Purpose of the study

The purpose of this quantitative, quasi-experimental, questionnaire-based study was to examine Norwegian seafarer`s perception of the shape of ship domain in open waters, hence examine whether there were any similarities to findings in existing literature. This master- thesis study collected data through an online questionnaire-instrument, Questback essentials. Some parameters from earlier research papers were replicated and were used in the questions. Such as ship sizes, dividing into open or restricted waters, and the size of the targeted ship used by Pietrzykowski and Uriaz, (2009) and Zhao, Wu and Wang (1993). The minimum distances for eight relative bearings (000º, 045º, 090º, 135º, 180º, 225º, 270º, 315º) were used, in the same way as Wielgosz (2016). "*To take into account for head-on, overtaking and crossing situations*" (Szlapczynski & Szlapczynzka, 2017, p 285). The scope was limited to Norwegian Seafarers. The respondent`s certificate had to be at least STCW Class D4 with minimum one-year experience.

This study will contribute to the field of ship domain by theoretically furnishing research in the ship domain field, from Norway. Additional to contribution will be to provide increased understanding among the practitioners within the ship domain field.

### 1.4 Research questions and hypothesis

The objective of this study is to find the navigator's ship domain at the given ships, the minimum comfort boundaries around the vessel. The master thesis study is a replica of earlier studies thus now tested on Norwegian seafarers. To accomplish this, the following research questions and hypothesis developed for this study are:

**RQ 1:** Do ship size affect the size of the ship domain in open waters? Based upon literature the domain size in this study will correspond to findings of increasing size of the ship domain as of Goodwin (1975). One specific hypothesis was developed to test this research question.

**H1:** The domain size increases when the ship size increases

**RQ 2:** What is the Norwegian navigator's opinion of the shape of effective ship domain in open waters? Based upon literature this study will correspond in shape to the ship domain for vessels within open waters, found by Goodwin (1975) (see figure 1 below). Two specific hypothesis was developed to test this research question.

**H2:** Following Goodwin, we expect the ship domain to be larger forward (relative angle 000º) than aft (relative angle 135º, 180º, 225º) of own ship.

**H3:** Following Goodwin, the ship domain will have a similar size on the starboard side (relative angles 045º, 090º) as to the port side (relative angle 270º, 315º) of own ship

### 1.5 Nature of the study

This master-thesis describes a quantitative, quasi-experimental, questionnaire-based research to find out what is the Norwegian seafarer's perceived opinion of the ship domain shape in open waters.

For this quasi-experimental study, a questionnaire design was applied to map the opinion of the population sample. The questionnaire was electronically distributed to a specific sample of seafarers.

### 1.6 Significance of the study

The ship domain can facilitate the assessment of safe navigation of ships in open waters. COLREGS states that all means available should be used to avoid a collision as described in rule number seven (Lovdata, 1975). The ship domain will be another aid to help the navigator make the right assessment.

The findings from this study will contribute to the research within the maritime sector and field of ship domain. Since there is hardly any research done in Norway within the field of ship domain, this study is an essential contribution to filling a gap in the literature available. The practical contribution of the research is to increase the understanding amongst practitioners and create a shared understanding and consensus on ship domain that will lead to an increased level of safety. The human element causes behind ship accidents *"…can be eliminated or at least reduced by the implementation of ship domains; this would enhance the safety of navigation*" (Pieterzykowski & Uriaz, 2009, p. 107).

### 1.7 Defining key terms

**Ship domain,** Ship domain is defined as:*"Surrounding effective waters which the navigator of a ship wants to keep clear of other ships or fixed objects"* (Goodwin, 1975, p.329).

**Open waters:** A common term in navigational science. There is no proximity to physical restrictions. A concept used to describe waters, which holds no particular hindrance for the vessel in question.

**Restricted waters:** A common term in navigational science. There is proximity to physical obstacles. A concept used to describe waters, which holds particular hindrance for the vessel in question.

**Proxemics:** The study of how people take up space in their surrounding areas (Zhao et al., 1993)

**Territorial waters:** This comprises the sea area extending up to 12 nm from the baseline at any point around the coastline of a country (United Nations Oceans and the law of the sea, 2017)

# CHAPTER 2. LITTERATUR REVIEW

*"Any violation of the ship domain is interpreted as a threat to navigational safety."*

- Pieterzykowski & Uriaz, 2009, p. 94

The purpose of this master thesis is to examine Norwegian seafarer's opinion of the ship domain shape, in open waters. Although ship domain is a widely used term within the research field, it is not in general use onboard sailing ships. The domain can be used as a helping aid for collision avoidance. A thorough search in HSN library search engine; Oria, Science Direct and Google Scholar with the search words, *Ship domain, ship domain in open waters/ restricted waters* and *effective ship domain* was done. The search was to see what sort of information there was to discover within the field of ship domain. Sourcing of all Norwegian maritime research conducted in the field of ship domain revealed a lack of any pertinent literature available.

## 2.1 The literature review

This literature review will describe the theoretical framework appropriate for the study conducted. Moreover, to fully understand the discussion of the academic literature, this analysis will provide the necessary background information concerning specific issues related to the theory of proxemics, as a theoretical framework. Although, the principal focus is the ship domain theory.

This literature review will systematically give the necessary background information to help to answer the research questions. From good, peer-reviewed articles, a theoretical framework (subchapter 2.2) to the ship domain makes the foundation for the research. Followed by a subchapter (2.3) to give insight into the background and history of the ship domain and a subchapter (2.4) on the three methods for developing a ship domain. Furthermore, a subchapter (2.5) who describes the different shapes found on the ship domain. Followed by a subchapter (2.6) on how ship domain is used for collision avoidance.

## 2.2. Theoretical framework

Anthropologist E.T Hall established a new form of social psychology in the 1950`s, called Proxemics (Hall, 1960). Hall defines Proxemics “as the study of man’s perception and use of space” (Hall, 1968, p. 83). Proxemics is the understanding of the personal space. How people make use of their surroundings in different social settings? In some cultures, there is a more narrow personal space, even to strangers. In other cultures, some distance is required to feel comfortable in the situation (Zhao et al., 1993; Hall 1968). Furthermore, when strange things, objects or people approach a person, the personal space will increase. A person cares more about what happens in front so that the personal space will be larger forward than behind of the person.  Thus within a large crowd, the personal space will decrease. Should a person be riding a bike or driving a car, the personal space will extend to include the object (Zhao et al., 1993; Hall, 1968).

The personal space is the person’s domain. The ship domain can be called the “*ship person*” (Zhao et al. 1993, p. 427).  When this happens, the ship-person will inhabit the same qualities as the person feels regarding the personal space. Hence, the ship person will need more space in front than in the back of it. The navigator will extend his personal space to include the ship. Simplified the ship will function as the navigator's body where the navigator is the brain. The ship person will have an increased need for space when objects approach with high speed as it will need smaller space with a high density of objects in the nearby surroundings (Zhao et al., 1993).

### 2.3 History and background of the ship domain

Fuji and Tanaka who researched the Japanese sea (Zhao et al., 1993, p 422) introduced ship domain as a term in 1971. Fuji and Tanaka (1971) defined their domain as a two-dimensional area surrounding a ship which other ships must avoid (Szlapczynski & Szlapczynska, 2017). A few years later Goodwin "*wanted to establish the water area required by anyone ship for safe navigation*" (Goodwin, 1975, p., 328). The domain from Fuji and Goodwin are concentrated on an area surrounding the ship where no other ship should enter. Davis (1980) used a similar approach (Dinh & Im, 2016, p. 99). Another author, who was much cited was Coldwell (1980). He redefined Fuji's (1971) ship domain as "*the effective area around a vessel which a typical navigator actually keeps free with respect to another vessel*" (Coldwell, 1980, p.432). There are numerous different ship domains which vary in shape by how they have been developed (Szlapczynski & Szlapczynzka, 2017, p. 277)

One way to establish a ship domain is by empirical sampling as done by Hansen et al. (2013). Ship domains determined by empirically data sets are often not to complex, as it is difficult to separate the different parameters within the dataset. Nevertheless, empirically based ship domains are based on the trajectories extracted from ships that have already sailed. (Szlapczynski & Szlapczynzka, 2017).). Also, many different shapes and sizes of ship`s domain are proposed within the literature (Wang & Chin, 2016; Szlapczynski & Szlapczynzka, 2017).

### 2.4 The three methods of developing a ship domain

To determine a ship domain, there are three groups of methods to choose. (Pieterzygowski and Uriaz, 2009, p.93; Pieterzykowski, Wielgosh and Siemianowicz, 2012; Dinh and Im, 2016, p. 99). "*They all tend to utilise the navigator's knowledge, both* *procedural and declarative*" (Pieterzygowski, 2008, p. 501).  The three methods have been constructed according to shape and size. When determining the domain, one should choose one method for developing it (Pieterzykowski and Uriaz 2009, p. 94).

**The Statistical method,** the original method used in the first ship domains created (Pieterzygowski 2008, p. 501; Pieterzygowski & Uriaz, 2009, p. 96). This method uses statistical data like trajectory data extracted from the ship's position. The statistical data is analysed to locate the area surrounding a ship, where other ships do not enter (Dinh & Im, 2016). The statistical method "is presented in a geometrical manner that would be more descriptive than declarative" (Wang, Meng, Xu & Wang, 2009, p. 653). The method relies heavily on the navigator's experience and knowledge. (Dinh & Im, 2016). Davis (1980), Coldwell (1983) along with Dinh and Im (2016) are amongst the researchers who used the statistical method.

**The analytical method** uses mathematics with advanced equations to reach a more precise and accurate ship domain, (Pieterzygowski & Uriaz, 2009).  "*It uses various variables in describing the calculation of the factor to create domain boundary*" (Dinh & Im, 2016, p. 99). The domain described by the mathematical formula present the shape of elliptical and rectangular domains. Moreover, it works as a function with geometrical dimensions (Pieterzygowski & Uriaz, 2009, p. 97). The geometrical shape makes the analytical domains simple to understand although not so easy to apply in real life (Wang et al., 2009, p. 643 "*These methods enable the consideration of selected factors affecting navigational safety*" (Pieterzygowski, 2008, p. 501).). Wawruch (1998), Smierzchaslki and Weintrit (1999) and Wang et al. (2009) used the analytical method (Pieterzygowski & Uriaz, 2009; Dinh & Im, 2016).

**The expert method or Artificial intelligence method (AI)**.), uses a set of gathered data. It enables the use of the navigator's knowledge with more benefits than in others methods when it comes to the utilisation of the experience while establishing the domain (Dinh & Im, 2016, p.99). "*This includes the declarative- descriptive knowledge that results from professional competence and experienced knowledge*" (Pieterzygowski, 2008, p. 501; Pieterzygowski & Uriaz, 2009, p. 97). To get the most out of the navigator's knowledge, most researchers use artificial neural networks, fuzzy logic or evolutionary algorithms, as tools to conclude the actual domain (Pieterzykowski, 2008)**.** Within AI the Fuzzy logic is used by researchers like Zhao (1993), Pietrzykowski (1999; 2008) and Pieterzygowski and Uriaz (2009).

### 2.5 The domain shape

The design of the ship domain has been separated into two- or three-dimensional shapes (Pietrzykowski and Uriaz, 2009). These shapes comprise a circle an ellipse and a polygon. The circular shape surrounds the ship, used by, amongst others, Goodwin (1975), Davis (1980) and Zhao (1993), (Wang et al., 2009, p 644). Fuji (1971), as well as Coldwell (1983), described the elliptical shape, surrounding the ship like an ellipse. The Polygonal shape, surrounding the ship as a shape with many corners (polygon) "*this domain is mostly functions of ship dimensions and ship`s speed about other navigational objects*" (Wang et al., 2009, p 645). Smierzchalski (2001, 2003) and Pietzykowski (2004, 2006, 2008) introduced the polygonal shape, (Dinh & Im 2018, p 99; Wang & Chin, 2016, p.268).

The three-dimensional shapes are similar to the two-dimensional formes but they also additionally take draught and air draught in the account. Those shapes have the form of a sphere, cuboid or ellipsoid (Pietrzykowski and Uriaz, 2009, p. 94). The two-dimensional domains can be turned into a three-dimensional presentation if merely draught is taken into account (Szlapczynski & Szlapczynzka, 2017). The domains are also developed from different types of sea areas. Wang and Chin have divided these into three categories; "*Open sea, restricted waters and narrow fairways and channels*" (2016, p. 268). Other factors determining the shape of the domain are:"*The domain`s radius is dependent of own ship`s: length (small, medium, large), own speed (slow, middle, fast) and sea state (gentle, medium, rough)*" (Szlapczynski & Szlapczynzka, 2017).

### *2.5.1 The domain shape findings*

Goodwin (1975) found a domain for open waters were the domain shape was equal in size in port and starboard side of the vessel. Furthermore, that the ship domain in open waters would be a more extensive area surrounding the ship than in restricted waters due to increased manoeuvrability (Goodwin, 1975, p. 338). Moreover, Goodwin (1975), Fuji (1971) together with Zhao (1993) argued that the domain shape would increase as the ship size increased.

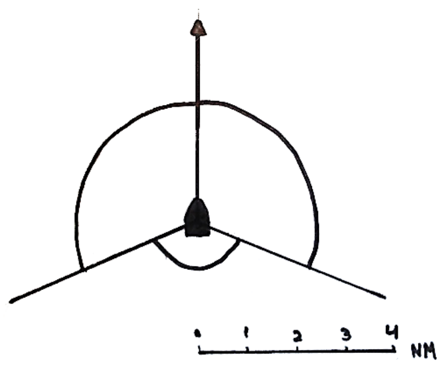


*Figure 1.* The Ship domain presented by Goodwin (1975) for open waters. Port side (247.5º-000º, Starboard side (000º-112.5º), Aft part (112.5º-247.5º).

Pietrzykowski and Uriaz (2009) found a domain with shapes based on in statistical mean that were larger in front of all ships ( lengths 100m, 200m, 300m), than behind them (2009, p.105).

Wielgosz (2016) detected a declarative ship domain for the ship sizes small, medium large to all have a larger shape in front and towards starboard side. In addition to a line more close to the ship to port and aft side (Wielgosz, 2016, p. 221)

## 2.6 The ship domain as an arena or several areas

The domain definitions used most frequently is the one by Fuji ( 1971) Goodwin ( 1975) and Coldwell (1983). Pietrzykowski (2008) claims that the quoted authors all explain an effective domain. The domain concept is perceived as ”*the concept of the domain is understood as an effective are around a ship that the navigator maintains clear of all objects*” (Pieterzykowski, 2008, p. 500). Some of the researchers take the perceived domain further. In 1980 Davis, Dove and Stockel defined the “super domain” or “the Arena”. Which is an area larger than the common domains found in the literature. The definition of the Arena is “*the distance from another ship at which a mariner would start to take action to avoid enclosed quarters situation*" (Davis et al., 1980, p. 217). Also, Dinh and Im (2016) divided different type of domain (into blocking and action area. The Blocking Area is the water area surrounding a ship where no other vessel should enter. The action area is an area further away from where the vessel must take action to resolve any situation of danger (Dinh & Im, 2016, p. 100).

### 2.7 The ship domain as a navigational aid

Wielgosz states that the ship domain as a navigational aid is most important in restricted waters or waters where traffic density is high. Further, he says that three possible ways of using the ship domain in the latest devices. Which would be current analysis and assessment of the situation, plan the collision avoidance manoeuvres or within navigational decision support system (2016, p. 217).

The Davis (1980), Pieterzykowski (2008) and Zhu (2001) models tend to be used as risk assessment, while the other is more suitable for collision avoidance. "*The Fuji and Coldwell models seems too risky for navigators to take action for collision avoidance*" (Wang et al. 2009, p. 652). Until now, the ship domains that have been used for collision avoidance "*are either older models or largely simplified versions of the contemporary ones*" (Szlapczynski & Szlapczynzka, 2017,p 286).

# CHAPTER 3. RESEARCH METHOD

"*A scientific methodology is a system of explicit rules and procedures. It provides the foundations for conducting research and evaluating claims of knowledge…* The methodology chapter …*creates a framework for replication and constructive criticism. Replication is the repetition of an investigation, in the same way, it was performed earlier. Constructive criticism is questions that embody criteria for evaluating claims for scientific knowledge*."

- Frankfort-Nachmias & Nachmias, 2008, p. 12-13

## 3.1 Research strategy and design

### 3.1.1 Research strategy

The selected method is quantitative for this study due to the numeric data. The quantitative researcher will deal with a larger sample of the population instead of a few persons. The researcher gathers data by "*sending out an instrument for the individuals to complete*" (Creswell, 2014, p. 185). The research will find its empirical answers by using for instance statistics (Frankfort-Nachmias & Nachmias, 2008).

This study collects data by questionnaire. Some advantages of using questionnaire are; the cost is low, the bias error you can get when performing interviews (qualitative research) is minimal. The anonymity is substantial, and the accessibility of reaching a more extensive sample of the population (Frankfort-Nachmias & Nachmias, 2008; Creswell, 2014). On the contrary, some disadvantages can be that there is no opportunity for probing. There is little to no control over who answers the questionnaire. One hopes that the respondent who owns the email address will respond. Moreover, the most considerable disadvantage is the low response rate, which by introducing a reward to the respondents might be reduced (Frankfort-Nachmias & Nachmias,2008, p207).

### 3.1.2 Research design

The research design is the path that will guide the researcher through the various stages of the research, moreover, the framework that helps the researcher come up with solutions to the research question and hypothesis (Frankfort-Nachmias & Nachmias,2008, p. 89).

The experimental design *"… allows for comparison, control, manipulation and generalisation*" (Frankfort-Nachmias & Nachmias, 2008,p. 103). A design that shares many similarities with the experimental design is the quasi-experimental design. The difference between the experimental approach proper and the quasi-experimental approach is lack of randomisation in the latter. Which makes the quasi-experimental weaker on internal validity; although it has a method of control, the quasi-experimental design relies on know-how analysis handling of data (Frankfort-Nachmias & Nachmias, 2008; Creswell, 2014. "*In quasi-experiments, the cause is manipulable and occurs before the effect is measured*" (Shadish, Cook & Campbell, 2002, p. 14).

As this study aims to analyse data from a questionnaire sent to individual members of a sample. The questionnaire had two independent variables, which were manipulated in the same way, as they would be in a proper experiment. The two independent variables are ship size and the relative angle (relative bearing) from where the targeted ship approached. The data collection happened over a period of 1.5 months. The quasi-experimental questionnaire based design was applied, and a within-subject analysis in addition to a non-parametric analysis was performed.

### 3.1.3 The research team

This quasi-experimental study aimed to answer the research questions and hypothesis. To do the data collection for ship domain in open and restricted waters, a research team was established, consisting of two master students: Johan Øen Strand and Mari Starup. It was agreed upon that Johan would deal with the restricted waters and myself with open waters. The research team did all data collection and the statistical analysis together. In addition, to receiving supervision as a team and alone by the same supervisors, Associated Professor Jarle Løwe Sørensen and Professor Kjell Ivar Øvergård.

## 3.2 Population

In the data collection for this study, the population was all seafarers holding, as a minimum, an International Standers of Training, Certification and Watchkeeping (STCW) certificate, class 4. Due to time and resources, reaching everyone filling the criteria was impossible. Therefore to make a selection the chosen respondents came from existing network. In addition to former students who had graduated in nautical science from the university college of Southeast Norway (USN), from the year 2010 until 2014.

## 3.3 Sample

A total of 53 respondents, 46 men and 7 women (13.2% female respondents), ranging from 23 to 68 years in age ($mean_{age}$= 36.2, $SD_{age}$= 10.1). The participants selected came from a selection process, nonrandom selected. Moreover, only a convenience sample from naturally formed groups as former nautical students and personal network were invited.

The possibility of determining the sample size appropriate for a study is feasible within social science. For the study in question, this was not achievable as this was a quasi-experimental study without the possibility of determining the size of the alpha level.

### 3.4 The questionnaire instrument

The instrument selected for study was a questionnaire (Appendix A) created in close cooperation by the research group, supervised by Professor Kjell Ivar Øvergård. Further development of the questionnaire happened in the net-based program, Questback essentials. As no former questionnaire instrument existed, for the sake of this study one was made. This questionnaire used the eight relative bearings 000º, 045º, 090º, 135º, 180º, 225º, 270º, 315º that Wielgosz (2016) introduced to get the navigational experts to determine the declarative domain around the vessel. Furthermore, the questions contained information on ship sizes (own and targeted) and if the scenario were in open or restricted waters. The question was based on Pietrzykowski and Uriaz (2009) and Wielgosz (1016) previous research.

The first six questions required the respondent's subjective experience for answering the eight different scenarios in each question. Question 6-12 was demographic questions, where the questions primarily were open-ended to avoid the respondent to adapt to preconceived answers (Frankfort- Nachmias & Nachmias, 2008, p.233).


**2) OPEN SEA, Own ship data: LENGTH= 50 m, Breadth =11 m, Draught = 3 m, Course = 000°, Speed = 12 knt, Current CPA = 0.0 NM Question: You are Officer of the Watch, what is the closest point of approach (CPA) you would be comfortable letting a targeted ship pass your own ship? Note: Collision avoidance takes place in the marked position and not at a later point in time. Answer with one decimal, in nm.**

* 000° * 045° * 090° * 135° * 180° * 225° * 270° * 315°

*Figure 2.* A question example from the questionnaire.

An expert group consisting of 10 people with expert knowledge within the field of navigation tested and gave feedback on the questionnaire in question. The input formed the final questionnaire distributed to the participants whose expert knowledge came from both theory and practice.

### 3.5 Operational definition of variables

**The closest point of approach** (CPA), the dependent variable that was measured.

The variables listed below were independent variables.

**Size of the ship**, a manipulated variable, where the respondents had no choice in what size the ship had in length. This variable was pre-defined solely to simplify with the length 50m LOA, 100m LOA, 200m LOA.

**Relative angles**, a manipulated variable, where the respondents had no choice in what size the ship had in length. A pre-defined variable solely to simplify. The respondent had to answer an exact distance in nm.

**Gender**, a variable solely to describe the sample. The respondent ticket of either male or female Where male was coded= 0 and female was coded= 1.

**Age**, collected solely to describe the sample. The participants answered about their age in an open-ended question, to explain the age of the participants accurately.

**Nationality**, collected solely to describe the sample. The participants answered about their age in an open-ended question, to explain the age of the participants accurately.

**The last rank onboard**, collected solely to describe the sample. The participants answered about their age in an open-ended question, to explain the age of the participants accurately.

**Certificate**, the respondents had to tick of the certificate they were holding on a prioritised drop-down menu showing certificate types from highest to lowest, top to bottom. A variable collected to test if the different certificate would have any significant value to the shape of the ship domain.

**Years of experience,** in an open-ended question the participants wrote by numbers how many years of seagoing experience they had, to describe the variable accurately. Moreover, to measure the different types of expertise and if they would matter to the size of the ship domain.

**Ship type experience** a variable where the respondent had to tick of suggested ship types, where several answers where possible to tick off. The variable measured was to be able to measure if the kind of experience would have anything to say when it came to the size of the domain.

### 3.6 Data collection

A hyperlink was distributed to possible respondents for data collection. The questionnaire opened by the respondents clicking on the received hyperlink. After the distribution of the first invitation, the participants received a reminder approximately 14 days later. The questionnaire closed after 1.5 months. The participation was voluntary in addition to anonymous as clearly stated in the pretext of the questionnaire. The collected data was, when downloaded, stored in the personal computers of the two members of the research team.

### 3.7 Data processing

To clean the data, it was exported from Questback essentials to an excel spreadsheet. To analyse data, the statistical program used was IBM SPSS version 24. As most of the answers were in numbers containing decimals, the participants varied in their use of dot or comma and how many decimals behind the comma. For SPSS to understand the numeric answers in the excel spreadsheet, the numbers had to contain a comma and were changed to hold no more than two decimals. To sort the responses answers from the excel spreadsheet into groups in SPSS they were coded with names such as “O_50m_000”. Additionally, each participant received an individual, random number for logistical reasons. Further, a change was made where respondents who did not give a precise numeric answer thus answered such as 0,7- 1,0 nautical miles (nm). The answer was changed to the smallest number assigned. Participants were deleted when they did not meet the set criterion.

### 3.8 Data analysis

IBM SPSS crunched the numbers. The analysis was divided into descriptive- and inferential statistic. The descriptive statistics used frequencies distributions and were tested with a Kolmogorov-Smirnov test to see whether the distributions were normally distributed or not. The answers were evaluated as containing skewness and or kurtosis. The differential statistics used a general linear model (GLM) repeated measures ANOVA analysis with a Within-subject comparison and a Non-parametrical analysis to answer the research question Rq.1 and Rq. 2 with the hypothesis, H1, H2 and H3.

### 3.9 Ethical assurances

The rules of privacy from the Norwegian centre for research data (NSD) was thoroughly examined before publishing the questionnaire in question. Also, an informal test conducted at the NSD webpage resulted in the questionnaire not asking for personal information as by NSD rules (Norwegian Center for research Data, 2018). Further, the questionnaire had a function to tick off if one would like to have the questionnaire hide the identity of those who replied. The hidden identity box was marked before the questionnaire was distributed. Whereas, the respondents were additionally informed in writing that the questionnaire was anonymous and could read more about privacy by clicking on a link, before answering any questions.

The research team followed good research ethics with ethical standards and integrity of a high grade (Research Council of Norway, 2017).

# CHAPTER 4. RESULTS

A presentation of a descriptive analysis containing a Kolmogorov-Smirnov test, And descriptive analysis presented by a non-parametrical analysis and repeated measure general linear model (GLM) analysis of Variance (ANOVA) to identify the study findings. The representation is merely the numbers explained without containing any discussion.

## 4.1. Descriptive results

### 4.1.1 Participants

The descriptive statistics show that n=53, no missing patterns. The participants, in total 53, 7 women and 46 men (15.2% women). The participants experience in years ranged from 1 to 41 years (mean= 8.94, SD.= 8.57). Certificate types ranged from D4 to D1 (mean= 1.77, SD= 0.86, median= 2.00, mode= 1.00).

A correlation test between ship sizes and relative angles was performed; 50-100m LOA= (0.853- 0.890), 100-200m LOA= (0.917- 0.950), 50-200m LOA = (0.813- 0.897). Observed result show a high correlation meaning the construct validity is and scale reliability is good.

### 4.1.2. Skewness and Kurtosis

A Kolmogorov-Smirnov test was used when evaluated the frequency distribution. The result is showing that all of the frequency distributions deviated from a normal distribution. Moreover, in all of the frequency distributions, the skew is above 1.03 above meaning a positive skew (see figure 3-26 below). Kurtosis occurs if the result is below or above (-2,2). A mesokurtic curve is ordinarily a peaking curve. A Leptocurtic curve is a curve with smaller shoulders and a higher peak than the mesokurtic. The results of this study show that the majority of the frequency distributions (20) all have positive numbers of kurtosis meaning (leptokurtic) kurtosis (see figure 3- 26) (IBM knowledge centre, 2012; Hinton, 2014).

Histogram Charts for each Angle for a Ship at 100m Length Over All (LOA).

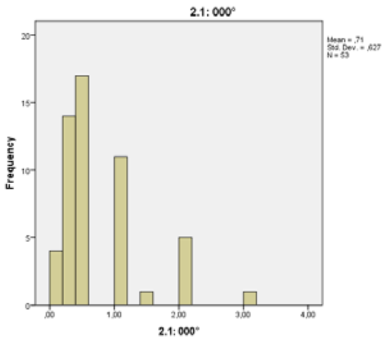


*Figure 3.*
Histogram Charts for Angle 000º (mean=0.71, SD=0.627).
The distribution deviates from normal with skew (1.7) and kurtosis (2.83).

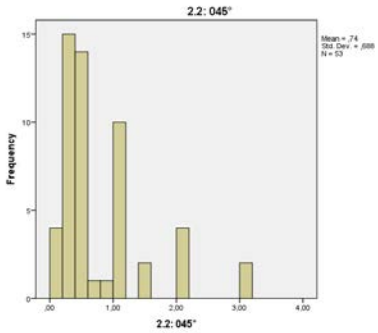


*Figure 4.*
Histogram Charts for Angle 045º (mean=0.74, SD=0.688).
The distribution deviates from normal with skew (1.77) and kurtosis (3.0).

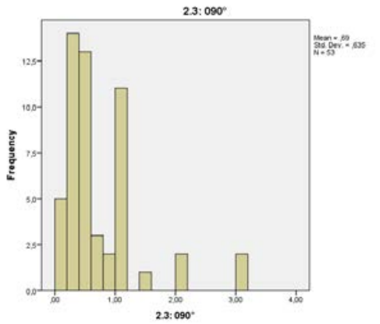


*Figure 5.*
Histogram Charts for Angle 090º (mean=0.69, SD=0.635). The distribution deviates from normal with skew (2.1) with kurtosis (5.4).

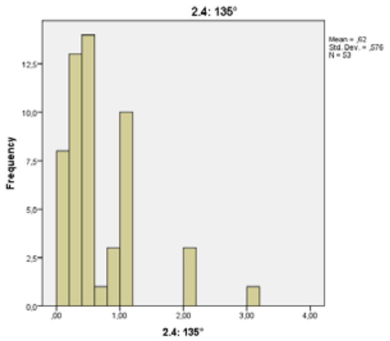


*Figure 6.*
Histogram Charts for Angle 135º (mean=0.62, SD=0.576).
The distribution deviates from normal with skew (2.1) and kurtosis (5.45).

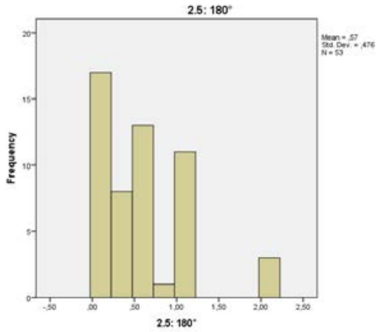


*Figure 7.*
Histogram Charts for Angle 180º (mean=0.57, SD=0.476).
The distribution deviates from normal with skew (1.57) and kurtosis (2.55).

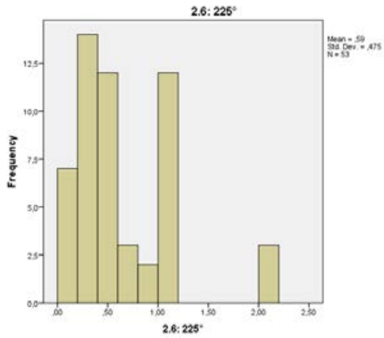


*Figure 8.*
Histogram Charts for Angle 225º (mean=0.59, SD=0.475).
The distribution deviates from normal with skew (1.45) and kurtosis (2.3).

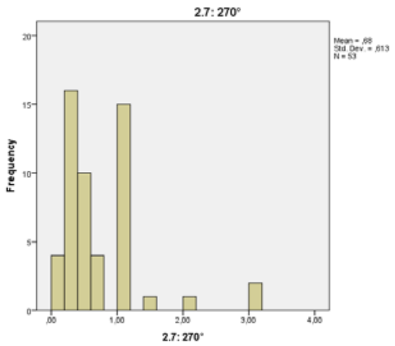


*Figure 9.*
Histogram Charts for Angle 270º (mean=0.68, SD=0.613).
The distribution deviates from normal with skew (2.24) and kurtosis (6.33).

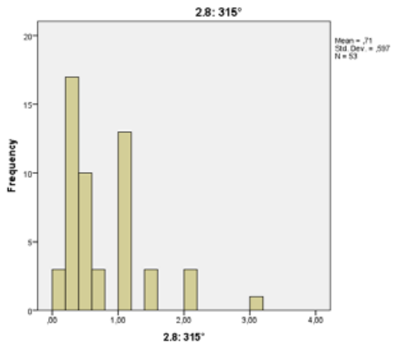


*Figure 10.*
Histogram Charts for Angle 315º (mean=0.71, SD=0.597).
The distribution deviates from normal with skew (1.64) and kurtosis (3.3).

Histogram Charts for each Angle for a Ship at 100m LOA

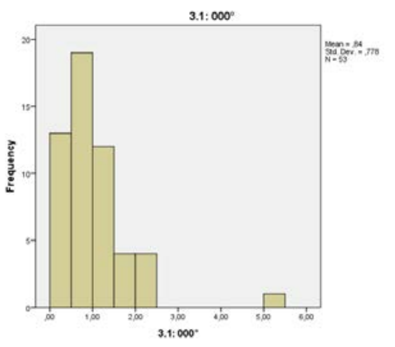


*Figure 11.*
Histogram Charts for Angle 000º (mean=0.84, SD=0.778).
The distribution deviates from normal with skew (3.24) and kurtosis (15.08).

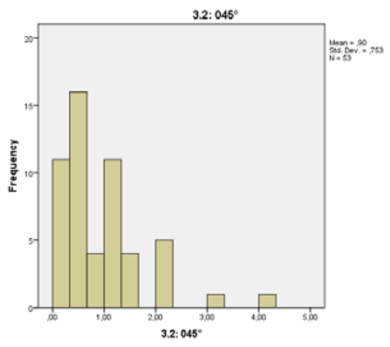


*Figure 12.*
Histogram Charts for Angle 045º (mean=0.90, SD=0.753).
The distribution deviates from normal with skew (1.98) and with kurtosis (5.1).

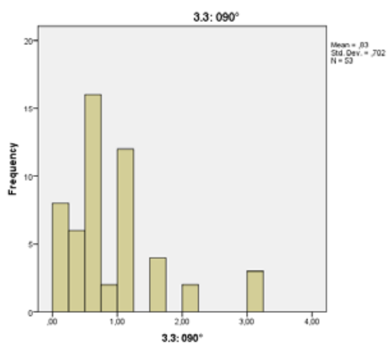


*Figure 13.*
Histogram Charts for Angle 090º (mean=0.83, SD=0.702).
The distribution deviates from normal with skew (1.8) and kurtosis (3.29).

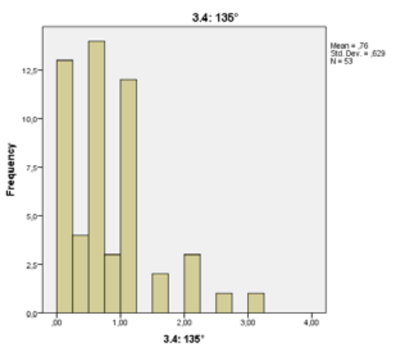


*Figure 14.*
Histogram Charts for Angle 135º (mean=0.76, SD=0.629).
The distribution deviates from normal with skew (1.6) and kurtosis (2.87).

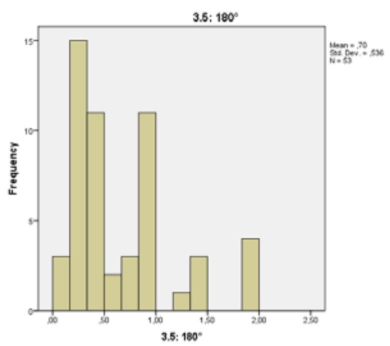


*Figure 15.*
Histogram Charts for Angle 180º (mean=0.70, SD=0.536). The distribution deviates from normal with skew (1.07) and mesokurtic Kurtosis (0.467).

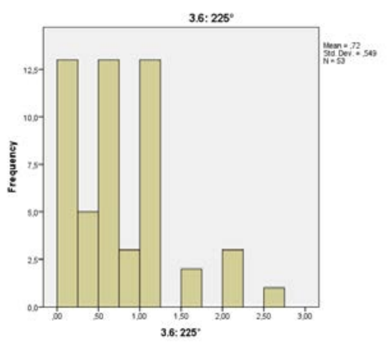


*Figure 16.*
Histogram Charts for Angle 225º (mean=0.72, SD=0.549).
The distribution deviates from normal with skew (1.29) and mesokurtic kurtosis (1.66).

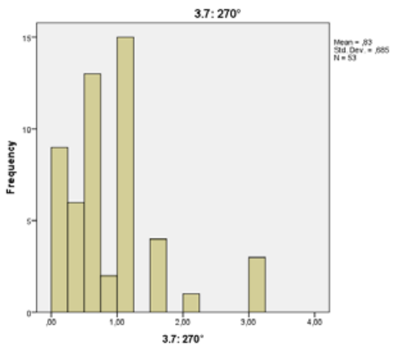


*Figure 17.*
Histogram Charts for Angle 270º (mean=0.83, SD=0.685).
The distribution deviates from normal with skew (1.85) and kurtosis (3.83).

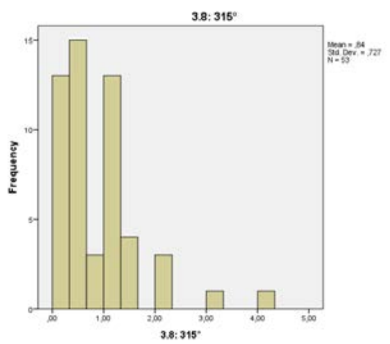


*Figure 18.*
Histogram Charts for Angle 315º (mean=0.84, SD=0.727).
The distribution deviates from normal with skew (1.26) and kurtosis (6.79).

Histogram charts for each Angle for a Ship at 200 m LOA

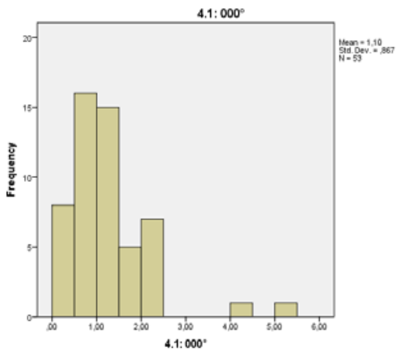


*Figure 19.*
Histogram Charts for Angle 000º (mean=1.1, SD=0.867).
The distribution deviates from normal with skew (2.59) and kurtosis (8.73).

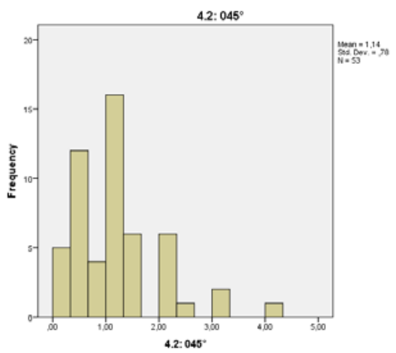


*Figure 20.*
Histogram Charts for Angle 045º (mean=1.14, SD=0.78).
The distribution deviates from normal with skew (1.53) and kurtosis (2.81).

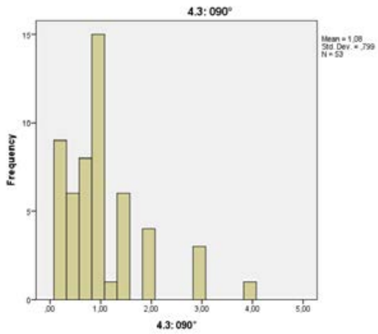


*Figure 21.*
Histogram Charts for Angle 090º (mean=1.08, SD=0.799).
The distribution deviates from normal with skew (1.67) and kurtosis (3.21).

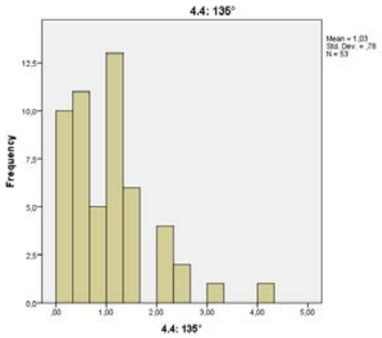


*Figure 22.*
Histogram Charts for Angle 135º (mean=1.03, SD=0.78).
The distribution deviates from normal with skew (1.61) and kurtosis (3.32).

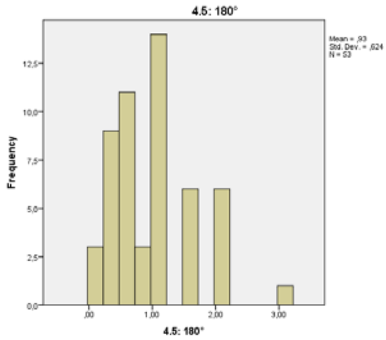


*Figure 23.*
Histogram Charts for Angle 180º (mean=0.93, SD=0.624).
The distribution deviates from normal with skew (1.07) and mesokurtic kurtosis (1.0).

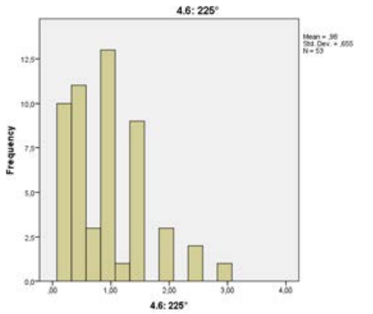


*Figure 24.*
Histogram Charts for Angle 225º (mean=0.98, SD=0.655).
The distribution deviates from normal with positive skew (1.03) and mesokurtic kurtosis (0.88).

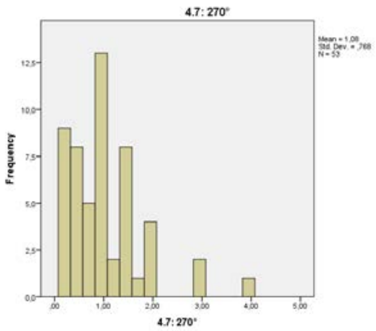


*Figure 25.*
Histogram Charts for Angle 270º (mean=1.08, SD=0.766).
The distribution deviates from normal with skew (1.6) and with kurtosis (3.52).

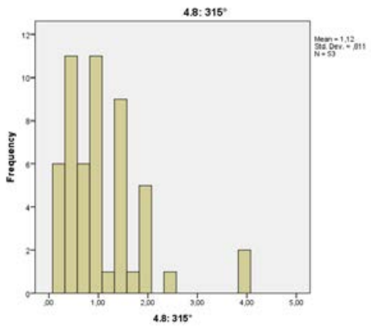


*Figure 26.*
Histogram Charts for Angle 315º (mean=1.12, SD=0.811).
The distribution deviates from normal with skew (1.79) and kurtosis (4.34).

### 4.2. The relation between ship domain size and vessel size.

A 3 x 8 repeated measures GLM analysis (size x angle) was used to test the results of the questionnaire. Mauchly`s Test of Sphericity showed that sphericity was violated[1] for all independent variables. The Greenhouse- Geisser correction was implemented to correct for the degrees of freedom (Field, 2012). A significant result with large effect size for the variable size of ship (Sphericity not assumed, $F_{1.63,\ 84.93}$= 44.324, $p$ <0,001, $\eta_p^2$ = 0.460) was found. Additionally a significant result with the low effect size for Relative Bearing (Sphericity not assumed, $F_{3.046,\ 158.408}$=4.065, $p$=0.008, $\eta_p^2$ =0.073). A GLM is also tested with the between subjects “gender” with no observed effect [2].

The results were presented with the domain distances in nautical miles (nm) displayed in table 1 below. See (figure 30) below for the domain shape.

Table 1. Results *for the Ship Domain of all Ship Sizes, by Mean.*

| Angle | Mean 50 m | Mean 100 m | Mean 200m |
|---|---|---|---|
| 000° | 0,71 | 0,84 | 1,10 |
| 045° | 0,74 | 0,90 | 1,14 |
| 090° | 0,69 | 0,83 | 1,08 |
| 135° | 0,62 | 0,76 | 1,03 |
| 180° | 0,57 | 0,70 | 0,93 |
| 225° | 0,59 | 0,72 | 0,98 |
| 270° | 0,68 | 0,83 | 1,08 |
| 315° | 0,71 | 0,84 | 1,12 |

[1] Mauchly`s test of sphericity: size ($x^2$= 12.968, df= 2, $p$ =0.02), angle ($x^2$= 260.673, df= 27, $p$ <0.001), size*angle ($x^2$= 522.312, df= 104, $p$ <0.001).

[2] GLM(Greenhouse-Geisser) size*gender ($F_{1.63,\ 83.34}$=0.41, $p$=0.935, $\eta_p^2$ =0.001), angle*gender ($F_{3.023,\ 154.15}$=0.878, $p$=0.454, $\eta_p^2$ =0.012), size*angle*gender ($F_{5.50,\ 280.55}$=0.305, $p$=0.923, $\eta_p^2$ =0.006),

Table 1. shows that the distances in nm for each ship size increases as the ship size increases. Further, the domains seem larger in nm forward (rel. angle 000º) than aft (rel. angle 135º, 180º, 225º) of own ship.

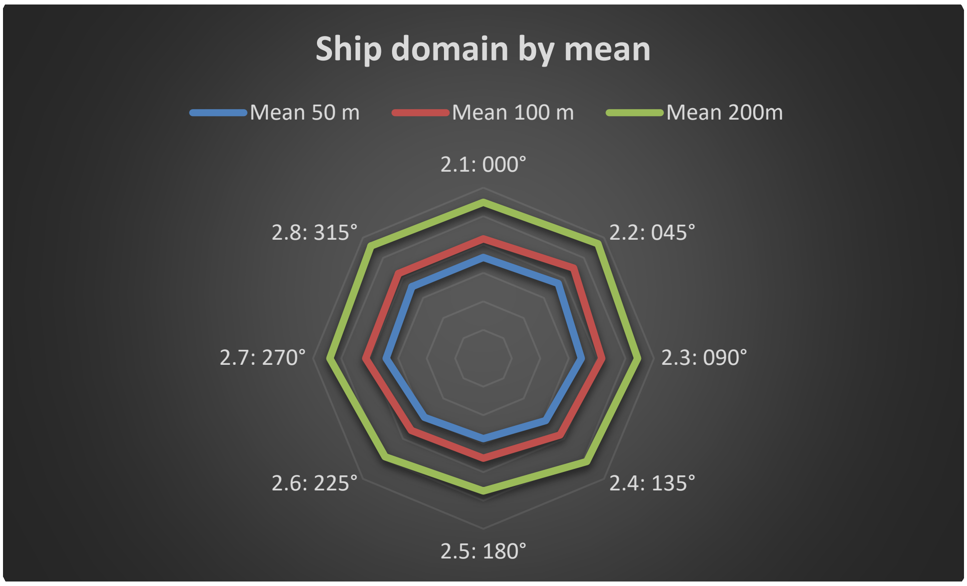


*Figure 27.* A ship domain displayed by mean at ship length 50, 100 and 200 m LOA

Figure 30 shows a domain shaped like a polygon that seems to have around elliptical shape, by mean for all the tree ship sizes. The aft part (relative bearing 135º, 180º, 225º) seems to be closer to the middle than in the front (relative bearing 000º).

The ship domain boundaries discovered is close to linear (equation 1). Below (see figure 28) shows that the relation between the average of a ship domain and the ship LOA is linear.

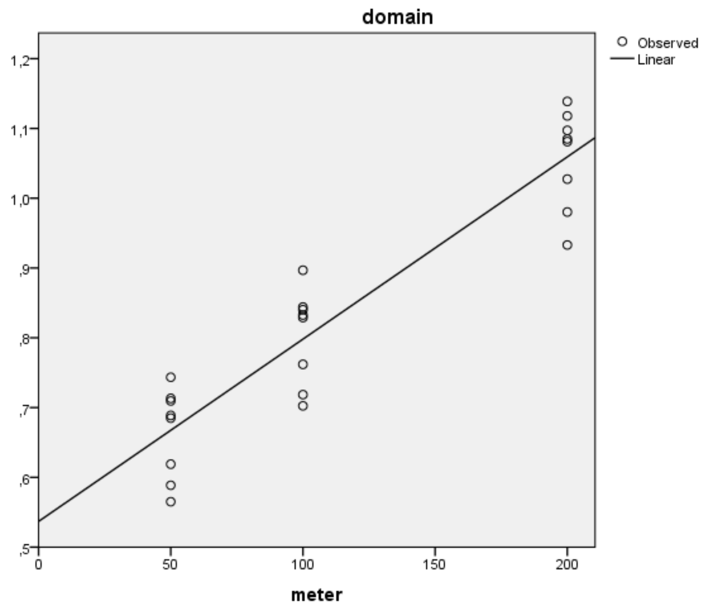


*Figure 28*. The regression line for the ship domain of all sizes Y= 0.537+0.03*LOA, by the mean.

The regression line for the data in figure 28 is:

$$\mathbf{Y= 0.537+0.026*LOA} \tag{1}$$

Where LOA is length overall for each vessel and Y is the mean of the ship domain

The domain size increases when the ship size increases, linearly (see fig 31 and 31). Hypothesis 1 is corroborated, as the domain size increases with ship size as of Goodwin`s (1975) findings.

### 4.3 The domain shape

To test whether the observed ship domain is of similar shape as Goodwin`s (1975) ship domain. This comprises two indirect tests of whether the declarative ship domain had the same form as Goodwin’s model, which was notably larger forward that aft and equally large on starboard and port side of own vessel.

To answer hypothesis 2 and hypothesis 3, non-parametrical test were performed presented in table 2 and table 3 below.

Table 2. *Test Results from Descriptive and Non-Parametrical test Forward and Aft of own ship.*

| | Mean (SD) | | Wilcoxon | | | |
|---|---|---|---|---|---|---|
| **LOA (m)** | **000º** | **180º** | **M*diff*** | **Z** | ***p*** | **Cohen`s *d*** |
| **50** | 0.709 (0.627) | 1.380 (1.169) | -0.671 | -5.023 | 0.000 | 0.725 |
| **100** | 0.840 (0.778) | 1.704 (1.313) | -0.864 | -5.821 | 0.000 | 1.009 |
| **200** | 1.097 (0.867) | 2.287 (1.591) | -1.190 | -5.226 | 0.000 | 1.102 |

Table 2 shows that for all ship sizes the domain is larger forward (rel. angle 000º) of the vessel than aft (rel. angle 135º, 180º, 225º) by nautical miles (nm). This result is supported by the significant value being less than 0.05. Also, the effect size is large, close to 0.8 and above (Cohen, 1988).

Table 3. *Values from descriptive and non-parametrical test starboard and port side*

| | Mean (SD) | | Wilcoxon | | | |
|---|---|---|---|---|---|---|
| **LOA (m)** | **STB** | **PORT** | **M*diff*** | **Z** | ***p*** | **Cohen`s *d*** |
| **50** | 1.088 (0.986) | 1.042 (0.891) | 0.046 | -0.748 | 0.454 | 0.140 |
| **100** | 1.313 (1.080) | 1.251 (1.034) | 0.062 | -1.441 | 0.150 | 0.191 |
| **200** | 1.681 (1.160) | 1.640 (1.160) | 0.041 | -0.594 | 0.553 | 0.087 |

Table 3. Show that there is nearly any difference in size of port and starboard side, presented in nm. There were no significant differences between starboard (rel. bearing 045º, 090º) and port side (rel. bearing 270º, 315º) for the three ship lengths (see table 3, above). Additionally, the effect size Cohens D is small, below 0.2 according to Cohen's classification of effect sizes (Cohen, 1988) which supports the rest of the findings from table 3. For this statistics, the results are similar to Goodwin (1975).

The resulting ship domain shapes are presented below (see figures 29- 31). As no distances are displayed in the figures (29- 31) the tables (4-6) below, accompany with distances in nautical miles (nm).

Table 4. *Parameters for the Ship Domain by Ship 50m LOA*

| Angle | percentile 10 | Mean | Percentile 90 |
|---|---|---|---|
| 000° | 0,20 | 0,71 | 2,00 |
| 045° | 0,20 | 0,74 | 2,00 |
| 090° | 0,14 | 0,69 | 1,30 |
| 135° | 0,10 | 0,62 | 1,00 |
| 180° | 0,10 | 0,57 | 1,00 |
| 225° | 0,10 | 0,59 | 1,00 |
| 270° | 0,20 | 0,68 | 1,00 |
| 315° | 0,20 | 0,71 | 1,50 |

Table 4 shows the domain sizes by mean, the 10th percentile to the 90th percentile in nm. The domain is more extensive for all parameters in front (rel. bearing 000º) of own ship than aft of own ship (rel. bearing 135º, 180º, 225º).

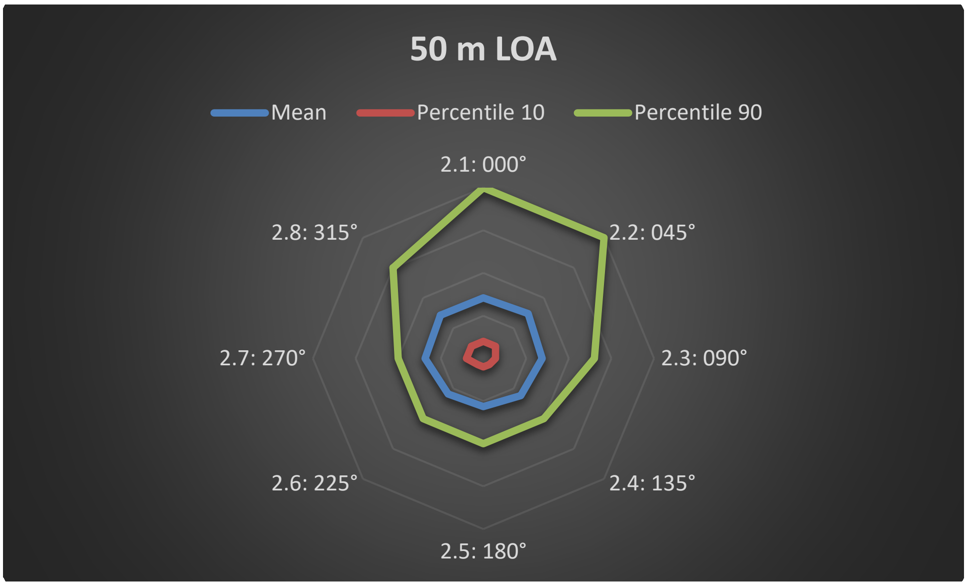


*Figure 29.* A ship domain displayed by mean, 10th and 90th percentile at ship length 50 m LOA.

Figure 29 shows a domain that seems to have a round shape by the mean. The aft part (relative bearing 135º, 180º, 225º) seems to be closer to the middle than in the front (relative bearing 000º). The 90th percentile looks more like the ship domain that Goodwin (1975) estimated for restricted waters.

Table 5. *Results for the Ship Domain by Ship 100m LOA.*

| Angle | percentile 10 | Mean | Percentile 90 |
|---|---|---|---|
| 000° | 0,20 | 0,84 | 1,80 |
| 045° | 0,20 | 0,90 | 2,00 |
| 090° | 0,20 | 0,83 | 1,80 |
| 135° | 0,19 | 0,76 | 1,80 |
| 180° | 0,20 | 0,70 | 1,50 |
| 225° | 0,19 | 0,72 | 1,50 |
| 270° | 0,20 | 0,83 | 1,50 |
| 315° | 0,20 | 0,84 | 1,80 |

Table 5 shows the domain sizes by mean, the 10th percentile to the 90th percentile. The domain is more extensive in size for all parameters in front (rel. bearing 000º) than aft (rel. bearing 135º, 180º, 225º). Starboard side (rel. bearing 045º, 090º) and port side (rel. bearing 270º, 315º) are quite alike.

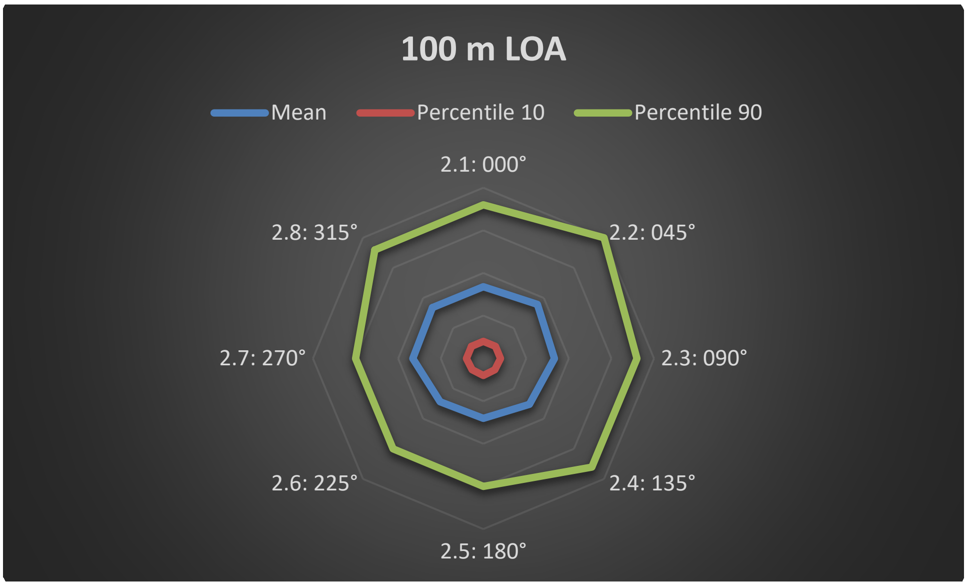


*Figure 30.* A ship domain displayed by mean, 10th and 90th percentile at ship length 100 m. LOA

Figure 30 shows a domain that has a round shape by the mean. The aft part (relative bearings 135º, 180º, 225º) seems to be closer to the middle than in the front (relative bearing 000º). The mean and 90th percentile show a tendency of having a domain shape that is larger out to starboard side of the vessel.

Table 6. *Parameters for the Ship Domain by Ship 200m LOA.*

| Angle | percentile 10 | Mean | Percentile 90 |
|---|---|---|---|
| 000° | 0,40 | 1,10 | 2,00 |
| 045° | 0,34 | 1,14 | 2,00 |
| 090° | 0,30 | 1,08 | 2,00 |
| 135° | 0,27 | 1,03 | 2,00 |
| 180° | 0,30 | 0,93 | 2,00 |
| 225° | 0,27 | 0,98 | 2,00 |
| 270° | 0,30 | 1,08 | 2,00 |
| 315° | 0,30 | 1,12 | 2,00 |

Table 6 shows the domain sizes by mean, the 10th percentile to the 90th percentile in nm. Starboard (rel. angle 045º, 090º) and port (rel. angle 270º, 315º) side are quite similar.

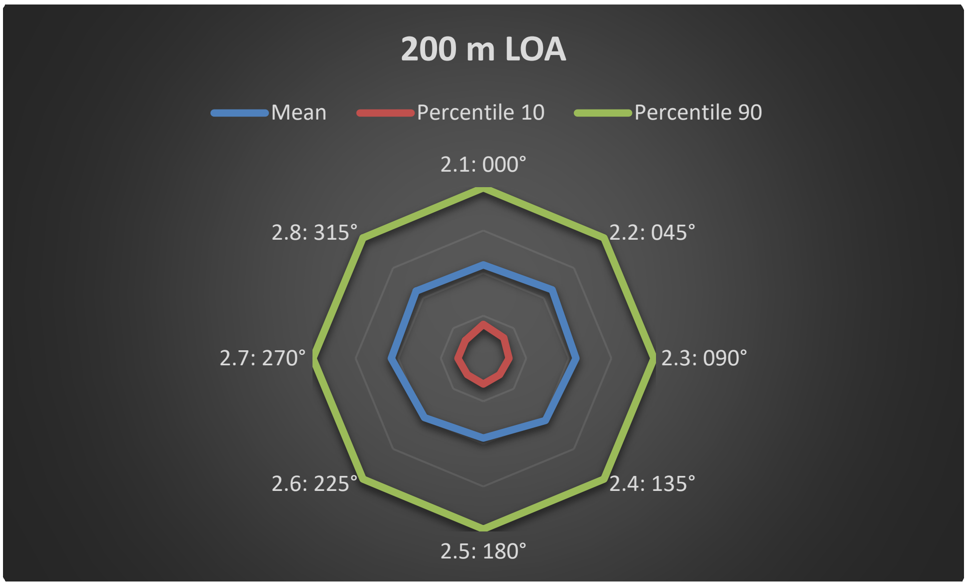


*Figure 31.* A ship domain displayed by mean, 10th and 90th percentile at ship length 200 m LOA

Figure 31 shows a domain that seems to have a round shape by the mean. Goodwin (1975) stated that the ship domain would be rounder as the ship size increases. The ship domains presented for ship sizes 50m, 100m and 200m LOA show that the domain shape both by mean and 90th percentile seems to be of a rounder shape.

Hypothesis H2 are corroborated. An effect of the difference in the size affecting the shape of the domain as it is larger front (rel. bearing 000º) than aft (rel. bearing 135º, 180º, 225º) of own ship.

Hypothesis, H3 is corroborated as there is no statistically identifiable difference between starboard (rel. bearing 045º, 090º) and port (rel. bearing 270º, 315º) side of the ship. The shapes found for H2 and H3 seems to be similar to the shapes detected by Goodwin (1975). Which means that the observed ship domain is larger forward than aft of the ship and that the domain is equal in size on both starboard (rel. bearing 045º, 090º) and port (rel. bearing 270º, 315º) side of the ship.

# CHAPTER 5. DISCUSSION AND LIMITATIONS

A quasi-experimental study examining the Norwegian navigator's effective ship domain`s size and shape was performed. The observed results will further be argued in the discussion, subchapter (5.1) followed limitations in the next subchapter (5.2).

## 5.1 Discussion

The first hypothesis, H1, declared that the ship domain size increases when ship size increases. The hypothesis was supported by the evident linearity (see equation 1) between the size of the ship domain and the size of the vessel. The descriptive statistics (see table 1) also clearly show an increase in the size of the domain, when ship size increases (50m, 100m, 200m length overall, LOA). These observed results seem to correspond with the results of other researchers on ship domains (e.g. Fuji, 1971; Zhao et al. 1993; Goodwin 1975) who all stated that the ship domain increases as the ship size increases. Additionally, Goodwin (1975) said that that the domain would be rounder in shape as the ship sizes increased, that statement seems to be as of the above results show (table 1, figure 27). The observed resulting ship domains found here seem to be elliptical polygons, which appeared to comply with Wang et al. (2009). Who states that the polygon shaped domain occurs when ships speed and dimensions are seen in relation to other vessels. The high effect size ($\eta_p^2 = 0.460$) supports the difference observed in ship size and domain size.

The second hypothesis, H2, declared that the domain shape was expected to be similar to Goodwin`s (1975) findings of the domain being larger forward than aft of own ship. From the non-parametrical tests (see table 2) were a significant ($p<0.001$) value obtained for all ship sizes. Supported by the large effect size of Cohen`s *d* (0.725- 1.102) (Cohen`s, 1988). The descriptive statistics seem to support the observed results as all ship sizes have a more extensive domain forward than aft (see table 4-6). These results comply with the results of Goodwin (1975), Pietrzykowski and Uriaz (2009) and Wielgosz (2016), who all found that the ship domain was more extensive in front of own ship than aft of it. The current results additionally seem to comply with  Zhao et al. (1993) who stated that Hall`s (1968) theory of proxemics included the navigator and ship as the ship person. The ship person would have a larger domain forward than aft of own vessel as the person navigating would care more about what happens in front than behind the ship. The theories seem to be an explanation of why the results presented in this study have a more substantial domain forward than aft of own ship.

The third hypothesis, H3, declared that the ship domain for open waters would be equal in size on the starboard and port side according to Goodwin`s (1975) findings. The statistical answers show that there is no statistical difference ($p>0.05$) in size and the effect size, Cohens $D<0.2$, is considered small (Cohen, 1988). These results comply with the findings of Goodwin (1975) (see figure 1) where there was no difference in starboard or port side of the ship domain. Goodwin (1975) stated that a ship in open waters would have a large domain as it has increased manoeuvrability. Nevertheless, Goodwin`s (1975) results of data from the open waters were collected in reduced visibility. Reduced visibility does not necessarily mean that the shape would be any different from a domain in the open waters in good visibility as radar assisted collisions do also occur in good weather due to wrong user assessment. Nevertheless, Goodwin's (1975) domain sizes all had a similar form of starboard and port side of the ship, in restricted visibility, no traffick density taken into account. Thus, for the area where the ship domain was observed in good visibility, and traffic density was high, the port and starboard had different sizes, where starboard was larger than port side. Though when the traffic density was low, in good visibility, there was no difference in the size of the port and starboard sides. It is reasonable to believe that in open waters, with low traffic density, and good visibility, the domain`s actual size in nautical miles (nm) would change, yet the shape would remain the same. It seems like Goodwin (1975) has allowed the term open sea to be closer to shore than what is defined in this study. Therefore it appears ok to assume that the definition of open waters in this study would mean that the traffic density would be rather low.

When developing the ship domain, the statistical method from the literature using expert knowledge and expertise was used (Dihn & Im 2016). And the results presented show that they comply with Dihn and Im`s (2016) predictions on how the development of the domain relied on the navigator's expertise.

Although the study was non-randomized, the study had an over-representation of women, (13.1%), seen in a navigational perspective where less than 2% are female navigators. Testing if the gender sloping would have any effect on the data was natural. Thus, no observed effect made, the assumption was drawn that the distribution of gender did not bias the outcome of the results.

A ship domain is a term difficult to measure direct as it is a psychological phenomenon. Therefore, to find out if what was desired to test was, in fact, the phenomenon tested a correlation test between ship sizes and the relative bearings were done. As a high correlation was observed (50-100m LOA= (0.853- 0.890), 100-200m LOA= (0.917- 0.950), 50-200m LOA = (0.813- 0.897). The high correlation supports that it seems that what was measured in the questionnaire was the same phenomenon as desired. It means that the construct validity is good. The scale reliability is also good with the high correlation observed here.

### 5.2 Limitations

The limitations of the ship domain obtained from Norwegian navigators are small sample size, a time limit and the possibility of common method variance (CMV).

The research conducted in this study is based on a questionnaire that 53 respondents answered. There is a small sample size which makes the study underpowered. Additionally, type 2 errors could occur (Cohens, 1988), which means that the type two error might have skewed the results. The type 2 errors could also lead to a wrong denying the null hypothesis. As such, this study cannot assume that there was no effect on the null hypothesis, even though none effects were observed. The results found seem to be like Goodwin`s (1975) results. Thus there might not have been a large enough sample size to see any differences. The deviations observed in the extreme values like 10$^{th}$ and 90$^{th}$ percentile, especially in a 100m LOA ships, where large variations also likely to be stemming from the small sample size. This means that the study is vulnerable to bivariation. Additionally, the standard error is extensive. It can be challenging to assume that two values are different with such a small sample size. If the sample size increased then the results would get closer to the population mean.

Due to the time limit of the master’s thesis, this study was simplified, thus focused, and the questionnaire scenarios do not take into consideration the following. Weather conditions like day vs night, wind, waves, current, visibility, or any difference in ship types, rudder types, type of engines and propellers or different ships speed, different cargo onboard the ships. As this is not taken into account in the study, it weakens the construct validity.

The results of the questionnaire might have (CMV) since all data are collected using the same method. To be able to test for CMV, additional data should have been obtained from; for instance, navigation performed in a simulator.

# CHAPTER 6. CONCLUSION AND RESEARCH PROSPECTS

Presented below is a subchapter containing conclusion followed by a subchapter on research prospects

## 6.1 Conclusion

The declarative ship domain in open waters based on Norwegian navigator's expert opinion; seem to correspond, linear, to Goodwin's (1975) findings of a ship domain that increases in size when ship size increases. Moreover, the Norwegian navigator`s declarative domain appares to be a ship domain with a round, elliptical form. Which seems to be similar to Goodwin (1975) with an equal shape for port and starboard side. Additionally, it seems similar for forward and aft of the ship, where the forward part of the domain extends more forward than aft.

## 6.2 Research prospects

Future research within the field of ship domain should examine several combinations of the different parameters, such as weather conditions and different ship types and ships speed, to increase the complexity of the domain. Additionally, as there are other ways of collecting data, future research should focus on avoiding CMV when obtaining data, in addition to using different methods of data collecting to increase the validity of the ship domain. As for future research, if same data collection instrument gave the same results, the reliability would be good.

## References

Andersen, S.R. (2017) *Regelverket til sjøss, reglene som kom etterpå skal forhindre at de samme ulykken skjer igjen.* Retrieved from: https://sysla.no/maritim/slik-har-katastrofene-endret-regelverket-til-sjos/

Cohen, J. (1988) *Statistical power analysis for the behavioural sciences*, (2nd ed.). St. Paul, MN: West Publishing Company

Coldwell, T. G. (1983) Marine Traffic Behaviour in Restricted Waters. *The Royal Institute of Navigation*. Doi: 10.1017/S0373463300039783

Creswell, J.W. (2014) *Research design: qualitative, quantitative, and mixed methods approaches* (4th edition ). California: Sage publication.

Davis, P.V., Dove, M.J. & Stockel C.T. (1980) A computer simulation of Marine Traffick Using Domains and Arenas. *Journal of Navigation*. 33, 215-222.

Dinh, G. H. & Im, N. (2016) The combination of an analytical and statistical method to define polygonal ship domain and reflect human experiences in estimating dangerous area. *International Journal of e-Navigation and Maritime Economy,* 4, 97-108. Doi: 10.1016.06.009

Field (2012) Repeated measures ANOVA. *Discovering statistics*. Retrieved from http://health.uottawa.ca/biomech/courses/apa6101/Repeated%20Measures%20ANOVA.pdf

Frankfort- Nachmias C. & Nachmias, D. (2008) *Research methods in the Social Sciences* (seventh ed.). New York: Worth Publishers.

Fuji Y. & Tanaka K. (1971) Traffic capacity. *Journal of Navigation*. 24, 543-553

Goodwin E. M. (1975) A statistical study of ship domains. *Journal of Navigation*. 28, 328.344

Golafshani, N. (2003). Understanding Reliability and Validity in Qualitative Research. *The Qualitative Report*, 8(4), 597-606. Retrieved from http://nsuworks.nova.edu/tqr/vol8/iss4/6

Hansen, M.G., Jensen, T.K., Lehn- Schøler, T., Melchild, K., Rasmussen, F.M. & Ennemark, F. (2013) Empirical ship Domains based on AIS data. *Journal of Navigation*. 66, 931- 940. Doi: 10.1017/S0373463313000489

IBM Knowledge centre (2012) *Display statistics*. Retrieved from https://www.ibm.com/support/knowledgecenter/en/SS3RA7_15.0.0/com.ibm.spss.modeler.help/dataaudit_displaystatistics.htm

IMO, (2018) *Convention on the International Regulations for Preventing Collisions at Sea*, 1972 (COLREGs). Retrieved from: http://www.imo.org/en/About/conventions/listofconventions/pages/colreg.aspx

Lovdata (1975) *Forskrift om forebygging av sammenstøt på sjøen (Sjøveisreglene).* Retreived from: https://lovdata.no/dokument/SF/forskrift/1975-12-01-5

Norwegian Center for research Data (2018) *Do I have to notify my project?* Retrieved from http://www.nsd.uib.no/personvernombud/en/notify/index.html

Pietrzykowski Z. (2008) Ships Fuzzy Domain- A criterion of navigational safety in narrow fairways. *Journal of Navigation*. 61, 499- 514. DOI: 10.1027/S0373463308004682

Pietrzykowski Z. & Magaj J. (2016) Analysis of ship domain in traffic separation schemes. *Scientific Journals of the Maritime University of Szczecin* 48(120), 88-95. Doi: 10.12402/181

Pietrzykowski Z. & Magaj J. (2014) The safe ships trajectory in a restricted area. *Scientific Journals of the Maritime University of Szczecin* 39(111), 122-127.

Pietrzykowski Z. & Uriasz J. (2009) The ship domain- a criterion of navigational safety assessment in open sea area. *Journal of Navigation* 62, 93-108. Doi:10.1017/S0373463308005018

Pietrzykowski Z., Wielgosz M. & Siemianowicz M. (2012) Ship domain in the restricted area- simulation research. *Journals of the Maritime University of Szczecin*, 32(204), 152- 156.

Rawson A., Rogers E., Foster D. & Phillips D. (2014). Practical Application of Domain Analysis: Port of London Case Study. *Journal of Navigation* 67, 193- 209. Doi:10.1017/S0373463313000684

Research Council of Norway (2017) *Ethical guidelines and good research practice*. Retrieved from https://www.forskningsradet.no/no/Artikkel/Etiske_retningslinjer_og_god_forskningsskikk/1182736867344

Shadish W. R., Cook T. D. & Campbell D. T. (2002) *Quasi-experimental design for generalized causal inference.* Boston, New York: Houghton Mifflin Company. Retrieved from: https://pdfs.semanticscholar.org/9453/f229a8f51f6a95232e42acfae9b3ae5345df.pdf

Szlapczynski, R. & Szlapczynskaj J. (2016) An analysis of domain-based ship collision risk parameters. *Ocean* Engineering. 123, 47-56. Doi 10.1016/2017.09.020

Szlapczynski, R. & Szlapczynskaj J. (2016) Review of ship safety domains: Models and applications. *Ocean Engineering*, 145, 277- 289

United Nations Ocean and Law of the Sea, (2017) *Agreement relating to the implementations of part XI of the convention.* Retrieved from: http://www.un.org/depts/los/convention_agreements/texts/unclos/closindx.htm

Wang Y. & Chin H. (2016). An empirically- Calibrated ship domain as a safety criterion for navigation in confined waters. *The Journal of navigation*, 69, 257- 275. Doi: 10.1017/S0373463315000533

Wang N., Meng X., Xu Q. & Wang Z. (2009) A unified analytical Framework for ship domains. *The Journal of Navigation*, 62, 643- 655. Doi: 10.1017/S0373463309990178

Wielgosz M. (2016) Declarative ship domains in restricted areas. *Scientific Journals of the Maritime University of Szczecin*, 46, 217-222. Doi 10.17402/140

Zhao J., Wu Z. &Wang F. (1993) Comments on ship domain. *Journal of Navigation* 46, 422- 436.

Zhu X., Xu H. & Liu J. (2001) Domain and its model based on neural networks. *Journal of Navigation*. 54, 97- 103

# Appendices

Appendix A

## Ship domain quest

- **Responsible for this questionnaire:**

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Mari Auby Starup, researcher, tel: +47 979 46 150

Johan Øen Strand, researcher, tel: +47 994 82 262

- **Purpose:**

To conduct research on behalf of the University College of Southeast Norway, Department of Maritime Operations.

- **Aim:**

To investigate seafererer`s evaluation of the ship`s domain

- **Ship Domain definition:**

Ship domain is the effective area around a ship, which a navigator would like to keep free with respect to other ships and stationary obstacles. In other words, a free space around your own ship. You may think of it as equivalent to personal space.

- **Instructions:**

Own ship: One Becker rudder, one propeller, one bow- thruster, eco speed = 12 knots

Target ship: Same characteristics as own ship

Bearings of targeted ship:  All relative to own ship, indicated by arrow

Headings of targeted ship: All headed towards own ship

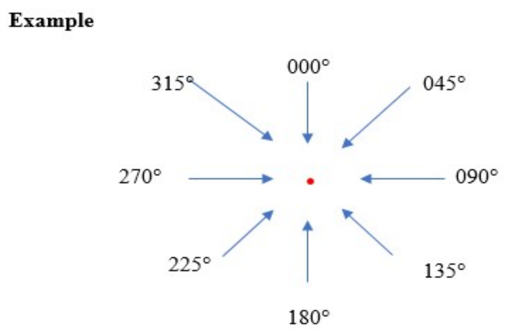
Weather: Daytime, Good visibility, no current, no wind,

Note: Each approach of the targeted ship is to be treated as an independent case

Participation is voluntary and anonymous.

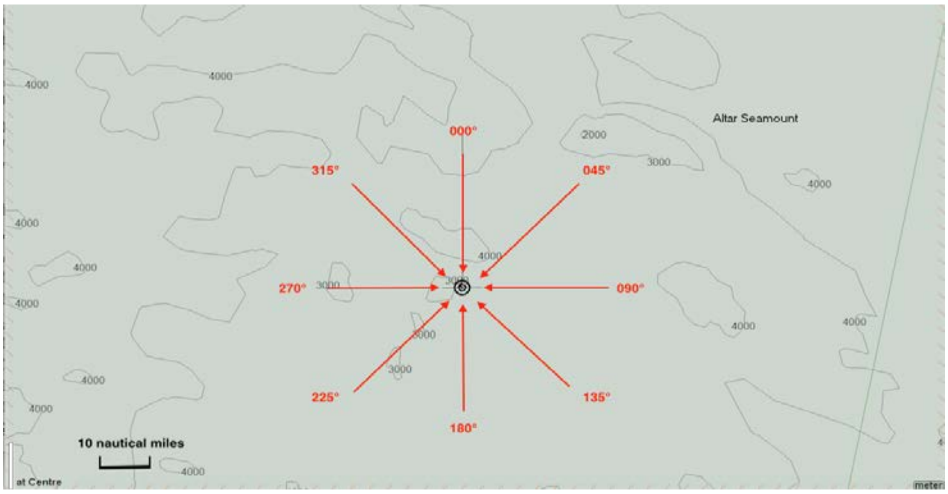
Your identity will be hidden

Read about hidden identity. (Opens in a new window)




1) **Collision avoidance takes place in the marked position and not at a later point in time**

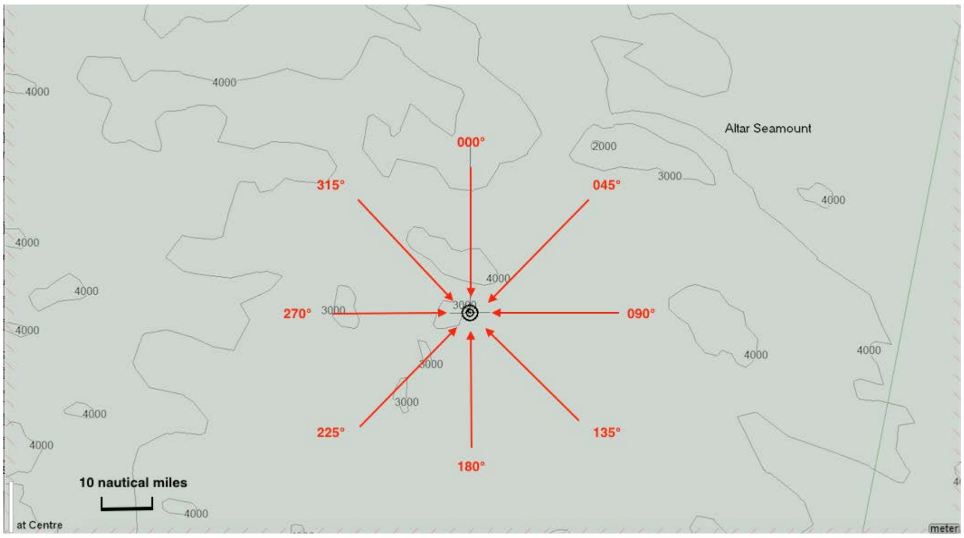
☐ok




**2) OPEN SEA, Own ship data: LENGTH= 50 m, Breadth =11 m, Draught = 3 m, Course = 000° , Speed = 12 knt, Current CPA = 0.0 NM Question: You are Officer of the Watch, what is the closest point of approach (CPA) you would be comfortable letting a targeted ship pass your own ship? Note: Collision avoidance takes place in the marked position and not at a later point in time. Answer with one decimal, in nm.**

* 000° * 045° * 090° * 135° * 180°

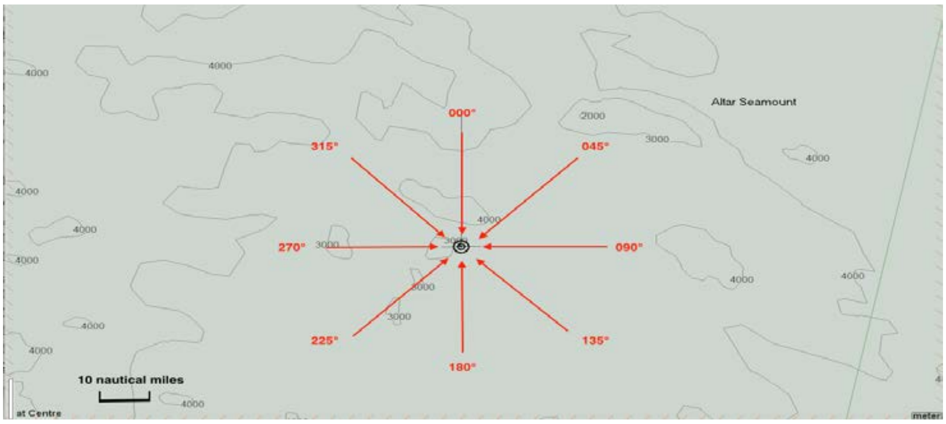
* 225° * 270° * 315°



**3) * OPEN SEA, Own ship data: LENGTH = 100 m, Breadth =20 m, Draught = 5 m, Course = 000° , Speed = 12 kt, Current CPA = 0.0 NM Question: You are Officer of the Watch, what is the closest point of approach (CPA) you would be comfortable letting a targeted ship pass your own ship? Note: Collision avoidance takes place in the marked position and not at a later point in time. Answer with one decimal, in nm.**

* 000° * 045° * 090° * 135° * 180°

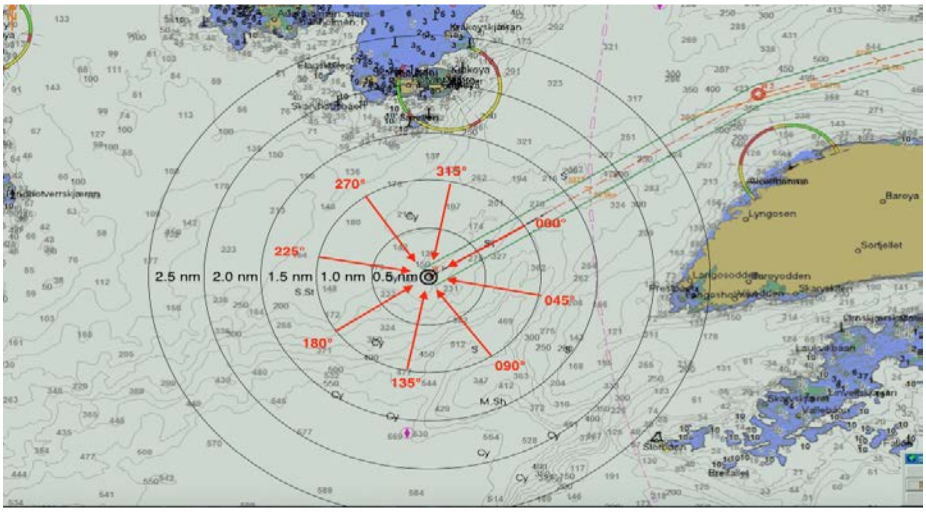
* 225° * 270° * 315°




**4) OPEN SEA, Own ship data: LENGTH = 200 m, Breadth =32 , Draught = 10 m, Course = 000°, Speed = 12 knt, Current CPA = 0.0 NM Question: You are Officer of the Watch, what is the closest point of approach (CPA) you would be comfortable letting a targeted ship pass your own ship? Note: Collision avoidance takes place in the marked position and not at a later point in time. Answer with one decimal, in nm.**

* 000° * 045° * 090° * 135° * 180°

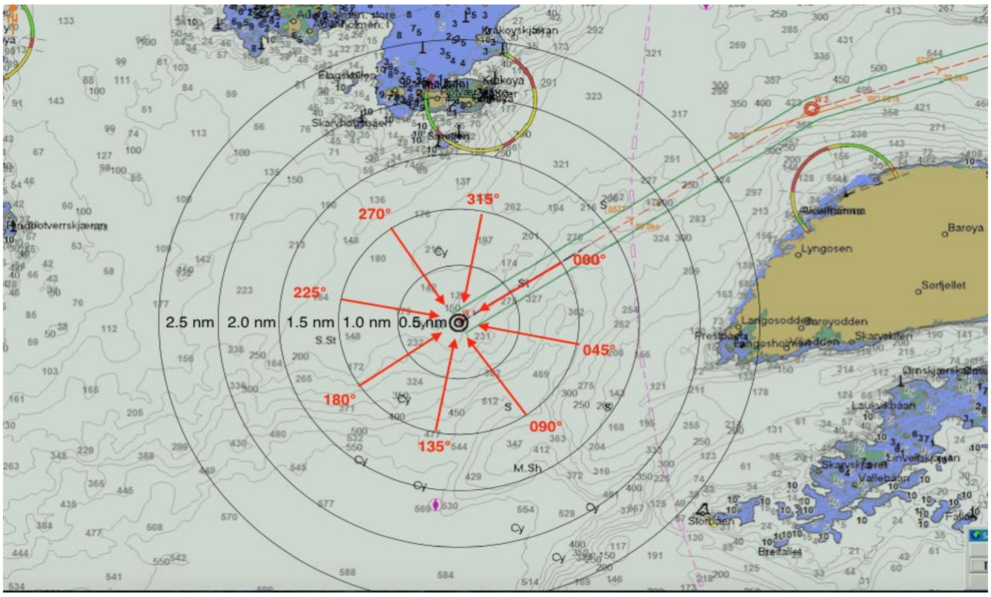
* 225° * 270° * 315°




**5) RESTRICTED WATERS, Own ship data: LENGTH= 50 m, Breadth =11 m, Draught = 3 m, Course = 057° , Speed = 12 knt, Current CPA = 0.0 NM Question: You are Officer of the Watch, what is the closest point of approach (CPA) you would be comfortable letting a targeted ship pass your own ship? Note: Collision avoidance takes place in the marked position and not at a later point in time. Answer with one decimal, in nm.**

* 000° * 045° * 090° * 135° * 180°

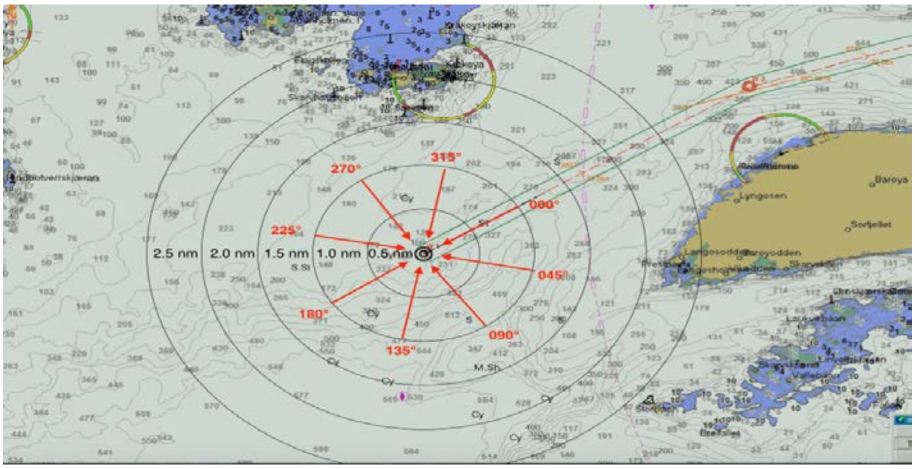
* 225° * 270° * 315°



**6) Own ship data: LENGTH = 100 m, Breadth =20 m, Draught = 5 m, Course = 057° , Speed = 12 kt, Current CPA = 0.0 NM Question: You are Officer of the Watch, what is the closest point of approach (CPA) you would be comfortable letting a targeted ship pass your own ship? Note: Collision avoidance takes place in the marked position and not at a later point in time.  Answer with one decimal, in nm.**

* 000°  * 045°  * 090°  * 135°  * 180°

* 225°  * 270°  * 315°




**7) RESTRICTED WATERS, Own ship data: LENGTH = 200 m, Breadth =32 , Draught = 10 m, Course = 057°, Speed = 12 knt, Current CPA = 0.0 NM Question: You are Officer of the Watch, what is the closest point of approach (CPA) you would be comfortable letting a targeted ship pass your own ship? Note: Collision avoidance takes place in the marked position and not at a later point in time.  Answer with one decimal, in nm.**

* 000°  * 045°  * 090°  * 135°  * 180°

* 225°  * 270°  * 315°

**8) * Gender?**

☐Female ☐Male

**9) * What is your nationality**

**10) * What is your age?**

**11) * How many years, as a seagoing experience, as an Deck Officer do you have?**

**12) * What was your last rank onboard?**

**13) * Which Deck Officer Certificate are you currently holding (or if outdated, which was the last you held)?**

- STCW Deck Officer Class 1, Master Mariner
- STCW Deck Officer Class 2
- STCW Deck Officer Class 3
- STCW Deck Officer Class 4
- STCW Deck Officer Class 5
- none of the above

**14) * What type of ship(s) are your sailing experience from? (multiple answers possible)**

- ☐ Passenger ferries
- ☐ Cruise ships
- ☐ Tankers
- ☐ Container ships
- ☐ Offshore vessels
- ☐ Bulk Carriers
- ☐ Fishing vessels
- ☐ Large Sailing vessels
- ☐ Naval ships
- ☐ None of the above