THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

“What are your intentions?”

-On Understanding Ship Bridge Decision Making

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Abstract

This thesis discusses central aspects of decision making on a Ship Bridge in its natural context with focus on the task of navigating in fairway. The background springs from the fast development of instruments related to work on the ship bridge. If not implemented and used correctly new technology may even contribute to accidents.

Initially a field study and a Hierarchical Task Analysis (HTA) are described. These exemplify how the task of navigation in fairway can be described and uncover aspects worth further investigation. Examples of results of the field study are examples of risk, differences in expected workload between Masters and Pilots and Pilots preferences of instruments. The HTA work model is used to identify and describe ordinary problems of navigating in fairway.

This is followed by a detailed proposal of a study in a full mission bridge simulator using a composite of data collection methods. The main objective of the proposed study is to compare two ship bridge types, one equipped with advanced technology and the other one equipped with traditional instruments. A second objective is to evaluate the different data collection methods to find out more about how this kind of data could be collected.

More knowledge of decision making on a ship bridge could be of use when discussing changes of instruments or work organisations related to a ship bridge, promoting safety and efficiency.

Preface and acknowledgement

During the last three years I have had the possibility of doing a very interesting voyage into a whole new professional world. I have not only joined a profession my self, in the world of academia, I have also had the opportunity to study work in the maritime domain. This had not been possible without the help of many colleagues, friends and organisations.

I would like to thank my supervisors and mentors. Olle Rutgersson for academic support and for opening doors, this work had not been possible without your way of thinking in new directions. Tommy Gärling, who with an open mind agreed to supervise me as a PhD student from a somewhat different background. You helped me open the door to the world of decision making, thank you. You have been a profound support, both with knowledge and time, during our meetings and when commenting my work you have inspired me. Margareta Lűtzhöft, thank you for your help and insights, sometimes I feel you have almost been “towing” me. Thank you for your patience and day to day support along the project. Amongst much you have showed me the values of thoroughness and how the track of “small” things adds to efficiency. I would like to thank Hans Hederstöm for introducing me to the maritime profession in general and the work on the ship bridge in particular. Over time I feel that we have covered a wide area from what jacket to wear, and when, to practical navigation techniques at M/S Poseidon. Your passion for the work on the ship bridge has been enjoyable to experience.

Thank you, colleagues at the Department of Shipping and Marine Technology for support, feedback and interesting conversations. Naming all of you with your individual contribution would be an essay in itself. In short, thank you for comfort and inspiration. Especially I would like to thank Martin Schreuder both for at start introducing me to the world of ship and damage stability, which I believe made the rest of my journey easier, and for interesting discussions on a more philosophical level.

This work would not have been possible without a lot of cooperation from organizations outside Chalmers. Of course I thank the sponsors, Swedish Maritime Administration and VINNOVA for trusting in our work. I also want to thank all the participants in the reference group for taking time to listen and for giving advice. Thank you all personnel at the Swedish Maritime Administration and Shipping Companies who made access to the practical part of our studies easy. Special thanks to all Pilots, Boatmen, VTS-personnel, Masters and Crews at ships and interviewees on land who welcomed us into their work. This research would not have been possible without your naturalness, flexibility and understanding. Thank you personnel at the Norrköping harbor for helping us with ship contacts and access to the harbor area, you have been very understanding and helping.

Leena Norros, at VTT, Helsingfors, thank you for interesting conversations, your work have inspired me. I would also like to dedicate a special thank you to Joakim Dahlman, Linköping University Hospital for accepting the invitation of discussing my thesis.

At last but most, a warm thanks to my family for being there for me. Nella, tank you for your support and love, to have you in my life is for me an inspiration in it self. Ville my son, 4 years old this Thursday, thank you for your love and the help with increased understanding of different perspectives whilst putting my pedagogical skills at test. For example with questions like “How long is the heaven?”

Robert
Göteborg, October 2007

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1 Introduction

"What are your intentions?" is a frequent question asked when two ships communicate because of doubts regarding the intended future position or actions of any of the involved ships. The intention with this thesis is to present proposals of how to obtain more knowledge of the work on the ship bridge in general and to understand factors affecting Ship Bridge decision making in particular. The research mentioned in this thesis is a part of the project "Knowledge based platform for the development of the interaction between technical systems, work organization and the decision making on the ship bridge" mainly sponsored by VINNOVA and partly sponsored by Swedish Maritime Administration. The subject is of interest to the maritime domain, one example of this is an investigation launched by the Swedish Government, through the Ministry of Enterprise, Energy and Communications, in December 2006 (Kommittédirektiv 2006:116). The investigation was to concern how new technology can be used to facilitate piloting and make it more efficient. The ministry also wants to investigate the prerequisites for "shore based pilotage".

This thesis springs from an interdisciplinary project including both technology and psychology. When aiming at enhanced knowledge of the work on the ship bridge understanding both the environment, including technological constraints, and human factors is essential.

1.1 Background

The development of technology related to the ship bridge and its implementation has been rapid during the last decades, especially automation technology. One example is the introduction of computer systems for navigation. When comparing the number of equipment specified by ISO-standards at the main workstations between 1990 and 2006, Lützhöft et al found that it almost had been doubled from 22 to 40 items (Lützhöft, 2006).

One example of new technology, still not implemented although tested as a prototype, is a program for calculating ship stability related to ship managing. The program can instantly calculate a value indicating the ship stability. This is very useful when loading cargo but of special interest in case of damage to the ships hull (Nilsson & Rutgersson, 2006a). To obtain information and calculate ship stability in a damage situation is a difficult, possibly even hazardous from work safety perspective, and time consuming process. This kind of instrument with connected gauges and computers to perform calculations makes vital information easily accessible and is intended as a decision support. When reasoning about decision making in crises it is a reasonable starting point to examine the decision making on the ship bridge during normal circumstances.

Another example of new technology is the ECDIS (Electronic Chart Display and Information System), which is one of the instruments that can be found on a ship bridge that has been equipped with the latest technology. The functions and information flow in and out of ECDIS can be seen in Figure 1. ECDIS is a good example of an instrument that can replace several other instruments and increases the operator's possibility to stay at the same place on the ship bridge when solving different tasks. Today the ECDIS can be used to create, display and monitor a route plan without a paper chart. One can also obtain information about other ships speed and position, which former was given by another instrument. The ECDIS may offer possibility to integrate the image of the Electronic Chart System with the radar image, which in turn render possibility to compare the virtual chart with an image of the reality from the radar.

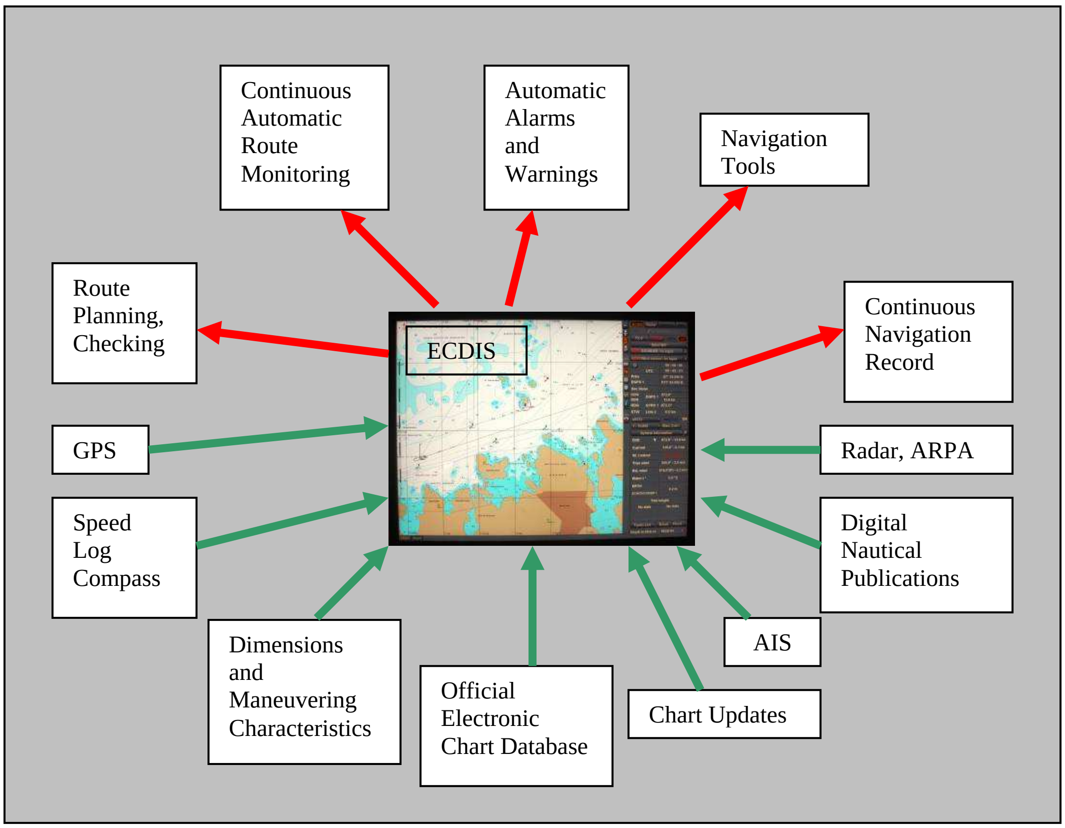

Figure 1. Functions and information flow in and out of an ECDIS.

Information that easily can be obtained is not in itself equivalent to higher safety. This can be exemplified by the accident of "Royal Majesty", where information regarding the position of the ship was unreliable (Lützhöft , 2002). New technology does not automatically or necessarily mean higher safety. It depends on how well the operator knows the instrument and its constraints. New bridge equipment is automated to a higher level, computers do calculations and information that earlier were spread can be gathered in one place. The automation of the ship bridge has possibly led to that the work to a higher degree consists of monitoring and supervising tasks (Kerstholt & Passenier, 2000).

New possibilities are in it self not always beneficial. There is at least one example where radar instructors have identified new behaviours during simulator training that actually violated existing rules for navigation (Lee & Sandquist, 1993). It is easy to imagine that one would be calmer with navigating closer to another ship if you had trusted information about a distance, assumed to be enough, to another ship than if you would have had to base the same navigation decision on more apprehensive information. Another interesting issue is that although it has been shown that integrated displays tend to give navigational advantages it also incurs higher operator cost, particularly fatigue (Saur et al, 2002). If the navigational advantages are to be prioritized it would be logical to ask ourselves if the bridge organization supports this increased operator cost?

1.2 Research objectives

The work on the ship bridge is complex and dynamic. To be able to learn more of this work, it is necessary to decide what an appropriate starting-point for research is. It is also necessary to make some assumptions and impose constraints. In this section the aim of the research, central questions at issue and constraints are presented.

1.2.1 Aim of the research

The aim of this research is to learn more about the work that is being conducted on the ship bridge with focus on the task of *navigating in fairway*. Central for this research are personal experiences of the work on the ship bridge and an increased understanding of the consequences of given prerequisites.

The aim is further to propose a composite approach of research that will provide a platform of basic knowledge about different instrument and technological settings, that are currently used on ship bridges, from the perspectives of safety and efficiency. An additional outcome of this research is a possibility for a broader Human Element Awareness which according to P. Ayllot (Göteborg, 26 June 2007[1]) is promoted by the Regulations of Standards of Training, certification and watch keeping for seafarers (STCW).

1.2.2 Central questions

Two central questions are posed. Both questions aim at increasing the knowledge of work that is conducted on a ship bridge in order to increase reasoning about how technology can be used in a supportive and efficient manner.

[1] Transas Simulation users Conference, title of presentation: "Standards of training, Certification and Watchkeeping 78/95"

1 A clear description of the task of navigating in fairway
This question aims at identifying important features or themes that could be studied further. One first step is to identify and learn more of central tasks and their goals.

2 Design measurements to be able to assess the work on a ship bridge
To be able to compare different conditions, to identify possible effects of different technology related to the ship bridge and factors related to decision making, appropriate measurements need to be identified.

1.3 Constraints

The task of navigation can differ depending on the ship to be navigated and the area to be navigated through. Normally there is no need for piloting out in the open sea. When modelling the pilot task, Norros (2004) divided piloting into two different types of piloting called sea piloting and harbour piloting. Sea piloting refers to the navigation through the archipelago and/or fairways and harbour piloting refers to the "maneuvering of the ship in the harbor area" (Norros, 2004, p. 186). The focus of this research will be *navigating in fairways*, which is comparable to what Norros refers to as sea piloting.

Safety issues are central for the interest in understanding factors affecting navigation in fairway. An accident close to shore may have a direct impact on several stakeholders. One example is the accident of the oil tanker Prestige outside of Spain and Portugal on the 19th November 2002. A lot of oil leaked into the ocean and actions for mitigation of consequences were delayed due to argumentation about responsibility. An accident of this kind can have high potentials of collateral damage affecting the environment.

There is an interest from the shipping industry in Sweden to make sea transports more efficient, to some extent through possibilities provided by new technology. The Swedish Ministry of Enterprise, Energy and Communications launched an investigation in December 2006 on possibilities regarding the use of new technology related to piloting. Navigating in fairway is a central part when piloting in the Swedish archipelagos. Norros (2004) discuss the effect of "habits" on task solving. These "habits" may develop differently in different organisations and cultures. In this study we are primarily interested in the situation in Swedish waters, and the work situation related to "habits" that may develop here.

This research is based on the assumption that humans use the best possible methods and work strategy available to solve problems and achieve goals under given circumstances. Although humans do their best there is no possibility to know everything and decisions and actions have to be taken on the basis of available information and interpretations, this limitation and work constraint has earlier been referred to in different theories as *bounded rationality* (Simon, 1982), *ecological rationality* (Gigerenzer, 1999) or *local rationality* (Woods et al, 1994). We strived for high ecological validity which means that we set out to study the task of navigation in its natural setting and wanted to focus on studies and methods that could be used closely related to the natural work and the task in its wholeness. We did not want to separate the task into small pieces and study them separately in fear of missing factors that could have an effect on the work in situ.

2 Frame of reference

In this section the frame of reference is presented, both regarding the equipment available on the ship bridge and central scientific theories.

2.1 Systems related to the ship bridge

One part of this research is to study human-machine interaction. The aim of using aids like machines is to perform well according to the expected goals and objectives. Smither (1998) writes:

> “Human factors is often defined as the study of ‘human-machine systems.’ From a human factors perspective, the machine and its operator are a system that must be considered as a whole. For example, a pilot and a control panel, or a typist and a word processor, are actually systems with mutually interdependent parts designed to accomplish some goal. Aspects of both parts - operator and machine - affect production” (p. 448).

Although we want to study human behaviour on the ship bridge as a part of a whole system, we still need to be able to talk about the different parts of work or instruments and their potential effects. To give readers, with less ship bridge experience, an introduction of the technical systems and information sources central for the work on the ship bridge will be presented. Readers with bridge experience may move to section 2.2.

2.1.1 Systems on the ship

In Figure 2 an example of how a ship bridge can be equipped and look like is shown, in this case the bridge in a full mission bridge simulator at Chalmers University of Technology. On the centre table instruments and controls for navigation can be seen. Electronic Navigation Charts and Radars are available on both sides of the centre table. In the middle of the displays the conning display provides information about the ship like for instance speed, draught and course. CCTV is a monitor used to show the function of binoculars in a simulator. The table for nautical chart is not shown in Figure 2, in that picture it is placed right beneath the position of the camera taking the picture.

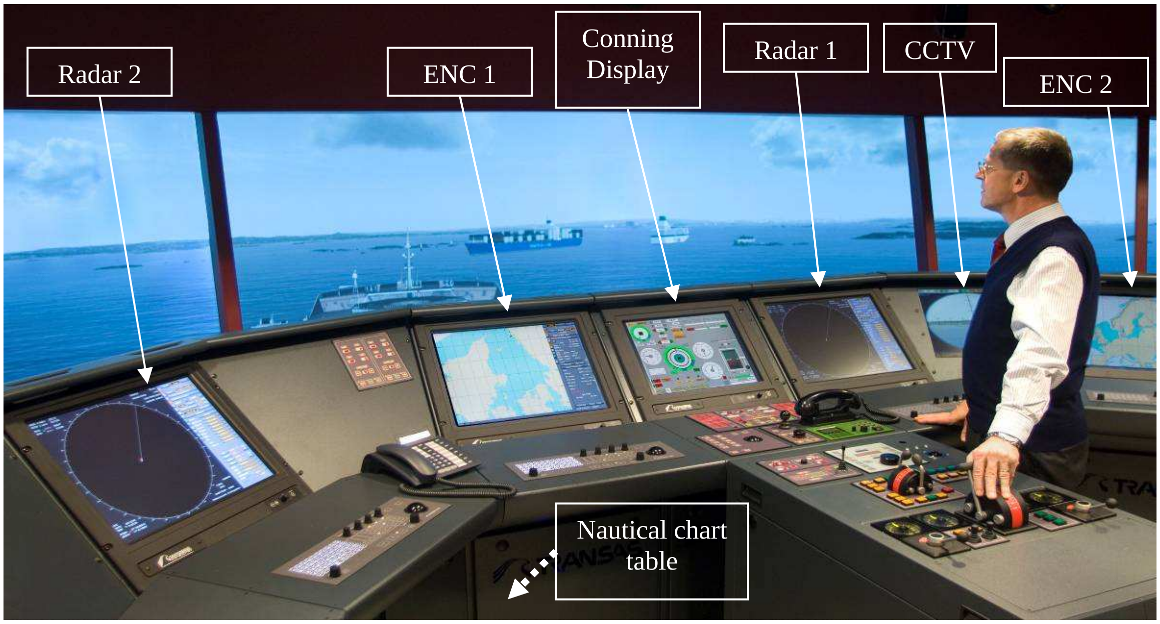

Figure 2. Example of a ship bridge and positions of instruments.

The following parts of the bridge system will be further described as they are central for navigation in fairway and serve as basis for understanding the ship system from the perspective of instruments that are used on the ship bridge:

- RADAR
- Nautical Charts
- Passage plan
- GPS
- AIS
- Means of Communication
- Depth indicator
- Compass
- Speed indicator

RADAR

RADAR (Radio Detection And Ranging) is an instrument that can be used both as means for navigation and traffic control. The RADAR can provide information that enables understanding of the surroundings by sending out radio waves. These radio waves are reflected by different objects in the surroundings and then received. The distance and position of objects, large enough to be detected, relative to the sending RADAR are then presented as an image at an screen called PPI (Plan Polar Indicator). In this way the RADAR functions as a digital eye and information from the RADAR is often described as “the reality”. Two functions available on the RADAR are Variable Range Marker (VRM) and Electronic Bearing Line (EBL). These can be used to establish distance and bearing to different objects in relation to the ship.

ARPA (Automatic Radar Plotting Aid) is a collision warning system. In 1976 technical demands for an ARPA were established. According to International Maritime Organization (IMO) the convention of SOLAS 97 (the rules of Safety Of Life at Sea) al ships bigger than 10 000 BRT built after 1984 and all tank ships must be equipped with an ARPA, unless there are some circumstances for exception due to traffic area. The ARPA is an aid for plotting (marking) other ships and is connected to the RADAR. Its function is to show other ships speed and course thereby provide information about the traffic situation and how it is changing due to other ships.

Nautical Charts

A nautical chart is a representation of the topography of the sea bed. Basically a nautical chart provides information regarding the depth of water. The depth can be based on data collected from the 19th century and its accuracy varies between different areas depending on how careful depth soundings have been done. To establish reliability The International Maritime Organisation and the International Hydrographic Office have set demands regarding the accuracy of charts (Navigation 3 – navigering med teletekniska hjälpmedel, p.155-156). In Figure 3 an example of a nautical chart table can be seen.

Figure 3. Example of a nautical chart table.

Besides the traditional paper charts, nowadays electronic charts are available. A part of a paper chart can be seen in Figure 4 and a part of an electronic chart system can be seen in Figure 5. An Electronic Chart System (ECS) is basically an electronic representation of the traditional paper chart. The electronic chart allows the information from the nautical chart to be integrated with other systems like for example the RADAR or AIS (Automatic Identification System). If an ECS can satisfy demands and guidelines regarding technical standards of compatibility with other equipment, issued by IMO, the ECS can be considered as an ECDIS.

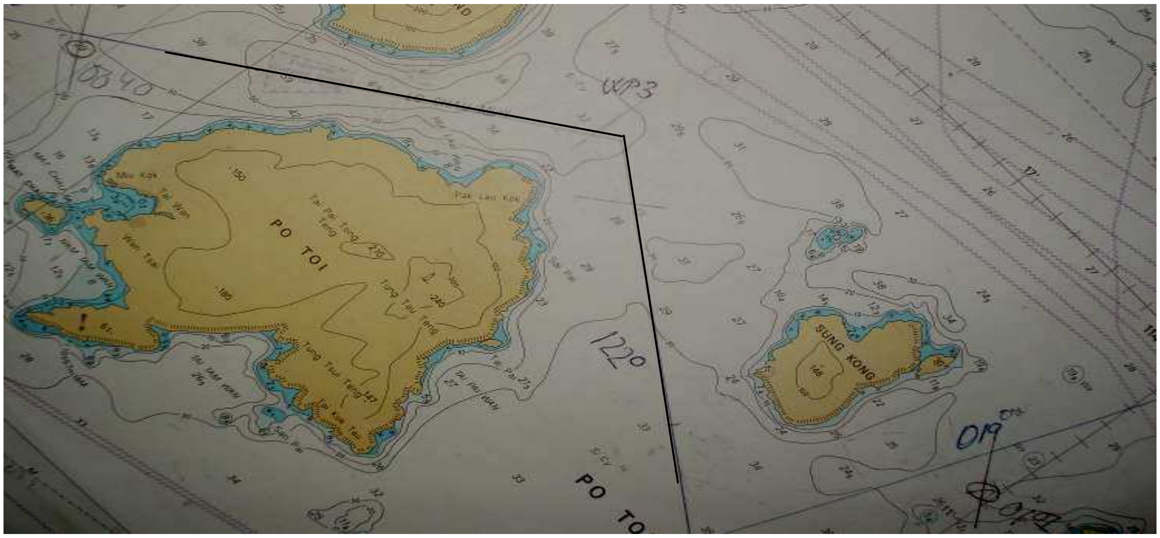

Figure 4. Picture of paper chart with a segment of a passage plan marked.

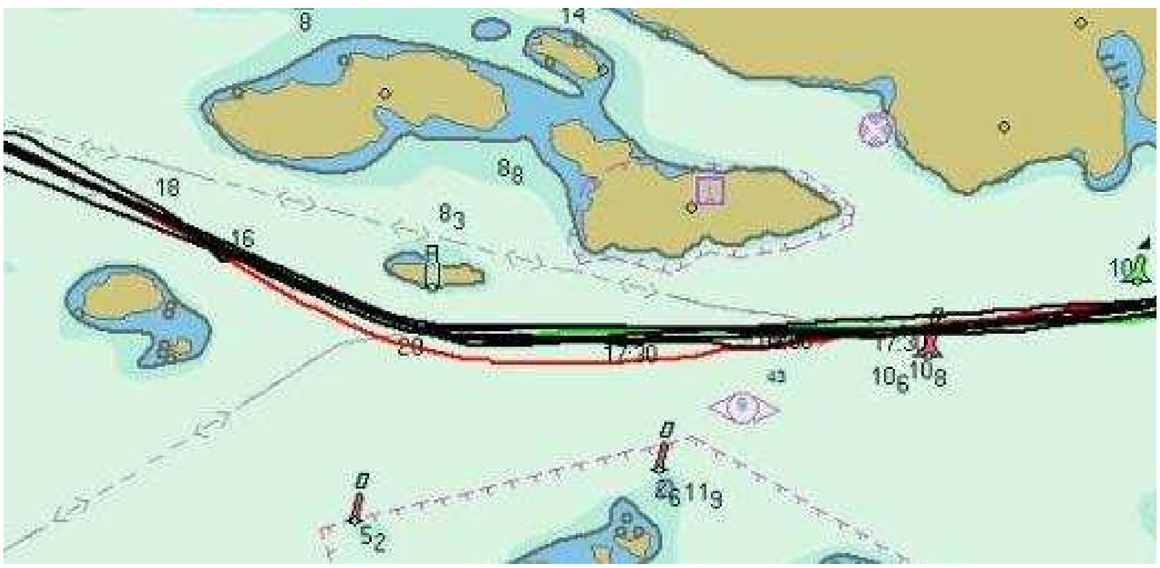

Figure 5. Image of Electronic chart with trails of passages marked.

Passage plan

The Master of a ship is responsible for having a passage plan for the whole passage from "quay to quay". The passage plan ought to be marked in an approved nautical chart and also ought to include information related to safe navigation of the ship. Part of a passage plan: track, heading for one of the legs and waypoint number can be seen in Figure 4 above.

According to the Bridge Procedures guide:

> "The passage plan should aim to establish the most favourable route while maintaining appropriate margins of safety and safe passing distance offshore. When deciding

upon the route, the following factors are amongst those that should be taken into account:

● the marine environment;
● the adequacy and reliability of charted hydrographic data along route;
● the availability and reliability of navigation aids, coastal marks, lights and radar conspicuous targets for fixing the ship along route;
● any routeing constraints imposed by the ship e.g. draught, type of cargo;
● areas of high traffic density
● weather forecasts and expected current, tidal, wind, swell and visibility conditions;
● areas where on shore set could occur;
● ship operations that may require additional searoom e.g. tank cleaning or pilot embarkation;
● regulations such as ships' routeing schemes and reporting systems;
● the reliability of propulsion and steering systems on board." (1998, p.17)

GPS

GPS (Global Positioning System) is a radio navigation system that is provided by the Defence Department of the United States of America. A European system Galileo is under development. The systems are based on satellites which are sending signals containing information of their position. These signals are in turn collected by a receiver on the ship allowing the system on board the ship to determine the position.

If a more accurate data than the one provided by the GPS is wanted there is a possibility to use Differential GPS (DGPS). The DGPS-system is enhanced through an additional station on land called reference station that sends information regarding the reliability and corrections regarding the satellites in space. By using these stations on land more accurate position data can be obtained.

AIS

AIS (Automatic Identification System) is a system that provides information about other ships that is transmitted either between ships or between ships and land. The positioning system in the AIS is based on GPS information. Other information available on the AIS include name of the ship, course, speed, depth and destination. AIS information can either be represented on a Minimum Keyboard Display (MKD) or integrated in an electronic chart. Example of how a MKD look like can be seen in Figure 6.

Figure 6. Example of Minimum Keyboard Display.

Means of communication

A ship is equipped with a radio for external communication as well as an internal communication system. Traditionally a VHF-radio is used for external communication. Computer communications (internet and email) and cellular phones are becoming more regular and hence these means of communications are also used in the work.

Depth indicator

Information about the depth is, on merchant ships, most commonly acquired through an echo-sounder that emissions a pulse at a certain frequency (sonic “ping”) towards the bottom. This pulse is reflected and received and hence the actual depth can be calculated and presented on the ship bridge.

Compass

Information regarding the ships bearing is according to regulations acquired by a gyro-compass and/or a magnetic compass. The gyro-compass is commonly used. It is exposed to different kinds of disturbances, like for example accelerations in different directions. The values from the gyro-compass can be compared to the magnetic compass. When navigating, two terms related to the ship direction is used, Course over Ground (COG) and heading. The ship can be affected by current and/or wind and the heading, direction of the bow related to the north, can differ compared to the COG which is the direction of the ship movement related to North.

Speed indicator

Two different terms are used to relate to the ships speed. One is *speed over ground* which can be acquired through the GPS or a Doppler log. The Doppler log uses sound pulses to measure relative motion between the ship and the ocean bottom. The other term is *speed through water*.

The values can be slightly different depending on current and/or wind. Speed through water is measured by an electromagnetic log or a Doppler log.

2.1.2 Systems outside the ship

Perception of systems outside of the ship bridge can be essential for how the situation on the ship bridge is experienced and can thus have a great impact on the decisions on the ship bridge. In this section examples of factors outside the ship will be presented.

Fairway

In Figure 7 a picture of the last part of the fairway to the harbour in Norrköping can be seen. On the top to the left you can see a lighthouse and how the fairway is marked by buoys. The marked part is a channel called “Pampusrännan”. Essential information regarding the fairway is how it is constructed, examples of important features are:

- How the fairway passage is marked with buoys
- How deep the fairway is
- How wide the fairway is
- How special circumstances like grounds are indicated by floating or permanent markings

Figure 7. Example of a fairway, with a lighthouse and buoys marked.

Surveillance
VTS (Vessel Traffic Service) is used for information regarding traffic and other information that can be relevant for the ship like for example special conditions regarding bad weather.

2.2 Decision Making Research

In this section decision making research that relates to the present research is presented. First an introduction is given and then frequent data collection methods are described.

2.2.1 Introduction to decision making research

Since the beginning of research regarding decision strategy and screening for choice, which started with Bernoulli in 1738 and Pascal in 1670, "decision theories has provided strategies to guide decision making" (Zsambok, 2002, p.5). Since the beginning this research has developed into different directions using different methodology. In the beginning it was often assumed that the human being to a very high degree was rational and made decisions on the basis of some kind of objective logic based on what the best possible outcome of the situation was, as if all affecting factors were known and could be considered. *Classical decision making* theories are based on these assumptions. The research continued and eventually there was a belief that humans made decisions based on *expected values*. *Expected values* played a fundamental part in *normative decision making* that assumes that there is a best solution for the given problem. *Normative decision making* can be considered as prescriptive since results often were based on how people should do to perform the best. These theories proved to be inadequate descriptions of how decisions are made and evidence presenting contradictory results regarding *normative theory* was presented (Kahneman, 2000). From the background of these contradictories a new direction called *descriptive theory* was formed. Descriptive theories aim at explaining intrapsychic decision process. One example of a descriptive theory is "prospect theory" presented by Kahneman & Tversky (2000). P*rospect theory* posits the existence of several alternatives to chose among when making a decision. The alternative which will have the highest value for the decision maker will have the biggest impact and hence be chosen. This value is dependent on a personal reference point regarding individual and subjective estimates and can hence be difficult to specify.

Traditionally a lot of focus within the cognitive area has been directed towards subjective *expected values*. This has according to Juslin and Montgomery (1999) led to many phenomena showing that human are victims of cognitive limitations in the decision making process. The human is described as a victim due to the reason that she can not reach the high rational demand that is expected. There are thus theories based on the perspective that humans do what they think is the best, that they believe their decisions to be the best and that they are not victims but actors as a part of a system (Zsambok et al., 1997, Gigerenzer et al., 1999, Woods et al., 1994, Hollnagel, 2002).These theories turn from the perspective of an objective logic that everybody supposedly can use and focus on systems consisting of available information and interpretation of information. Based on these premises decisions cannot be studied as separate and individual actions but only as a part of a system. Decision processes and actions ought not to be evaluated by normative and best possible ratings from an objective perspective but by ratings related to the constraints of the situation.

Within the Swedish decision making research there has been a tradition of following a different philosophy than the classical decision making and subjective expected values. One line of research in Sweden "has been influenced by the probabilistic functionalism of Egon Brunswik" (Juslin & Montgomery, 1999, p.2) that advocated *ecological models,* which propose that the situation that is to be examined to a high degree must correspond with the real problem and situation that is under investigation. This Brunswikian line of research was unusual in the rest of Europe before 1965 (Hammond, 1999). In several cases "microworlds" like for instance computer simulations of a system designed to artificially resemble reality have been used. Microworlds have been a popular method for research within theories of *dynamic decision making*. Research within d*ynamic decision making* grew from the disappointment of not getting adequate answers to some problems using *normative models*.

> "it is concerned with what people actually do in these kinds of tasks, rather than with the optimality of their decisions. As we examine their behaviour, we shall find that although this behaviour may not be optimal, it is at least reasonable in the sense that it 'gets the job done'… they explain why the world is not in the sad state that we would expect from the blanket statement that man is an irrational and incompetent decision maker"(Brehmer,1999, p.10).

Brehmer further states that "dynamic decision tasks have three important characteristics:

- they require a series of interdependent decisions;
- the state of the task changes, both autonomously and as a consequence of the decision makers actions;
- the decisions have to be made in real time." (1999, p10)

The decisions that have to be made on a ship bridge can be considered as dynamic. A clear example is the task of navigation in confined water like for instance an archipelago. The ship has to be manoeuvred from one position and place to another. The movement of the water around the ship is affecting the way that manoeuvring has to be conducted and how the ship reacts to the current position is partly dependent on how the ship was brought in to the position. When planning ahead for the next manoeuvre one needs to estimate how the ship will be affected regarding the transition from the current position to the next. Thus, decisions are interdependent and the state is changing both autonomously and due to previous decisions. How to manoeuvre the ship has to be decided in real time.

Another research area that grew from the unsatisfactory explanations of *classical decision making* is *naturalistic decision making* (NDM). Within *naturalistic decision making* focus is directed towards how decisions are made in natural problem or work settings where the context is assumed to have great impact on decisions that are made and may thereby not be neglected. "NDM is the way people use their experience to make decisions in field settings" (Zsambok, 1997, p.4). This direction within decision making research has also focused on differences between how experts and novices make decisions in their natural environments and context.

Eight key contextual factors that affect the real-world decision making and that distinguish NDM from traditional decision making paradigm are according to Zsambok (1997, p 5):

1. Ill structured problems (not artificial, well structured problems)
2. Uncertain, dynamic environments (not static, simulated situations)
3. Shifting, ill-defined, or competing goals (not clear and stable goals)
4. Action feedback loops (not one shot decisions)
5. Time stress (as opposed to ample time for tasks)
6. High stakes (Not situations devoid of true consequences for the decision maker)
7. Multiple players (as opposed to individual decision maker)
8. Organizational goals and norms (as opposed to decision making in a vacuum)

Several of these key factors can be traced to the dynamic work on the ship bridge. Unexpected situations like breakdown of machines or instruments can be treated as ill-defined problems. In bad weather, which can occur very sudden and unexpected, both high stakes and time pressure can be experienced on the ship bridge. On bigger ships there are normally more than one person working on the ship bridge and then decisions can be assumed to be affected by multiple players.

One model closely related to NDM is Recognition Primed Decision making (RPD) theory (Klein, 1997). This theory was formulated in 1985 and was one of the themes under consideration when the NDM-label emerged in 1989 (Zsambok et al., 1997, Lipshitz et al., 2006). The theory treats how decision makers make decisions based on a merge of earlier experience and knowledge. A situation (or problem) is assessed and some central cues important for the situation at hand are identified. These cues guide the decision maker, through the individual bank of experience and knowledge, towards a solution that is regarded the best. No choices between different options are necessarily made.

2.2.2 Example of methodology used within decision making research

Until the 1990s mainly two methods have been used for studying underlying cognitive processes (Ford et al., 1989). One is *structural or statistical modelling* and the other is process modelling. "*Structural models* focus on describing the relation between information stimuli (input) and decision responses (output)" (Ford et al., 1989, p75). By manipulating factors for input and measuring factors for output statistical models are developed in order to predict individual choices and to draw inferences of possible underlying cognitive processes. Ford et al. states that research using *structural modelling* has shown robust linear models for predicting choices. They further states that there are models that according to Einhorn shows more than the prediction of judgments "they may capture a fundamental characteristic of the decision making process" (Ford et al., 1989, p.76). From another perspective the statistical model may give more information about how the model agrees with the task or problem characteristics than it indicates characteristics of human behaviour. Two different underlying processes may have characteristics that in some way resemble each other without actually being the same, although they are assumed to be the same, perhaps because of the low sensitivity in the statistical model. This means that the model could predict the right decision but for the wrong reasons. How these models are developed have an effect on the possibility of generalisations and applicability. *Process modelling* focuses on observing behaviour before a decision and the process that led to a decision (process tracing). Two common techniques are *verbal protocol* (think aloud) and *information boards*. Both techniques can be used to identify different decision strategies. Verbal protocols have according to Payne et al. (1993) been argued to be valid and can provide information regarding intermediate stages of decision making processes. Payne et al. further state that verbal protocols is a useful technique regarding tracing cognitive process but also stresses that they are labour intensive (Payne et al., 1993, p.145). The verbal protocol works best if the protocols are interpreted in relation to a theory or model. Problems can occur if thoughts are hard to verbalize and there is a risk of missing parts if the participants them selves have forgotten them or are unaware of them. Only processes that are conscious can be traced with the verbal protocol but of course this method could be combined with observations of information search (*information boards*).

An information board usually involves the task of choosing between existing alternatives. If studies of information search are to be conducted, the information search has to be observable. There can be a problem to follow the work if the registration of information search involves an unnatural behaviour, for example, might directing markers and clicking with a mouse instead of just looking at an icon contribute to additional cognitive work load. Payne et al. has also conducted simulations of decisions. Different decision strategies were developed and later assessed by measuring effort through Elementary Information Process (EIP) measured in time units. The strategies were then tested under different conditions and the results indicated that results from simulations agreed with the results from observing participants doing the information search. Of course, think aloud, information search, questionnaires and regular interviews can be combined.

Methods of task analyses have been developed. Examples include Hierarchical Task Analyses (HTA) and Cognitive Task Analysis (CTA). Task analyses can be seen as a method within *process modelling* and aims at identifying central parts of a task through a work analysis. A task is examined through specially developed series of questions and methodology that aim at identifying central and essential parts of the work. CTA in it self has served as starting point and been developed into different methods. One further development of CTA called Applied CTA has been tested if it could be used by layman and proven the method efficient even without any special domain knowledge about the investigated area (Susi, 1999, Lützhöft , 1999). However, it was also shown that these lay men need skill of interview technique and some insights in subjects related to human factors in order to collect good data. Core Task Analysis is another method developed within the later decision making research (Norros, 2004). In addition to a work analysis this method also includes an examination of the work culture including the tracing of how one usually solves the tasks, so called *habits*.

2.3 Workload

One of the aims of the present research is to identify possible impacts of changes of equipment on the ship bridge. When comparing different ship bridge equipment discussions of workload is of special interest, especially since technology has been more and more automated in order to make tasks easier to perform and hopefully to less human errors. In this section we will present workload as it is related to in this research. Thus, Westrenen (1999) notes

> “The reason that researchers are often interested in mental workload is that there might be an increased level of human failure in situations of high load. However, the relationship between high workload and human failure is not clear” (Westrenen, 1999).

Westrenen (1999), who studied workload during pilotage, further states that there are two types of risks connected with high workload. One is related to a high workload under a long period of time resulting in

exhaustion. The other risk is related to the complexity of task and time pressure. Many decisions have to be made under time pressure and if there is a high workload coinciding with the demand of decision there is, at least theoretically, a higher risk of erroneous decisions.
This kind of reasoning is strengthened by studies showing that problems on a ship bridge are dealt with sequentially (Kerstholt & Passenier, 2000).

According to Wickens & Hollands (2000) workload can be viewed in three contexts: workload prediction, assessment of workload imposed by the instrument and workload experienced by the human operator. The second view aims at optimizing systems whilst the third view aims at choosing between operators or to know more of appropriate training possibilities. Any of the three contexts can initially be “represented by a simplified single-resource model of human processing resources” (Wickens & Hollands, 2000, p. 459), see Figure 8. This model assumes some kind of absolute workload which I believe can be difficult to relate to when you have complex work with several parallel processes that have to be controlled over the same time.

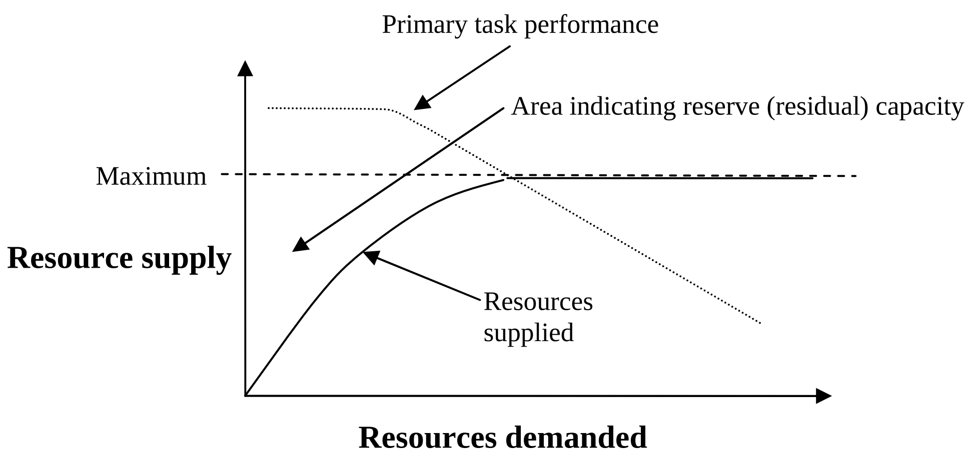

Figure 8. Simplified single resource model (Wickens & Holland, 2000).

Wickens & Hollands list five criteria that should be ideally met when assessing workload:
Sensitivity: the measurement index should be sensitive to task difficulty or resource demands.
Diagnosticity: the measurement index should both indicate workload variations and the cause of variation.
Selectivity: the measurement index should be selectively sensitive only to differences in resources demand that is assumed to affect the workload.
Obtrusiveness: the measurement method should not affect the primary task, especially not when the task is solved in real time and can be related to risk, or include safety perspective, like for instance navigating in confined water.

Bandwidth and reliability: The measurements should be reliable. The measurement should also be able to give information relatively quickly so that transient changes can be estimated.

Three different types of measurements are proposed by Wickens & Hollands (2000): primary-secondary task, physiological measurements and subjective measurements. *Secondary task techniques* is based on the possibilities of estimating how much resources that is left when the primary task is being solved. The secondary task performance is assumed to be inversely proportional to the demands of the primary tasks. Different measurements have been used as secondary task measurements. Some examples are generating series of numbers or produce finger taps at a constant rate. It is important that the secondary task is adequate to the kind of residual resource you want to investigate. *Physiological measurements* can be used to assess workload. When using these methods one measures of manifestation of workload or resource mobilization from autonomic or central nervous system. Examples of measures are heart-rate variability, measurements of pupil diameter and visual scanning. When using these measurements one has to be aware of the possibility that factors not related to the tasks may have an effect on the measurement. If, for instance, a participant suddenly remembers that he has forgotten to pay an important bill, this could affect the heart rate and give unexpected readings. *Subjective measures* are based on self-reports from participants that can be acquired for example through questionnaires or interview questions.

High workload is not necessarily bad, but workload at a level where resources are not enough can have a negative effect. Wickens & Hollands (2000) state that there are at least four different types of adaptations possible for handling excessive workload:

1. People may allow performance of task to degrade.
2. People may perform the tasks in a more efficient way, consuming less resource.
3. People may shed tasks as they experience them to be most optimal, for example not prioritize unimportant tasks.
4. People may shed tasks without taking optimization of the performance into account.

These four types of adoptions may be compared to behaviour changes related to decision making according to a theory proposed by Payne et al (1993). In this theory the tradeoff of accuracy against effort plays an important role. According to Payne et al. one could expect more effort be put into decisions that are perceived to be important, because they are related to higher payoffs. Three strategies for handling higher experienced demands are presented:

1. The decision maker may do more of what he or she is already doing.

2. The decision maker may change some parameters of the decision making strategy that is used.
3. The decision maker may change decision strategy (from a selective non compensatory strategy to a more compensatory strategy).

Payne et al. (1993) further states that “We believe that increased incentives will generally lead to greater effort but not necessarily to the increased use of more optimal (reduced error) decision strategies” (p.14). This can be related to the challenge for designers and producers of decision tools that are to reduce workload and support good decision making. Payne et al.’s theory hypothesizes that people tend to change decision strategy when solving similar tasks depending on the workload. For example is choosing one of two choices related to careful and accurate comparisons between many factors while choosing one out of 20 possible alternatives is related to some kind of selections strategy dependent on key factors weighted as important for the selection. It ought to be mentioned that although this is interesting in it self, Payne et al. (1993) focus on preferences for and choices among alternatives more than “inferences about the real world” (Gigerenzer, 1999, p.26). When solving problems, one does not always have prepared alternatives to chose between. One may need to search for information or even start a process to get some kind of feedback.

Research related to Finish pilots’ navigating in confined water has shown that personal navigation styles affect more of how work is conducted than available technology (Norros, 2004). Westrenen (1999) shows that pilots workload increase as time to boundaries decrease. Boundaries are in that case exemplified by turns in confined water or other traffic related to the own planned passage, the workload increases independent of navigation style as the ship closes the boundary. Questions of knowledge, experience and skill do seem to have an effect, but where and when? If instrument or bridge systems are to enhance safe navigation and make work easier they have to be carefully designed and more knowledge of workload and human performance and limitations, for example related to specific instruments and situations, would be useful.

2.4 Perspective of risk and safety at sea

Taking a ship of the berth is in a way always related to some kind of risk and “Seafaring will never be without its dangers” (Bridge procedures guide, 1998, p. 4). The wide scope of threats to safety can also be understood from the wide description by Boisson (1999):

> ”In expressions of ’safety at sea’ and ’Maritime safety’ safety is both the material state resulting from the absence of exposure to danger, and the organization of factors intended to create or perpetuate such a situation” (p.31).

Boisson (1999) further states that the concept of risk is more difficult to define than safety and states that risk can be interpreted from different perspectives like technical terms or legal aspects by lawyers. He further states that risk, although highly diversified, may be placed under two headings:

> "1. Personal risks, namely injuries and accidents suffered by those aboard ship; such events are the same as on shore, although their consequences may be increased by shipboard conditions;
> 2. Collective risk peculiar to a ship, its cargo or conditions of navigation; these can lead to accidents at sea, injurious events caused by the occurrence of fortuitous circumstances or negligent or deliberate acts" (p.31)

In this study focus is directed towards conditions of navigation. In order to help seafarers to obtain safety at sea some rules and procedures have been proposed. One example related to the work on the ship bridge is the *bridge procedures guide* developed by International Chamber of Shipping (ICS). The recommended procedures are based on internationally agreed rules called STCW (Standards of Training, Certification and Watch keeping for seafarers). In the *bridge procedures guide* ICS stress the importance of safe navigation:

> "Safe navigation means that the ship is not exposed to undue danger and that at all times the ship can be controlled within acceptable margins" (p.5).

Recommendations from the bridge procedures guide and STCW regulations will play a central part in the present research for the assessment of work and performance on the ship bridge. Although one has to understand the context where tasks are solved since:

> "Even for highly constrained task situations such as nuclear power operation, modification of instructions is repeatedly found and operators' violations of rules appear to be quite rational" (Rasmussen & Svedung, 2000, p.13)

Rasmussen & Svedung further state that humans as part of systems seem to develop some kind of work strategies that are followed and that:

> "following an accident it will be easy to find someone involved in the dynamic flow of events that has violated a formal rule just by following established practice…A task description or an instruction is an

> unreliable model of judging behavior during actual work” (2000, p.13)

In the safety at sea policy launched by the Swedish ship owners’ association “Sveriges redareförening” it is the personnel that are the key to high safety (Internet, 2007-08-22)[2]. One human mistake can make years of safety work worthless. It is stressed that creating high safety awareness is central to *eliminate the erroneous human factor* in order to obtain high safety at sea. Furthermore, the importance of education, training and drills as well as social well being at work is stressed.

To eliminate al erroneous actions is a difficult task. Swift & Bailey (2004) write that:

> “Most accidents occur because there is no system in operation to detect and consequently prevent one person making a mistake, a mistake of the type all human beings are liable to commit.” (p.1)

As one step towards fewer accidents Swift & Bailey propose a practical guide to bridge team management. These guides can be helpful if understood and used. Commercial interests may of course impact the use of instructions, procedures and rules. Rasmussen & Svedung state that:

> “It should be considered that commercial success in a competitive environment implies exploitations of the benefit from operating at the fringes of usual accepted practice. Closing in on and exploring the boundaries of normal and functionally acceptable boundaries of established practice during critical situations necessarily imply the risk of crossing the limits of safe practices” (2000, p.14)

We believe that safety can be increased through deeper understanding of “the erroneous human factor”. One example is development of proactive support, through well designed decision aid or work procedures, to make the handling of risks safer and mitigation of unwanted consequences more efficient. In the present research we focus on risks related to the task of navigating in fairway. In this study increased level of risk is related to factors contributing to lesser limits of safe practices when navigating in fairway.

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2 http://www.sweship.se/Sveriges_Redareforening/Om_SRF/Policydokument/Sjosakerhetspolicy_DXNI-7487_.aspx

3 Studying the work environment

The first step in this study was to learn more of the work on the ship bridge with the overall aim to provide input for a detailed plan of study regarding the continuation of the research. Two studies with different techniques of data collection were initially chosen. One was to conduct a field study and the other was to perform a task analysis. Both studies are presented in more detail below.

3.1 Introduction of Field study and Task analysis

3.1.1 Introduction Field study

The field study is called "Pre-study for prescription of method and description of data requirements for analysis of decision support systems for navigating and manoeuvring ships in fairway" (Nilsson et al, 2006b). It was conducted as an initial part of the research and set the direction for the rest of the study. In this section a summary of the field study report, which is available in Swedish, will be presented. Only parts that are regarded as most relevant to the continued research will be presented in this thesis.

The field study was launched from the perspective of learning more of the work on the ship bridge in real work settings. This was to identify which data and potential problems that could be of special interest for future studies and was also expected to provide information of factors vital for the decision making on the ship bridge.

Study issue

The main question was to identify central work areas and data about the work on the ship bridge. Initially we chose to focus on four areas that were regarded as central of the work on the ship bridge and that had clear connection to safety, decision making and workload (described in the *Frame of reference*, chapter 2). We focused on:

- Identification of central themes and processes of the work
- Use and preferences of instruments
- Experience of work load
- Communication

Constraints

This field study was conducted in the fairway of the port of Norrköping. 17 passages were followed due to recommendations from a reference group connected to the project. The total amount of arrivals of ships to Norrköping was 1120 in the year 2005. We also needed authorization from the shipping companies.

3.1.2 Introduction Task Analysis

The second method was to perform a task analysis. A work description or "common ground" was needed to be able to reason about factors affecting the work on the ship bridge. This description was also expected to be of help in the work of outlining main questions and focus of future research.

Study issue

We needed a work model of the task of navigating in fairway to relate the work and eventual findings to. A model was also expected to clarify relations of different parts of the work task and offer possibilities for deeper understanding of problems related to different parts of the work.

Constraints

We focused on the task of *navigating in fairway*. The task analysis was performed from the task goal of safe navigation and safety at sea. When conducting the task analysis we choose to interview 4 Pilots and 7 Master Mariners which opinions will have a great impact on the results.

3.2 Methods used in Field study and Task analysis

When conducting a field study and task analysis there are different methods and techniques available to choose between. In this section methods that were used are presented.

3.2.1 Field study techniques for data collection

Many different techniques can be used for collection of data during a field study. Today a lot of technical equipment like photo cameras, video cameras and tape recorders are small and easy to bring during travel. Although technique using cameras and sound recording give high validity of what is actually said and done there can be problems with establishing confidence so that the participants can feel comfortable in their work situation. If the comfort is not accomplished this may affect the work even more than the mere presence of extra manning (researchers) on the bridge (Lützhöft, 2004). In our study we did not expect to have time to go through a procedure of getting allowance for using cameras on the bridge, establishing the bridge team confidence and setting up the camera gear. Initially eye movement registration and measurements of HRV were also discussed but these methods were rejected due to uncertainties of the quality with available means, for example regarding time of calibration and the risk of not getting reliable data and disturbing in a sensitive part of navigation. When choosing technique one has to match the aim of the study against resources. Both former Masters and Pilots are represented within the research team. Therefore we believed ourselves to have a good basic knowledge of the work on a ship bridge. We chose three techniques: observations, interviews and enquiries for collecting information because we judged they would be trustworthy, efficient and manageable. All methods are described in more in detail below.

Observations

Observation is a method that is most successful when the observer has reasonable access to the environment to be studied, the area is possible to quantify and the observation area is limited (Waddington, 1999). From the perspective of the research team, due to work experience and domain knowledge, the work on the ship bridge was well understood and thus regarded as easy accessed. Some problems were anticipated regarding the quantification of the data. The ship bridge in itself can be considered a limited area although the work task of navigating in fairway is broad. We decided to do observations because it would be both efficient and sensitive enough to obtain data describing the work that could give us some new perspectives and deeper understanding of how the task actually is performed. We set out to have two observers following each ship, preferable two observers with different background experience in order to get a wider perspective of the observations.

An observation technique of open communicated observations was chosen. The objectives and the role of the observers were communicated before and the observers were not to engage in any part of the task solving and had no responsibility related to the task. The aim was to make documentation without disturbing the work. Open communicated observation is less questionable from an ethical perspective and observations can be explicit and followed by direct questions without hiding any reasons for asking. Explicit procedures are self conscious and capable of reconstructions (Weick, 1985). The presence of the observer risks of affecting the performance.

Observation protocols and observation instructions were designed on the basis of which communication that was assumed necessary and which instruments that were available and assumed to be frequently used during navigation. The aim of having protocols and observation instructions was to guide observers and facilitate transcriptions of actions and central phenomena. The observation instructions can be found in Appendix A and observation protocols can be found in Appendix B (Both only available in Swedish).

Talks & Interview

Interview is a flexible method. It can be initiated at one point in time and then completed over time. A question can be answered when there is time which is advantageous when information is gathered while the person needs to be available for others due to the task. When a Master is interviewed on a ship bridge s/he might be needed to answer a question related to the work or the ship with short notice. An interviewee does not need to think about how s/he will be experienced by others, which s/he could be if s/he was to be recorded on a film. An interview gives the interviewee possibility to ask questions back if there are any uncertainties regarding the questions and normally you get answers to all your questions, which you can not control if you for example send a questionnaire by mail.

Before the start of task solving, pilots were to be asked questions regarding experience and preparation in order obtain more background- and demographical information. The questions were structured which would make quantification easier and decrease the risk of forgetting any questions. During the work and task solving on the bridge, questions which were not structured could be asked. These questions could be asked to clarify circumstances regarding reasons for actions and perhaps make work strategies more salient.

After the observations onboard a series of complementary telephone interviews with pilots were made. One objective was to find out what instrument that was prioritized by Pilots. The telephone interviews were semi-structured which gives the interviewer a firm base for questioning although it allows additional questions if needed for further clarification. The main question of the telephone interview was to ask the pilots to place instruments in order of preference. Which instruments do they feel is the most important ones to solve the task of navigation on the bridge? We were interested in what instruments would be mentioned spontaneously by the pilots, which was considered to be instruments that was important based on their experience of working on the bridge. If we were to give pilots alternatives we thought we might attain answers more related to formal procedures of work or rules than to their spontaneous comments which we considered to be connected to what they actually do or believe they do.

Questionnaires

Questionnaires are advantageous from the perspective that you do not risk losing any of the raw data. They are all in the questionnaire given the questionnaires to be understood and filled in a proper manner. If questionnaires are mailed to the respondent one takes the risk of getting low answer frequencies (Ejlertsson, 1996), but with a well prepared questionnaire one may very well have high answer ratings. We were to hand the questionnaires over our selves and anticipated to have a high response rate.

Two different forms of questionnaires were used. One questionnaire was used to gather information regarding the work intensity. This questionnaire was based on the assumption that subjective self assessment would give us the data we were interested in. Subjective measures are normally easy to derive but one has to be careful with interpretations (Wickens & Holland, 2000). Do the participants really understand the question you pose and can they describe the answer? We used pictures of the fairway to make it easier for participants to see what we were asking.

The Pilots and Masters were to indicate the anticipated work intensity by marking the track along the fairway with different colours. Green indicated normal conditions (low intensity), yellow indicated higher intensity and red indicated the highest level of intensity.

A second questionnaire was used to collect opinions regarding the communication situation between Pilots and Masters. It has been shown that there can be inconsistencies in opinions regarding the communication on the ship bridge (Marine Causality Branch of the Canadian Coast Guard and the Transportation Board of Canada). The study shows that the person (Master, Officer of the deck or Pilot) sending a message often think they are clear while the message receiver not necessarily thinks so. Norros (2004) found that 6 out of 17 studied cases of normal pilotage situations had little shared awareness of the situation.

We were interested in the communication situation in Swedish waters. A questionnaire was developed. Our aim was to investigate if communication between Masters and Pilots was regarded satisfying or not. If not, this could uncover potential problem areas. We focused on questions related to communication that was assumed to be essential for the task solving. We did not want too many questions as we knew that we were to expose the Pilots and Masters for several different methods for information gathering and we did not want to disturb them more than necessary. Too many questions under time restriction would also risk that the questionnaire would not receive the proper attention.

The questionnaire was to be answered both by Masters and Pilots after a transit. A lot of focused was directed towards making the questions and the response mode clear and unambiguous. The questionnaire was tested on co-workers at Chalmers before the final construction, which lead to the change of some words that were misleading or could be leading (implying that there actually were communication problems). We decided to use a graphic rating scale, which is one of the most frequently used scales (Pedhazur & Schmelkin, 1991). An example of a questionnaire handed to the Pilots can be seen in Figure 9, a questionnaire corresponding to this was handed the Masters. This kind of questionnaire can point out interesting issues but does not give any explanations of why the situation is experienced in a certain way.

PILOT

Did you get enough information about the ship?

-5 Satisfying +5

Did you get enough support from the Bridge Team?

-5 Satisfying +5

To what extent do you feel the Bridge Team participated in the navigation?

-5 Satisfying +5

If you for some reason had become incapacitated - Do you think the Bridge Team would have been able to take control of the navigation?

-5 Satisfying +5

In your opinion, how much information did you supply the Bridge Team with?

No information Information as normal Extended information

Figure 9. Questionnaire handed to the Pilots.

3.2.2 Method for Task analysis

The aim of the task analysis was to demonstrate how work tasks and operations are connected and how the work is conducted in order to accomplish safe navigation in fairway. According to Stammers and Shepard (2001) the most direct use of a task analysis is when evaluation of an existing system is done. They further state that “as redescription develops, the analyst is able to:

- express the system’s goal more explicitly;
- identify appropriate features of the context with more precision;
- establish methods for accomplishing the overall goal” (Stammers & Shepard, 2001).

To describe the work on a ship bridge, a Hierarchical Task Analysis (HTA) was chosen. HTA is often used as a first step in other cognitive task analysis (Annett, 2003) and is therefore considered as an appropriate first step here. HTA could serve as a platform (“common ground”) for future research. When having a work description we anticipated to be able to identifying potential problems related to the work description in order to identify relevant issues for future research and planning.

The method of HTA was developed in the 1960s by Annett (2003). Initially, the method was developed for training in process control tasks performed in steel and petrochemical industries. Since then the method has been developed and has been used in different areas. Today the HTA is used in many different contexts like for example interface design and error analysis.

HTA is a way of describing a task through decomposition of operations and goals in the task into sub-operations and sub-goals. The decompositions into sub-operations normally clarify the central parts of a task which makes the understanding of the task easier. If the sub-operations and their goals are properly described, the HTA can work as a good platform for analyzing the task and its components. HTA in itself does not include diagnostic categories or other tools for analyzing. The analyzer can, through the HTA, find answers and develop hypothesis and explanations in relation to the stated questions. This is one reason why the research issue has to be clear from the start. The hypotheses and answers worked out through the method can be doubted if the purpose, system of interest or what components the system consists of is misunderstood or interpret differently by different participants. The decomposition of a task may look differently depending on what the perception of the goal with the task is and how the task is to be performed.

Annett interpret a task as “any piece of work that has to be done” and a goal as “the object of effort or ambition” (Annett, 2003, p.19). The HTA is done by decomposition and redescription of goals. The fundamental unit of analysis is an *operation* which has a goal. First there is a main task that can be seen as an operation that has a goal. This operation can be divided into sub-operations and sub-goals. It is important that an operation is described with a specific goal because an action, which can be conducted within a task or operation, can be performed in order to achieve different goals. For example the task “to not drive too fast” is not the same as “driving fast enough” and their operations may look different although both can contain the action of checking the speedometer. How a goal of an operation is to be achieved can be explained by a plan containing different actions (or sub-operations). According to Annett (2003) there are three different types of plans. One type is “do this, then this, then this” and another type is “if X, then Y”, these two types imply that the operator has knowledge for example of the procedure of the task or the environment it is performed in. A third type of plan is *time-sharing* or *dual task* plan which means that a super-ordinate goal not can be fulfilled unless two or more of the sub-ordinate goals are attained.

An operation can be divided into sub-operations and sub-goals repetitively and therefore it is important to set a stop-rule of where to stop the deconstruction of task on beforehand. Generally one is supposed to stop when further investigation does not contribute much to the answering of the main question. An optimal stopping rule is "when you have all the information you need to meet the purposes of the analysis".

According to Stammers et al. (2001) "conduction an HTA entails the following stages

● Considering the systems goal.
● Examine the tasks that have to be carried out to attain these goals.
● Judge whether current systems performance is satisfactory.
● If current system performance is unsatisfactory, then seek to manipulate task components to ensure satisfactory performance- that is, look for interface design, job-aiding, training and other ergonomics hypotheses.
● If an ergonomics hypothesis cannot be proposed, redescribe the goal in terms of sub-goals and an organizing plan.
● If the goal can not be properly redescribed, examine the relaxation of the current constraints." (p.156)

This description can be guiding when one is analysing a specific instrument or function and if one wants to find solutions for potential erroneous actions. A more direct recommendation for how to conduct a HTA is presented in seven steps by Annett (2003):

1. Decide the purpose of the analysis.
2. Get agreement between stakeholders on the definition of task goals and criterion measures.
3. Identify sources of task information and select means of data acquisition.
4. Acquire data and draft decomposition table or diagram.
5. Recheck validity of decompositions with stakeholders.
6. Identify significant operations in light of purpose of analysis
7. Generate and, if possible, test hypotheses considering factors affecting learning and performance (p.22)

We choose to work according to the recommendations by Annett. Initially we planned to interview pilots in order to construct a description of the task of navigating in fairway. This description was to serve as a base for identification of potential problems related to the work description. The problem identification was planned to be conducted with Master Mariners. By using Pilots as experts for creating the HTA, we expected to obtain a good description of the work based on experience from several different ship types and ship bridges related to fairway navigation. We decided to use Master Mariners to identify problems since they have a slightly different perspective. They are assumed to have less experience of the particular navigation but have more experience from different fairways. Master Mariners do sometimes work parallel with Pilots and are thus engaged in the same task and they usually have the full responsibility for the ship, and are thus assumed to be sensitive to possible problems. To use Master Mariners to identify the problems related to the HTA model developed through interviews with pilots gave us the possibility of validating the HTA model. Even though we based the interview on this HTA model we expected the Masters to react and complain if it was experienced as unrealistic.

3.3 Process of Field study and Task analysis

3.3.1 Data and data collection during the field study

Collecting data in the field can be sensitive. From a safety perspective it is important to not disturb the work or to increase the workload in sensitive parts. In this section more of the data we obtained and the process of acquiring it is described.

Sample

During 6 month from the end of 2005 to the middle of 2006 we followed 17 voyages in the passage in and out of Norrköping. Some ships are not big enough for being obliged to have Pilots and some of the Masters have Pilot competence them selves and do hence not need Pilot services onboard. We wanted to do observations on ships both with and without pilots to see if there were any differences. 12 passages were made with ships going through the fairway with a pilot onboard and 5 passages were followed without a Pilot. In total we observed 5 Ro-Ro (Roll on Roll off) vessels, 3 tank vessels, 4 dry cargo vessels and 5 container vessels. The ship size varied, the smallest ship without obliged pilot service was less than 100 m length overall and the largest more than 200 m length overall. The draught varied between 4 and 10 meters. 9 Ships were followed in and 8 ships were followed out through the fairway. Three ships were followed two times, both on the inward and outward journey. We collected observations from all of the ships. We managed to conduct questionnaires regarding the estimated work intensity from 5 of 12 ships following pilots and from 3 out of 5 ships making passages without pilots. 8 questionnaires regarding communication were answered by Pilots and 7 by Masters. 6 of 12 pilots were interviewed by phone regarding priority of instrument. The 6 Pilots were chosen by availability.

Collection process
Initially observation protocols were designed. Assumed communication and use of instrument was in focus. The protocols were tested twice in the fairway of Göteborg. After the test the protocols were adjusted, for example regarding how to write activity related to an instrument. Initially activity with an instrument was to be written down on a timeline. This was not very practical since it would take a lot of attention to administer the timeline itself. Instead time was written in hours and minutes close to the activity. Special boxes with place to document questions or actions related to instruments were to be more efficient.

The research team consisted of four persons. Three of the four observers had personal experiences of navigating in fairways and one had just basic theoretical knowledge (my self).

Regarding the observations the first step was to contact Pilot organisations, the harbour of Norrköping and ship owners to communicate the aims of research and to get their approval. Usually we got information about ships that we could follow through survey of the harbour traffic on the internet. We made requests of which ships we wanted to follow to the harbour organization of Norrköping, they in turn got authorization from the ship owners and management. Ship traffic is very dynamic and we normally set out to do observations in sets, several passages during a couple of days, to minimize the travel to Norrköping. We were allowed to follow all but one ship that we requested. We were declined due to doubts that our insurance was sufficient.

Basically we followed the pilots at work. We made all the arrangements regarding transport with the local Pilot station. We normally interviewed the pilot at the pilot station, before going out on our transport to the ship, or in the harbour. But as the work at sea is very dynamic there was not always time to do all of our test procedures and we had to adapt to the circumstances. Sometimes the Pilots were interviewed on the transport out to the ship and unfortunately sometimes there was no time judged appropriate and interviews were not conducted. This could be due to sudden rescheduling of the journeys or that the circumstances on the pilot boat were inappropriate for interviewing due to weather or to not disturb the Pilot during preparation. We interviewed the Masters when the time was judged appropriate. Questionnaires regarding work intensity were filled in both before and after the passage by both Masters and Pilots.
Normally we followed the Pilot when boarding the ships and well onboard we confirmed our participation with the Master. We boarded ships in the harbour or at sea, normally we boarded and left the ships more or less at the same positions at the pilot boarding/debarkation point in the fairway. Our presence was always communicated beforehand and we always informed the Pilots and Masters to stop us if we were experienced to affect the work in a negative manner. During the work we tried our best to not ask questions at times which might interfere with the work, although this could be difficult. Especially for me personally, at

least in the beginning, who do not have the background experience of the work on the bridge and hence not the natural feeling or understanding of when it could be less appropriate to engage bridge team members in conversation. It was not possible to have all the Masters and Pilots answering the questionnaires but the ones we decided to give it to all responded.

All but four fairway passages were covered by two observers and all but one passage were covered by an observer without personal navigation experience. All observers were introduced to the task by the observation instruction. During the observations it became clear that the observer protocol showed to be difficult to use for the observers with maritime experience. A blank piece of paper or paper copies of the paper chart to mark special events showed to serve better.

After the field studies telephone interviews were conducted. During two weeks 6 Pilots were interviewed over the telephone for approximately 45 minutes each. Pilots were chosen by availability during the two weeks that were available for this work. Pilots were not easy to get hold of over the phone during normal working hours. When they do not work on a ship they are very restricted in time due to the recovery and rest time needed before next shift of work. Pilots were contacted through the local Pilot station and asked to participate. If there was an interest to participate and there were no possibility of conducting the interview directly another time was agreed. There was no information given on beforehand. The purpose of the interview was given over phone. The Pilots were interested to participate and no one declined the possibility of taking part in an interview. Pilots were asked to rank the five most important instruments on the ship bridge generally and if they would like to have more information regarding the ship bridge before coming onboard for pilot duty, like for instance to see a picture of the bridge.

3.3.2 Work process Hierarchical Task Analysis

We decided to mainly base our work on the work plan proposed by Annett (2003) and here follows a more detailed description of the work process. In this section we will describe the numbers 1-4 in Annett (2003).

1. Decide the purpose of the analysis.
In this research there is a focus on the task of navigating in fairway. This navigation differ in some way to navigation in open water as it usually comprises navigating closer to land which means that there are other constraints related to the task compared to when navigating in open water. The purpose of the HTA is to create a platform explaining the task of navigating in fairway. By decomposing the task of navigating we want to identify central parts of the work, which subtasks are vital in order to accomplish safe navigation. A further aim is to identify potential problems and hazards related to the task. The HTA has to be generalisable

to some extent since ship bridges generally differ in which equipment that is available. A too specific HTA can be less generalisable whereas this had to be accounted for when considering stop-rules.

2. Get agreement between stakeholders on the definition of task goals and criterion measures.

Safe navigation is a fundamental goal in the professional maritime world. It is in all the involved partners' interest that the ship, crew and cargo reach the destination of the trade in a safe and reliable manner, how this can be obtained can be treated as overall question of the work (See section 2.5, Perspective of safety at sea).

3. Identify sources of task information and select means of data acquisition.

In this study the focus is directed towards navigating in fairway. Earlier studies have shown that there are differences, between different nations and stakeholders, considering how this task is performed (Norros, 2004). In this work we have chosen to study Swedish Captains and Pilots. Since Pilots work daily with bringing ships through fairways, working on different ship bridges, they are seen as experts in the area. This HTA is based on interviews with Pilots.

4. Acquire data and draft decomposition table or diagram.

The HTA is based on data acquired through interviews with 4 pilots that are considered as experts in the work field. Three of the interviewed Pilots are currently working as Pilots, the fourth a former "Master Pilot" is engaged in teaching. Each interview lasted about 2 hours and was conducted at two different locations. Two interviews were conducted in a conference room at Chalmers University of Technology and two interviews were conducted at a local pilot-station. Interviews were conducted after mutual agreement that was considered appropriate of both researcher and Pilots. The interview purpose was communicated in the first contact whilst method was explained in detail when meeting. No preparation from the Pilots were asked for or considered necessary. The interviews at Chalmers were conducted during daytime whilst the interviews at the pilot-station were conducted, in relation to just finished work, during night time. The interviews were all conducted in a location well known by the Pilots and that was well suited for talking about the task and working with the process of developing the work model. The interview started with presentation of the aim and method of task analysis.

During the interviews a task tree was drawn on a paper sheet of A3 size. After being briefed about how the interview was planned the identification of subtasks and their goals started with a question like "How would you divide the task of navigating in fairway". The description was drawn and written on the paper and then the interview continued with identifying subtasks and their goals. Pilots mainly did the talking whilst I was drawing and writing. The tree was completed with descriptions of the tasks, subtasks and goals. To have the image of the task tree to grow in front of you facilitated the understanding of the connection of tasks and subtasks. Notes of goals were drawn directly on the sheet, after two hours the sheet looked like a big mind map.

As each operation was identified, questions were discussed regarding need of input/information, need of feedback, which action that had to be taken, potential problems and difficulties "what can go wrong and what is probable or common". As soon as possible after the interview the work description was rewritten in a protocol. Table 1 shows an example of how a protocol is put together. After all the interviews had been conducted the results from each interview were merged into one description.

Table 1 Example of a written protocol from HTA interview.

No.	Description of operation	Info	Feed-back	Problems	Redescribed
1	Navigation in fairway, make the ship follow a planned track.				1.1-1.2
1.1	Controlling the movements of the vessel				1.1.1-1.1.2
1.2	Maintaining orientation of the vessel				
1.1.1 1.1.2	Control course Control speed			Misunderstanding of digits	

Since the task of navigation in fairways is a broad task and ship bridges generally differs a lot in which equipment that is available the HTA ought to be like an Overview Task Analysis which has the main feature of "facilitate comparison of task content between jobs with the same or similar jobs…it uses a stopping rule of redescription which specifies that the tasks are generalisable between different companies and organizations in the same industry" (Patrick, 1992, p.173). The "P&C rule" (Annet,2003), related to **P**robability of failure without proper training and potential **C**osts of failure, was difficult to use due to the complexity of judging values for P and C. Possible failure of many of the subtasks can individually lead directly, but not necessarily, to high level of risk. The "P&C rule" would probably be easier to use when relating to a specific bridge, organization and crew. Usually the redescription stopped when the interviewed Pilots were unable to redescribe the tasks further.

3.4 Analysis of data in work process part 1

3.4.1 Analysis Field Study

After the return of a fairway passage, data from the observations were transcribed in to protocols. These protocols were analyzed through a process of creating themes and later searching the content of protocols from the perspective of these themes. First all of the observation protocols were read. Second, themes related to risks and safety at sea were created. The themes were identified on the basis of the content of the observation protocols. Examples of themes that were identified are:

- Risks
- Procedures
- Decision support
- Perspectives
- Communication

As a third step all protocols were read again and content related to themes were identified. Each protocol was read by two researchers. We focused on presenting important issues related to risk and safety. Some of the themes maybe related to one another and some of the theme content could perhaps be argued as a belonging to another theme, or even several themes.

Questionnaires regarding work intensity were compared and merged into one. The analysis rule was that the colour that most frequently was indicated at a special part of the fairway was to signify that part of the fairway. If two parts of the fairway had the same frequency of two colours the colour signifying the most intense work was to be chosen. Due to time restrictions in the analysis phase, only questionnaires filled in beforehand were analysed.

The questionnaires on communication were analysed by interpretation of the answers on the scales. Example of questionnaire can be seen in Figure 9. The middle of the scales indicated by *normal* and *satisfying* was treated as the number zero. The metric system was used to measure the distance of each answer from zero, and approximation to the nearest integer was used. The questions without numerical end values used the wording *no information* and *extended information.* These textual end values were transformed to numerical values (-5 to +5). All data were gathered in tables and means and medians were calculated. The results for each question was then analysed individually.

Interview protocols regarding priorities were transcribed and summarized. In some cases Pilots did not want to make difference between the rankings of two instruments. Therefore, an order of precedence, rank point system (tied ranks), was established regarding the most preferred instrument on the ship bridge. When two instruments were given the same rank we decided to split the rank-point of the two positions between the instruments. If for example ECDIS and GPS were both ranked as the most prioritized instrument, they were to be assigned rank one and rank two which corresponds to five respectively four points in the rank point system. The ECDIS and GPS would hence be assigned 4,5 points.

3.4.2 Analysis of Hierarchical Task Analysis

In this section the work process related to work packages 5-7 according to the procedure for HTA proposed by Annett (2003) is described.

5. Recheck validity of decompositions with stakeholders.

After making the outline description of a work model this was communicated with the interviewed Pilots and eventually some amendments were made. When the HTA work model was developed seven Master Mariners were interviewed regarding problems related to the tasks given by the model (see work package 6). In this way we had additional opportunities for feedback regarding the HTA work model.

6. Identify significant operations in light of purpose of analysis

When the HTA work model based on Pilot interviews was finished it was used as background for further work of understanding the work on the ship bridge. Seven Masters Mariners were interviewed with the aim of identifying problems related to the work on the ship bridge when navigating in fairway. The Master Mariners were chosen by the criteria of availability, some were asked when undertaking a course at Chalmers University of technology and some were asked by personal contacts. We strived for a sample that would be of different age and experience. The seven interviewed Masters were between 27 and 58 years old, three of them were for the time being not working to sea any more, two were working at sea full time and two still worked at sea from time to time. Two of the masters interviewed were teachers engaged in simulator training at a maritime academy. The one with least experience of life at sea had 10 years of experience (still active at sea though) and the Master with most experience had been working at sea for 30 years. The interviews were conducted in pairs two times and individually three times. Each interview lasted between one to two hours. The interviews were conducted in different locations, al in calm and suitable environments for interviews. The interviews were based on the work model given by the interviews with Pilots. Each task in the model was worked through in order to identify problems related to that specific task. After seven interviews, the data on problems seemed saturated, in this case less new information was gathered and it was decided that enough data to start the analysis had been collected.

7. Generate and, if possible, test hypotheses considering factors affecting learning and performance.
We expect to be able to relate findings to the HTA work model which also is expected to simplify analysis of the work process. For further discussion see section 3.6.

3.5 Results

3.5.1 Field study

In this section results of the field study are presented. First examples of *themes* identified in the observation protocols are described. After that Pilots *priority regarding instruments* and estimated workload are presented. At the end *experienced communication between Masters and Pilots* is presented.

Themes
Risks
One potential for higher level of risk is if there are no procedures that definitely determine conditions for what size of ship that is to be taken in and under what circumstances the size of ship is to be allowed to be taken in or out through the fairway. If the Pilot himself when asked has to set the boundaries, these can differ and individual experienced pressure can lead to a higher risk if the Pilot is not sure of his own or the bridge team capacity.

Errors can happen suddenly and without warning, sometimes accidents or incidents are avoided due to sheer luck. At one time after taking a ship through fog a Pilot expressed "lucky the fog lifted since the compass indicated wrong". The compass error was weird according to the Pilot since his compass courses gave the correct heading earlier in the beginning of the fairway but not when the ship was at the end of the fairway, closer to the quay. According to the Pilot the compass error was identified when he operated on visual cues only, although some feedback probably was sought since the error was detected.

Procedures
Procedures or procedures not followed can contribute to higher levels of risk. One example is a bad planning of the passage in the fairway which ought to be done by the Master before each journey. This indicates that Masters have high confidence for the work and capacity of the Pilot. Several errors were detected in the Pilot-card that is to be a part of the MPX (Master Pilot Information Exchange) that is to be conducted when the Pilot joins the ship. In a conversation with a Pilot an example of a locally agreed rule was given. The Pilot mentioned a place he knew of where a ferry was supposed to give way for other, commercial, traffic in that fairway, even though this was in conflict with COLREGS (Collision regulations). Locally agreed rules can be considered to increase risks,

especially if these agreements are forgotten to be communicated to new personnel or temporary substitutes.

Information and experience is not always spread in the organisation. One example of this is that one has to be careful with some light sectors of a certain lighthouse due to that possible cracks in the glass could give the wrong information. When discussing this phenomenon it became evident that the Pilot did not know if anybody else had experienced it or thought about it during work.

Decision Support

Decision support like radar can cause a higher level of risk if it is difficult to use. Pilots usually have to work with many different types of equipment and are used to adapt quickly. Usually this gives all the information needed. But, in one occasion nobody knew how to get the information of speed over ground presented at the display. This ended in a work situation where one member of the bridge crew was put on the task to manually read the speed out loud. In most observed cases the used paper charts were of an inappropriate scale. The charts were not detailed enough which indicates that the bridge team relied a lot on the competence of the Pilot and that there were a lower redundancy than necessary. In one case an ECS was observed to be scaled down below recommendation. Although a sign in the corner indicated "not recommended scale" this setting was used.

Perspectives

Different perspectives by the different stakeholders may affect the experience of risk. For example, differences in preferences were observed regarding passage choices through the fairway. Pilots normally chose the passage close to land whereas Masters, with Pilot competence, tended to choose the other passage a bit further from land. At least one time a master on a ship with a Pilot on board explicitly experienced higher risk when going close to land compared to going on the passage some distance from land. The passage choice situation can be viewed in Figures 10 and 11 at the section describing workload, both passages indicate high anticipated work intensity.

Generally, three factors were observed to initiate higher work intensity on the ship bridge. These were (1) when passing areas marked red in Figures 10 and 11, (2) when passing other ships, and (3) when the weather became bad.

Communication

Lack of communication can induce risk. One example is when a Pilot at one time decided to take a shortcut without briefing the Master, which initially caused some confusion. In another situation a Master left the bridge without briefing anyone. That the Master left the bridge was not noticed until the Pilot called for the Master to ask a question. The Pilot then looked around the bridge before deciding to ask one of the Mates instead. Use of different languages or agreements that are made in non-common languages and not translated can cause higher levels of risk. New technology like mobile telephones is more widely being used in the daily work, for example between Pilots and tugboats. Since communication through mobile telephones is not announced through the speakers at the bridge, or perhaps is not carried out in an agreed work language, it runs a higher risk of not being understood by all which in turn may increase level of risk.

Priority regarding instruments

Table 2 shows how instruments were ranked by the Pilots. The results in points are based on ranking that Pilots did when they were asked to spontaneously mention the most important instrument.

T*able 2. Pilots ranking of instruments.*

Instrument	Points
Radar	30
Gyrokompass	19
(D)GPS	16.5
ENC (ECDIS)	12
AIS	3.5
Rodder indicator	3.5
VHF	3
Logg	2
Rate-gyro	1
Mobile telephone	0.5

None of the Pilots answered that they would be interested in having a picture of the bridge layout presented before going out to the actual ship

Workload

Workload was studied through anticipated work intensity during the passage through the fairway. Pilots and Masters were asked to rate the expected work intensity on a chart representing the fairway into Norrköping harbour. In Figures 10 and 11 the anticipated work intensity rated by Pilots and Masters is shown. The open sea is to the right side and the harbour is to the left side of the picture. Green indicates normal conditions (low intensity), yellow indicates higher intensity and red indicates the highest level of intensity.

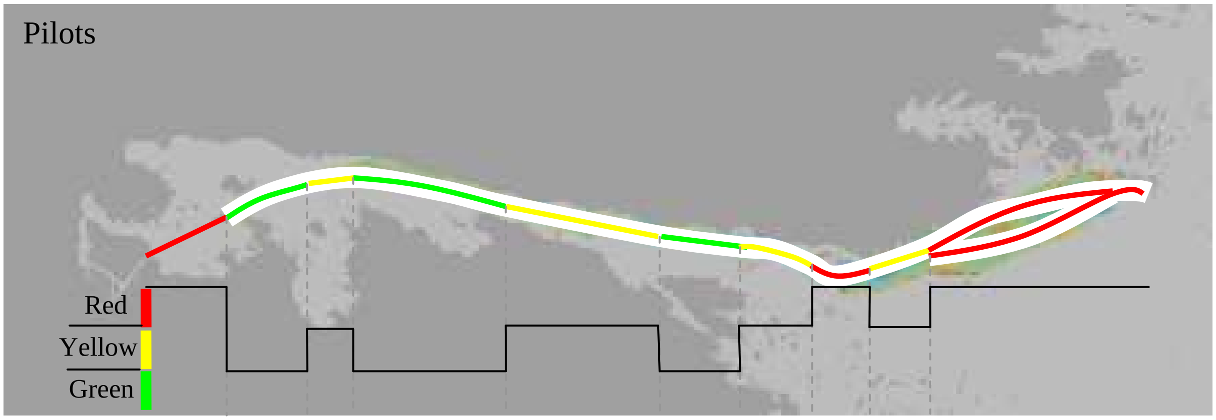

Figure 10. Pilots rating of anticipated workload.

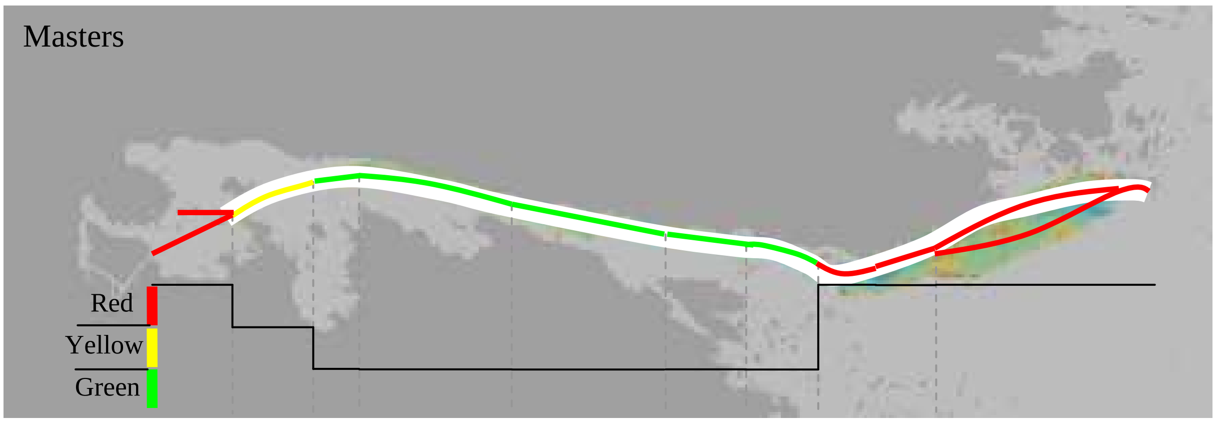

Figure 11. Masters rating of anticipated workload.

Experienced communication between Masters and Pilots
The results are based questionnaires from 8 Pilots and 7 Masters (Captains of the ship). Results to specific questions regarding experienced communication can be seen in Table 3.

The results show the participants' experience of communication situation. Both Pilots and the Masters are generally satisfied with the information they receive. Pilots tend to feel that they could have informed the Masters more, which is interesting to note since Masters feel that Pilots gave enough information. The questions regarding *information I gave* and *experience of participation* by the bridge team varies much between different bridge teams.

Table 3. Results of experienced communication.

	Pilots's opinion		**Captain's opinion**	
	Mean	Median	**Mean**	Median
Information I received about ship/route plan	**2**	2	**2.3**	3
Information I gave about route plan/ship	**-1.5**	0	**2.8**	5
Support I received from bridge team/were intentions clear?	**1.7**	Between 2 and 3	**Clear intentions. Two captains confused once.**	
Experienced participation in navigation by bridge team	**0.8**	0	**2.3**	5

3.5.2 Results Hierarchical Task Analysis

The main objective of the HTA was to describe the task of navigation in fairway. Task and sub-tasks were decomposed into different levels. In this section an example of how the task can be decomposed will be explained, the whole HTA work model can be seen in Appendix C. The example of task decomposition will be followed by examples of problems that were identified based on the HTA work model.

Example of HTA work model

The HTA work model consists of decomposition of the task of navigating in fairway from the perspective of navigating the ship in a safe manner. The HTA work model will be exemplified by relating the main task of navigating in fairway with one of the tasks at the lowest level, after decomposition, in this case the task of turning a ship. In Figure 12 we can follow the decomposition of tasks through the whole work model tree. The highlighted squares indicate the flow of how the task of navigating in fairway is decomposed into subtasks. The arrows indicate the relationship of the tasks and subtasks. Arrows indicate the direction of the task flow. Some tasks and subtasks are sequential, as indicated by an arrow in one direction. Some boxes have several arrows going out or in, indicating parallel processes.

The task of navigation in fairway is decomposed into the task of planning and executing a plan. Executing a plan is then decomposed into supervising, navigating ship, communicate plan and reconstruct plan. Navigating ship is further decomposed to speed control and steering. Steering is in turn decomposed into turning or maintain course. Turning can be conducted through the use of either autopilot or helmsman, which both may initiate the turn.

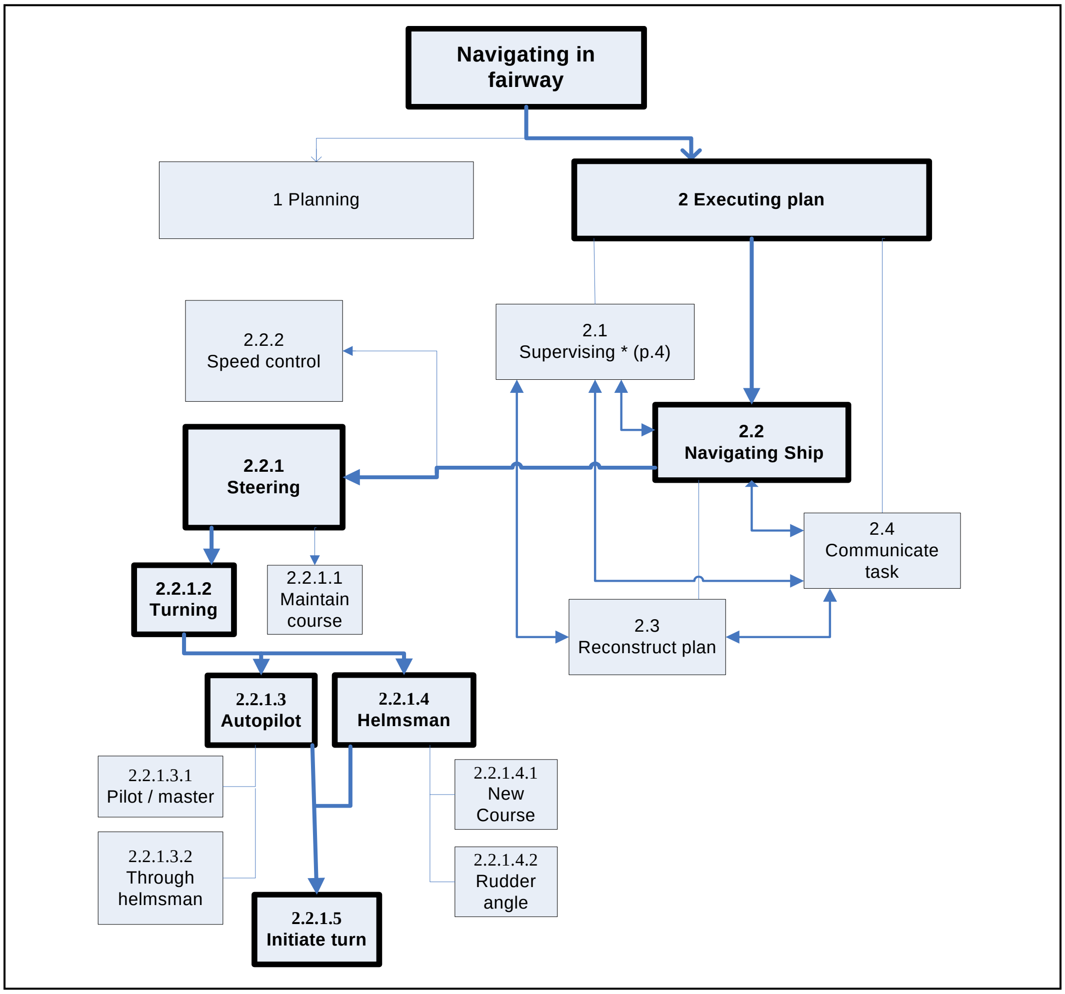

Figure 12. Example of how a task is decomposed in the HTA work model.

Every task is explained in a table stating name of the task, description of the operation, the goal, and input needed for the task. Examples are presented in table 1 section 3.3.2.

Problems identified, based on the HTA work model

In the HTA work model focus is directed towards tasks related to supervising. Analogous with this follows that problems identified in relation to the HTA work model concerns the task of supervising. All of the problems identified in relation to the HTA work model can be found in Appendix D.

In general three types of high level problems were identified; error in execution of task, technical breakdowns and difficult external factors. Four examples of errors related to execution of task are: to read the wrong value on an instrument, to wrongly interpret an echo on the radar as a target although it eventually shows that there was nothing there, to take the wrong measurement on a nautical chart or to confuse one of the cardinal points. East and north is especially sensitive to be confused close to the zero meridian, which may result that the ship is heading towards the wrong direction. Technical breakdowns are exemplified by malfunctions of the instruments or other artefacts that is not connected to any erroneous usage, for example autopilots or compasses breaking down. Problems related to difficult external factors are especially related to bad weather or currents.

3.6 Discussion Field study and Task analysis

The aim of the field study and task analysis was to learn more of the work on the ship bridge and to provide a task description of navigating in fairway. Before we can reason about factors and measure them we need to know how and why we ought to measure. To this end, we used the field study and HTA which shows the complexity of the work on a ship bridge when navigating in a fairway. Potential risks, differences and similarities regarding work strategy, experience and instrument prioritising have been presented. By this, several areas that can be further examined has been uncovered. Additional areas worthy of further study will be uncovered in the discussions of specific methods below.

During the field study and task analysis we used qualitative methods to get detailed examples of action in context. We used questionnaires as a complement to gain quantitative data. We documented our procedures and the circumstances during which they were made to provide possibility to track, evaluate and replicate them. None of the samples, observed ships, are randomised in any way that we can argue for a representative sample for any statistical calculations. But, our goal was to gain insight and collect information of how navigation in fairway is conducted in its natural setting.

We argue for high reliability since we have been observing work being performed on ships in a natural setting. We have seen and experienced everything that is written down in our protocols. The question of repeatability can be discussed. Repeatability is closely related to the interpretations of the observations and observation can not be conducted without interpretation (Lipshitz, 2000). We are assuming that the team making the observations had enough knowledge of the investigated area to make realistic interpretations. If a similar situation would be observed again it is probable that the same observations could be made. But, when observations are made in the “real world” on ship bridges one is not in control of the study environment, and clearly dependent of interpretation, which implies that even if our study was to be repeated it is not sure that it would give repeated results. We made observations onboard different ships within the range of ships that visit the port of Norrköping. This gave us the possibility to see a large variety in how the task of navigating in fairway can be conducted.

We did not distribute questionnaires on all ships. We judged that in some situations this was not appropriate due to the participants work load. However, all questionnaires that were distributed were answered. This shows the sensitivity of the situation of measuring during work.

The fact that we had to have authority from both the ship owners and the Master of ships may have had an impact on which ships we were allowed to join. How large this effect was is difficult to estimate, but we were only declined to join one journey.

Below follows discussions related to specific data collection methods and their results.

Themes

Since there is no formal procedure to determine which ships to grant entry, and under what circumstances, there is no agreement that both Masters and Pilots can refer to. This can be one contributing factor to what Norros (2004) found as little shared awareness of the situation.

If no formal system for spreading information and experience is used there is a higher risk of losing information and experience that could be valuable for Pilots when solving tasks. Information distribution can be related to culture aspects and attitudes. Perhaps the informal information distribution is regarded sufficient? An example of information sources that can be used but may not be reliable is when electronic charts are set to the “not recommended” scale. This exemplifies that if information sources can be used, these may actually be used although not always reliable. Related to the perspective of safety discussed in section 2.4, it would be good to put a constraint on the instrument in order to not allow actions such as zooming in below the original scale of the scanned nautical chart when using ECS.

The different choices of passage through the fairway could be due to the feeling of control which is described by Westrenen (1999) who argued that some tend to navigate on the boundaries to have a “feeling” of them and some wanted to keep away from the boundaries to know that they were safe. Is it possible to measure and reason about experienced control on the ship bridge? Could it be that a more procedural Master Pilot information exchange might lead to an increased understanding of different perspectives that decrease levels of uncertainty?

Ranking of instruments

The ranking of instrument based on the rank point system indicate that there are some instruments that most Pilots consider more important. For example, the radar is unambiguously ranked as most important by all Pilots, which means that the radar is seen as having a central role. The lower ratings at the lower part of the table may represent personal differences. One interesting question is if the radar has the same meaning for all the Pilots and if a central work strategy dependent on the radar could be identified? This could also be studied regarding other instruments. Differences of preferences can be related to Norros (2004) findings that how the ship is navigated depends more on the personal “style” of the Pilot than what equipment that is available on the ship bridge. To identify different personal styles would be interesting, especially since strong personal preferences may lead to what could be called “irrational” choice. This has been shown in other domains, for example activity scheduling, related to choice between means of transportation (Gärling, 2004). For example, people that are used to taking the car are more likely do so even though they might just as easily have walked. This may seem irrational if you are concerned for the environment. Working in a complex environment with a high pace of change, such as a ship, may lead to resistance to using or learning new equipment, and instead “you do what you have always done”.

Workload

The perception of which part of the passage involved more workload was homogeneous within the two groups. The Pilot ratings seem to be somewhat more nuanced. This may depend on that Pilots usually have more experience of making the passage and also navigate with ships of various types. Their ratings may represent a wider potential of problems. For example, the yellow part marked on the chart, halfway through the fairway, was sometimes described as risk of squat. Masters that filled in the questionnaire were usually navigating smaller ships that perhaps did not have potential problems with squat in that area. It would complement the data well if we were to measure experience of the work situation in one more way, for example how the work is related to personal affect and emotions.

Experienced communication

Overall the communication situation seems to be satisfactory, although according to the Pilots, more information could have been given. Results to the question on *information I gave*, answered by Masters, is skewed. In this case it indicated that the answers varied much and that answers not were positioned close to the calculated mean value. This also applies to the question of *participation of navigation answered*. One reason for this may be the lack of a common reference of what is normal, too much or too little information or participation. This may confirm the findings of Norros (2004), that there is discrepancy regarding shared awareness between Masters and Pilots.

HTA

The HTA work model clearly shows the complexity of the task of navigating in fairway. One example is the interaction between the stages of 2.1 to 2.4 related to supervising, navigating, communicating and reconstruction of plan, which are clearly dependent of each other. It is further evident that a large part of this HTA work model is concerned with tasks related to supervising. This is very much in line with the statement made in the introduction of this thesis that the automation of the ship bridge has led to that the work to a higher degree consists of monitoring and supervising tasks (Kerstholt & Passenier, 2000).

The HTA work model very evidently distinguishes planning and performing the navigation as two different phases. This distinction in combination with the loops between supervising and navigating the ship suggests that a comparison of the HTA work model to a theory of control and activity, the Extended Control Model (Hollnagel, 2002) may be rewarding. The Extended Control Model (ECOM) describes multiple levels of activity, which is exemplified through a model of a process control. This process control model proposes a distinction of four levels of activity; targeting (goal setting), tracking, regulating and monitoring. Activities exemplified in ECOM related to the four levels can be seen in Figure 13. The different parts of the HTA work model and the ECOM model of activity and control have several similarities. ECOM could be a highly relevant theory to use in analysis of future data.

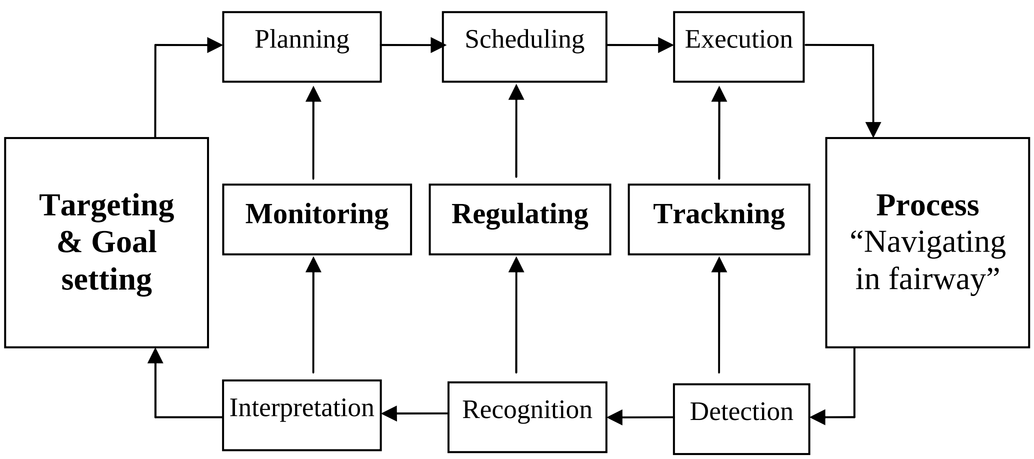

Figure 13. Activity and control model of process control according to ECOM.

Problems identified, based on HTA work model

The problems identified have a great variety. Some problems are more frequently mentioned and seem very likely to happen like, for instance, buoys moving due to ice or heavy wind. Other problems are rare and seem unlikely to happen, for instance, in one occasion when the electrician by mistake turned off the rate gyro in a moment when this was especially needed. The last example can be compared to the situation in the field study when we were “lucky the fog lifted”, see section 3.5.1. Talking about safety can be related to procedures of establishing a safe manner to work. The last two examples shows that one cannot be prepared for everything and that an important aspect of safety is the capacity of handling new and unexpected events.

Two subtasks related to the task of supervising were related to a higher frequency of identified problems. These subtasks are: *supervising position* *through radar* and *supervising course*. One interesting difference between these is that for *supervising course* the problems are mainly technical, whereas for *supervising position* the problems are both technical and erroneous usage. Is the supervising of course, although possibly problematic, less related to activity and interaction from the operator?

Lessons learned

When using these data collection methods the use of pilot tests and preparation time has turned out to be essential. In hindsight this could be conducted even more systematically. If observation protocols had been tested more, and inter-rater reliability tests performed, the differences in how to note observations could have been avoided.

As an observer I have learned a lot about observation. It is important to have a clear objective with the observation. What, why, how and when are important questions when you want to observe specific situations. When you are discovering a new area it is important to state your assumptions openly when going in. Make the observations and you try to push the conscious interpretation away until it is time for the analysing phase. If this is not possible, one should make notes so as to be able to separate observations from early interpretations.

After about 6-8 passages I started to write less in my observation protocols as the situation became more familiar to me. I started to think like “now this turn is conducted like that”. When I realised this I had to concentrate to try to focus on what actually was being done and how I could write about it.

As an observer I was not supposed to be engaged in any task solving or responsibilities. At one time on a big ship in a dense fog, the situation was a bit tense. Everyone was engaged in looking out of the bridge window, trying to identify buoys. I found my self engaged in the search for buoys without consciously considering it.

When conducting the questionnaires I must admit we focused a lot on how the questions would be experienced by the respondents. If I had focused more on what I was to do with the data, how I was to analyse them and taking that into account when constructing the answers and scales, this could have saved me some effort in the analysing phase.

4 Recommended further studies

We set out to learn more about the work on the ship bridge. Through the field study and the task analysis potential areas for further studies have become uncovered. In this chapter it is explained how the knowledge obtained in the field study and generic models created in the task analysis can be used to investigate concrete questions.

4.1 Aim and purpose

As presented in the introduction of this thesis new technology and instruments on the ship bridge are of interest. We propose a study to compare two different types of ship bridges, one bridge equipped with state-of-the-art instruments and one more conventional bridge. The aim of the study is to compare if there are any differences of how the work of navigating in fairway is conducted and experienced when using these ship bridges. To validate a set of different methods for collecting data is also a central question in this study.

4.2 Proposal of study in a Full Mission Bridge Simulator

We propose to use a simulator for studying the potential impact of different advanced instruments on bridge work, especially during fairway navigation. In the field study it was difficult to separate potential effects, for example weather or ship type that had an actual impact on how the work was conducted. To gain more knowledge of a specific question, we recommend that the next step in this research is conducted in a simulator. Then factors like weather, ship type and instruments that are of interest to be studied can be controlled and kept the same for all test participants. Potential hypotheses are easier to test if the task solving and adjustments of instrument settings by the participants are recorded. A simulator study also allows research that can test different measurement methods which potentially may disturb the solving of a task in its natural setting. In this section a recommendation for such a study is described (Nilsson et al., 2007).

When Funke (1988) discusses the use of simulators, he states that “it should be analyzed how participation in simulation affects problem solving in ‘real’ life problem situations” (p. 297). The simulators of today are considered highly realistic which for instance allow pragmatic training. The relevance of the full mission bridge simulator used for preparation for “real life problems” can be understood from the stress on simulator training expressed by cruising companies like Star Cruises. One example, given by the former director of the Star Cruises ship simulator H. Hederström (personal communication, Chalmers University of Technology, 10 November 2006.), is a ship crew that navigated during demanding conditions for at least one hour of a four hours sail up the

Saigon River. The crew had not been sailing up that river before and it was the biggest ship ever to sail up the river to Hue Chi Min City. The training was thoroughly carried out in a simulator before going into practice "live". The crew conned the ship them selves under supervision of a Pilot and managed well. Afterwards they emphasized the importance of simulator based training and the 1st Officer reported that he felt like he had "been there" many times before. Another argument for using a simulator for this kind of study is exemplified by a statement by Jansson (1999) who studied effects of strategies on the performance of work: "we can only hope to understand what a participant is doing if we know what he or she is trying to achieve" (p.24). By having participants solving tasks in a simulator that are well communicated and realistic we know both the given prerequisites and what participants are tying to achieve.

4.3 Aspects to study

We propose to focus on six aspects of the work on the ship bridge with the purpose to reason about factors affecting decision making on the ship bridge. The six aspects are performance, work strategy, communication, experienced work situation, workload and control. The aspects are chosen due to the close relationship with decision making on the ship bridge and have clear connections to the previous field study and HTA. Performance is primarily to be used to compare different bridge types. Work strategy and communication, experienced work situation, workload and contril have been discussed in the field study (Chapter 3). The question of control became even more evident during the work with the HTA work model.

4.4 Proposed data collecting methods

In this section methods for collecting data related to the different aspects to study are presented. All aspects and their relation to different data collection methods can be seen in Figure 14. The proposed data collection methods can be used for triangulation. In this way the different factors can be compared against each other and can thus give a nuanced analysis of the work on the ship bridge related to the two bridge types. The dotted line between the data collecting method of Swedish Core affect Scale (SCAS) and Heart Rate Variability indicate that earlier studies of SCAS has shown to correlate with variation of heart rate (Västfjäll & Gärling, 2007).

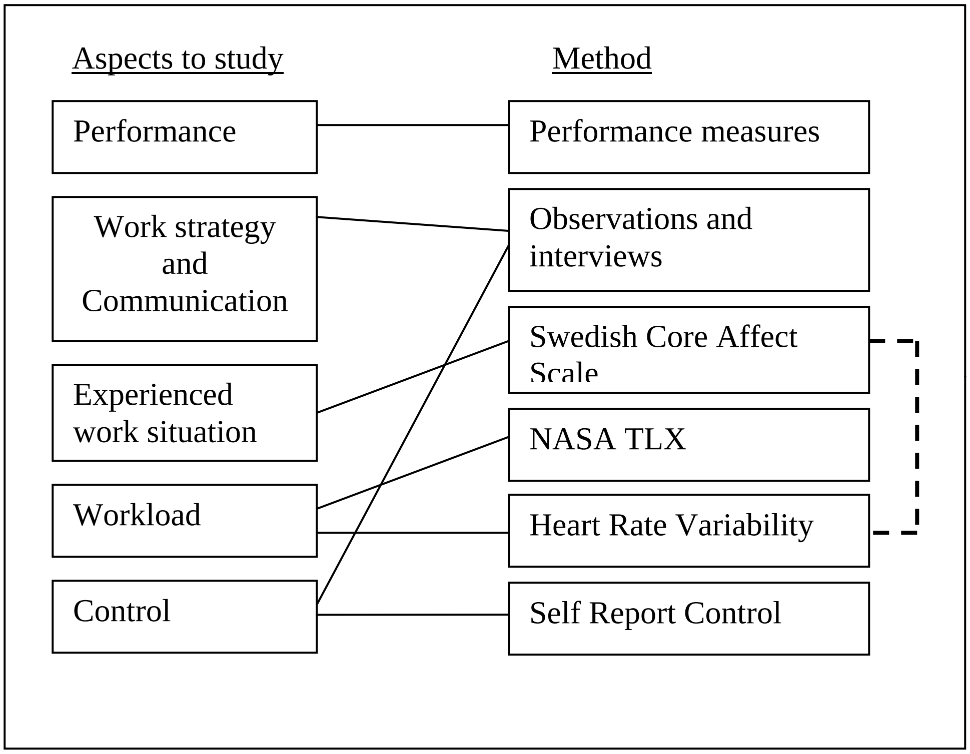

Figure 14. Methods related to aspects to study.

4.4.1 Performance

We want to investigate possible differences in performance due to the use of different bridge types (the bridge types will be presented in section 4.5.1). It is important to stress that when measuring performance we are not interested in assessing the bridge-teams performance individually. We are interested to see if there are similarities and/or differences between teams and groups of teams. Collecting data for classification or subdivision, due to earlier experience of the participants, is necessary. Our main objective is to identify potential differences between the use of a traditional and advanced bridge type. In this study, measurement of performance will be focused on navigation in fairway in relation to safety at sea

Judging performance related to safety at sea is a complex matter. We propose the use of experts to assess performance based on existing rules and procedures. Expert ratings have been used before (Saur et al., 2002) and we argue that it is important that expert rating is to be conducted by a professional with much experience of the work field. One advantage with the use of expert rating is the possibility to capture the situation that is to be assessed from a holistic view of safety. The holistic approach of experts, although based on rules and procedures, may contain factors like advance planning, use of instruments and available information directly related to the actual problem at hand. The holistic approach is important since the task of navigating in fairway is dynamic.

How each ship and bridge-team will encounter the planned problems may differ depending on previous decisions related to turns and speed. Expert ratings provide possibilities for a deeper understanding of the constraints of the situation. This is in line with theories of *bounded rationality* (Simon, 1982), *ecological rationality* (Gigerenzer, 1999) or *local rationality* (Woods et al, 1994) mentioned in section 1.3.

One way of measuring navigation is the use of Cross Track Error (XTE) which can be used as an indicator of performance (Saur et al., 2002, Donderi et al., 2004). We argue that XTE in our case is less accurate from the perspective of safety at sea. To follow a planned route in detail is not necessarily safer than to deviate from the plan since the environment is dynamic and deviation might be explained by an attempt for higher safety. Furthermore, to ask the captains (participants) to focus on staying on the track as the main task is considered unrealistic. It will probably lead to the risk of the participants not doing what they would normally do in order to try to stay on track. Instead we want to use measurements of *safe margins*, that measurement is based on one or several specific points along the passage in the fairway that it generally is good to have a large distance to. This measurement is based on the fact that in case of an unforeseen event keeping a safe margin would mean having a larger distance to potential dangers and hence result in a bigger window of opportunity to act. We argue that although Masters may perceive the situation differently, these points are to be chosen so that larger distances are better than smaller distances. Although some Pilots according to Westrenen (1999) like to navigate close to boundaries to have a sense of control, no one is likely to sail on the verge of stranding a ship.

We propose an adjusted measurement of Closest Point of Approach (CPA) which is a typical measurement for collision avoidance (Saur et al., 2002, Donderi et al., 2004). CPA is a measure of how close two ships will pass each other if course and speed are maintained by both vessels. This is a measure that has to be dealt with carefully to not overestimate the danger. A ship can pass another ship by the stern with a pretty small CPA and still have acted safely. The same CPA could probably be less safe if the ship was to be passed by the bow. One way of adjusting the CPA is to measure time for CPA-values below recommendations (Saur et al., 2002).

4.4.2 Work Strategy and Communication

The main question of this aspect is to identify work strategies and potential changes of work strategies due to the different bridge types?

First, we need to identify work strategies in order to be able describe the work on the ship bridge in more detail which in turn would make discussions of potential affects due to different bridge equipment easier. Examples of work strategies related to the task of turning a ship is described in the HTA work model in section 3.5.2. The Master may use either the autopilot or manual steering and may either take the whole turn all in one or divide the turn into smaller segments. Which method that is used has been related to the need of control and feedback and are hence central for decision making. Second, we are interested to se if we can identify any changes of work strategy due to the different bridge types?

We propose observation for identifying potential work strategies. “It is a truism that we learn about our physical and social environment through observation” (Pedhazur & Schmelkin, 1991, p.142). We argue that systematic observation (Weick, 1985) is useful for a deeper understanding of the work on the ship bridge since through observations we may describe and paraphrase the prerequisites, events and actions on the ship bridge during the scenarios in more detail.

When conducting observations it is important to know what you want observe and that observation “…is an active process. This implies a specific frame of reference, which entails selectivity in the ‘What’ as well as the ‘how’ of observation.” (Pedhazur & Schmelkin, 1991, p.142). When making observations the perspective of the observed actor is important, in this study we propos the perspective advocated by Weick (1985) who states that “…the model of an observational statement is…’If a person is in situation X, performance Y will be judged appropriate by native actors’” (p.572). Observations of the work and communication on the ship bridge can be based on and compared to other research related to decision making on the ship bridge, like for instance indicators of actions describing the work during pilotage (Norros, 2004) or recommendations from the *bridge procedures guide* (International Chamber of Shipping, 1998).

In the Full Mission Bridge Simulator that is proposed to be used, the work on the ship bridge may be recorded by two video cameras that can be manoeuvred. Recording of audio is also possible. In this way the recordings of the work conducted on the ship bridge can be played several times during analysis.

Although the task solving is recorded, we propose to do observations during the task solving on the ship bridge. General observations related to the task solving should be registered. In this way questions related to the task solving and clarifications regarding certain activities could be sorted out during debriefing after the fairway scenario has been completed. Central questions regarding communication is if there are any salient changes in communication, related to the different ship bridges that might affect the work?

4.4.3 Experienced work situation

In this study we recommended to focus on possible differences of experience related to the use of two different bridge types when solving the same task. The reason for this is that how a work situation is experienced is essential when reasoning about different prerequisites for work and appropriate instruments.

Measurements of experience of work situation can be problematic due to the question of what to measure and why. Västfjäll et al. (2002) argue that although

> "A consensus seems to be slowly emerging about how to define concepts like emotion mood, affect, feeling and temperament (Averill, 1975; Frijda, 1993; Lewis & Haiveland, 1993, Watson and Clark, 1994b; Zajonc, 1997). Clarification is, however, still necessary at both theoretical and empirical levels" (p.19).

We propose to use the Swedish Core affect Scale (SCAS) for measuring experience of a situation. SCAS measures core affects which according to Västfjäll et al. (2002)

> "…are cognitively accessible elements of a current mood, an emotional reaction, or anticipated emotional reaction. They are present at any given time, even at a neutral level." (p.19).

According to Västfjäll et al. (2002) the core affects can be described in two dimensions; *valence* and *activation*.

> "The valence dimension is interpreted as reflecting the degree of affect that provides information about current well being (Russel & Feldman Barret, 1999)." and "…activation, refers to the subjective experience of energy and mobilisation (Russel & Feldman Barret, 1999)." (p.20).

We argue that because valence "is clearly a fundamental dimension of human experience" (Västfjäll et al., 2002, p. 20) it is appropriate for comparisons of experience related to the use of the two ship bridge types.

We propose measurement of the two dimensions by rating adjectives both before and after the solving of a task in order to identify potential differences in experience of the situation. Västfjäll et al. (2002) argue that adjective ratings are "reliable measures of the independent valence and activation dimensions proposed" (p. 19). The method to be used has to be easy to make use of and not very complex since it has to be a part of several measurements and we do not want to exhaust the participants with too many or to demanding measurements. Thus, a method where only two scales are to be rated is judged efficient.

In addition, SCAS has been shown to have a positive correlation with Heart Rate Variability (Västfjäll & Gärling, 2007) which is one of the proposed measurements for workload.

4.4.4 Workload

In the field study we identified differences in ratings of anticipated work intensity by Pilots and Masters (3.5.1). This could be due to many different factors like for instance experience and knowledge. When comparing two bridge types, we propose to measure workload in order to find out if there are any differences in experienced workload related to the different bridge types.

We propose the use of two methods for measuring workload, a subjective measurement and a physiological measurement. Using both subjective and physiological measurement has several advantages. It provides two information sources that can be compared and evaluated against each other. Strength and weaknesses can be combined for optimal analysis. If results correlate, which it generally does for comparable tasks (Wickens & Hollands, 2000), the results can be interpreted as confirming. If they do not correlate, we might have caught important differences of constraints giving deeper insight. One example is if workload will show to be difficult to verbalise, then physiological measures may give insights into the aspect of workload. On the other hand, sometimes physiological measures have been shown to be affected by factors not related to the requested measurement. If the HRV data is to be proved not useful, then subjective measurements may be more frugal. In short using two methods provides possibilities for a broad and nuanced description of workload. Neither of the proposed methods is interfering with the task on the ship bridge. That is also one reason why NASA TLX is recommended more favourable than Secondary-Task Technique (Wickens & Hollands, 2000), which is another measurement technique that has a long history in the field. The Secondary task technique engages the participants with additional tasks and is hence difficult to motivate if one strives for task performance in a realistic environment.

Subjective measurement of workload

We are interested to measure how much workload that is experienced in the scenarios, this could be used both as a control of the scenarios as it will serve as information regarding the workload experienced in the different bridge settings. We propose to use the NASA Task Load Index (NASATLX) as a method for assessing workload, both physical and mental. When using NASA TLX the workload is defined as the "cost incurred by human operators to achieve a specific level of performance" (Gawron, 2000, p.130). When using NASA TLX the participants are asked to rate the task on six different dimensions directly after the task solving in the simulator.

Compared to another subjective measurement called SWAT the NASA TLX has a "greater number of scales and has a greater resolution per scale that allows it to convey more information and appears to provide a more reliable measure" (Wickens & Hollands, 2000, p. 467). We propose to use the NASA TLX for two reasons. One reason is that NASA TLX is a measurement that has a long history of usage (Wickens & Hollands, 2000) and is regarded useful for answering the question of potential differences. This will also allow the results to be compared to other domains. Two, measurements can be made swiftly and thus possible to combine with the other measurements. In our research approach we want to test different methods but we do not want to disturb the participants too much with one measurement.

Physiological measurement of workload

Heart Rate Variability (HRV) has been used to measure mental workload as "variability is generally found to decrease as the load increases" (Wickens & Hollands, 2000, p.465). In aviation research, tests have been conducted to compare reactions in the real world with reactions in simulators (Magnusson, 2002). The results indicate that the psychophysiological reaction patterns for the two settings are very similar, either because the mental workload registers more evident than physiological or because there is anticipation related to the task.

Westrenen (1999) who studied pilots in work writes about HRV measures that "At low and intermediate levels of workload they provide a sensitive measure of mental workload" (p. 129-130). One reason why this motivates the use of the HRV as a data collection method is because this concurs with the realistic testing environment that is representative for normal work, which is proposed for the scenarios (See section 4.5.3).

4.4.5 Experienced Control

The main question related to the aspect of control is if there are any differences of experienced control related to the different bridge types.

One way of interpreting experience of control is to understand it as congruence between anticipated and experienced performance of a Joint Cognitive System. From the Joint Cognitive System (JCS) point of view both the bridge crew and the bridge equipment are constituents of the system that we would like to study (Hollnagel, 2002).

The Contextual Control Model (COCOM) is a systematic model of control that "requires that that the human must be a model of the process in order to control it" (Hollnagel, 2002). This differs from other models that more frequently are based on that human "must have a model of the process to be able to control it" (Hollnagel, 2002, p.1).
Hollnagel describes COCOM as:

> "COCOM focuses on the functions deemed necessary to explain orderly performance and is intended to be applicable to a range of systems, including individuals, joint cognitive systems, and complex social technical systems" (p.9)

This is comparable to the work environment on the ship bridge where all the above described different systems can be seen as active and studied. The captain, an individual, is working on the bridge, which is a part of a joint cognitive system to control the ship, which in turn is a part of the social-technical system of the whole ship together with the land organisation owning and commanding it. COCOM has three constituents which are: competence, control and constructs.

● **Competence** refer to what a system can or cannot do. These are the constraints of what is actually expected from the system. The model of competence is controlling the level of possible analysis, the system is not expected to go beyond the model of the system. In our case competence could be exemplified by the HTA work model (se section 3.5. or Appendix C). We will initially relate findings to this model and we do as a start not expect to find something outside the model. In time it may become evident that the model is insufficient in some aspects and then development of the model may be necessary.

● **Control** characteristics in COCOM simplify the description of control to four generic control modes called scrambled, opportunistic, tactical and strategic. These control modes are "…regions of continuum, which ranges from no control to completely deterministic performance." (Hollnagel, 2002, p. 9)

● **Constructs** refer to the systems understanding of the situation at hand. "Constructs are artificial…Constructs are similar to the schemata of Neisser (1976) in the sense that they are basis for selecting actions and interpreting information" (Hollnagel, 2002, p. 9).

Important from the control perspective is to know what to do with the system from the systems perspective in short-term. The four control modes are related to different type work methods and characteristics of performance. Although the JCS control of a particular situation may change continually COCOM stresses to distinguish between the four control modes. Johansson (2003) who studied dynamic systems and its relation to time explained the four control modes:

> "**Scrambled** mode is when the next action of the controlling system is apparently irrational or random. In this mode the controller is subject to trial and error, and little reflection is involved.
> **Opportunistic** mode describes the kind of behaviour when actions is a result of salient features in the environment, and limited planning or anticipation is involved. The results of such actions may not be very efficient, and may give rise to many useless attempts.
> **Tactical** mode is characteristic of situations where performance more or less follows a known procedure or rule. The controller's time horizon goes beyond the dominant needs of the present, but planning is of limited range and needs taken in account may sometimes be ad hoc. If a plan is frequently used performance may seem as if it was based on a procedural prototype – corresponding to, e.g., rule based behaviour – but the underlying base is completely different.
> **Strategic** control represents the mode where the controller uses a wider time horizon and looks ahead at higher level goals. The choice of action is therefore less influenced by the dominant features of the situation. Strategic control provides a more efficient and robust performance than the other modes." (p. 31)

COCOM has been used before in relation to work on a ship bridge. One example is a study where control and the "boatfeeling" related to the movement of a ship was studied (Jacobson, 2006). We propose to use the same questionnaire as Jacobson where participants rate which of the four statements, directly related to one of the control modes, that most correspond with the experienced situation. With this data collecting method we may identify potential differences of experienced control between the bridge types.

This data collection method is the only one which may be obtrusive to the participants. Cooperation and task performance not related to the task will be required from the participants since they will be asked to rank an experience during navigation. The situation in it self is not necessarily unnatural, it could for example be compared to a situation where another ship is calling up the ship bridge regarding clarification of position or intention. The answering of the question of which out of the four statements that is most significant for the experienced situation is not assumed to disturb the work or cause any additional problems. The participants are to be trained on the four categories before entering the ship bridge which will enable a quick response.

4.5 Proposed bridge settings and procedure

In this section proposed test setting is described. The proposals are based on that the study is to be conducted in a full mission bridge simulator as suggested in section 4.1. First the proposed bridge types proposed to be tested are introduced. This is followed by recommendations regarding participants to recruit and scenarios to be used in the study in a full mission bridge simulator. Last a proposed test procedure is described.

4.5.1 The bridge types

We propose a study to compare two different types of ship bridges, one bridge equipped with state-of-the-art instruments and one more conventional bridge. We want to compare two bridges that have different technology available. One ship bridge is to be equipped with traditional instruments and the other ship bridge is to have an Integrated navigation System (INS). The proposed differences between the ship bridge types can be seen in Table 3. The ECDIS may be used for navigation if it is approved according to IMO requirements (Safety of Life At Sea, SOLAS, chapter 5, regulation 18-21). We propose to compare the two extremes that are authorised by IMO. This means that the ship bridges should provide the possibility to navigate either with the help of ECDIS or with paper charts. We propose this, since “It is currently estimated that most SOLAS ships have some form of ECS aboard although very few actually meet the ECDIS requirement” (Edmonds, 2007).The use of an advanced autopilot with the functions of curved headline and automatic compensation for drift is supposed to make navigation easier. Curved headline is a function that shows an estimated future position of the ship. The possibility of overlay which enables merging of several instruments information is supposed to make important information more salient. A study of different interface designs by Sauer et al. (2002) shows that an integrated display tends to give navigational advantages but it incurs higher operator cost contributing to higher levels of fatigue.

One problem encountered during the selection of instruments for the two bridge types is familiarity with the equipment. Ship bridges differ much in which instruments that are available and how technologically advanced they are. This is a finding from the HTA interviews with pilots. It is very salient, for example, when pilots mention that they usually only use the most basic functions of the radar, like Variable Range Marker and Electronic Bearing Line, and that these are easy to find on good radars. There is a risk that the preparation time for the bridge types will not be sufficient enough to show all the assumed positive effects of the available technology. This might from one perspective question the mundane realism - how similar the situation is to the real world. On the other hand, anecdotal evidence suggests that many officers get little training on the bridge equipment before or after signing on to a new ship. However, we expect to have a high experimental realism - that the task is taken seriously (Pedhazur & Schmelkin, 1991). The risk of under-training has to be taken because proper training can take up to several weeks according to H. Hederström (Personal communication)[3]. Several weeks of preparation for each participant cannot be provided in this study. However, how participants will perform with limited preparation time can be interesting in itself. If the available technology proves to be very difficult to use, this may give new insights into adaptation to new work environments on a ship bridge.

Table 3. Major differences regarding the ship bridges.

Planned setup of the Ship Bridges	
Traditional Bridge	**Advanced Bridge**
- Paper Chart - AIS through MKD	- Electronic Chart System and Paper Chart - AIS Integrated in ECS or Radar - Radar and ECS overlay possible - Curved headline/EBL - Conning Display

4.5.2 Participants

Each bridge is to be navigated by a bridge team. A recommendation for the bridge team is that there are at least two active officers. The tasks of navigation will be of that kind that two officers is appropriate. This provides possibilities to study work organisation.

The participants conducting the navigation in the simulator ought to be as representative for the population as possible, in this study focus is directed towards Swedish Masters. The prerequisite for becoming a participant in this study is that participants either have papers as Master Mariner or are in the last year of the study to become a Master Mariner, this because we want to study professionals in their natural context.

4.5.3 Scenarios

The task of navigation has to be as realistic as possible. The problems encountered ought to be representative and are recommended to be chosen among the presented problems related to the HTA work model presented in section 3.5.1. We propose the use of problems related to difficult external factors. Some problems related to technical breakdowns or errors in executing tasks are dependent on the actual instrument, which

[3] Head of Chalmers Simulator Centre, Chalmers University of Technology, 10 November 2006.

may vary much. By focusing on external problems, the different bridge types can be tested against external factors.

The overall goal in the tasks of the proposed simulation is to be well known and although the environment is complex and dynamic there are instruments supposed to make the task easier to perform. Each scenario that is to be used is proposed to be split into different parts related to specific problems. These problems can then separately by assessed by experts following a protocol. The scenarios for the proposed study in the simulator are to be considered as normal and realistic and not a study of crises management. This implies that the task in it self is not to be considered as causing high level of stress, which according to Westrenen (1999) enables measurements of HRV in this domain, see section 4.3.4.

4.5.4 Proposed procedure

To obtain sensitive data it is proposed that each bridge team solves the task of fairway navigation during journeys in two scenarios using the two different ship bridge types. To test the ship bridge types two different scenarios will be developed so that the order of the ship bridge to be used can be balanced (Kirk, 1995). Although the order of which bridge type or scenario to start with ought to be balanced, the other prerequisites for the problem solving ought to be as equal as possible, for example, the same ship model should be used when participants are to navigate with the two different ship bridge types. In Figure 15 a recommendation of test procedure is shown.

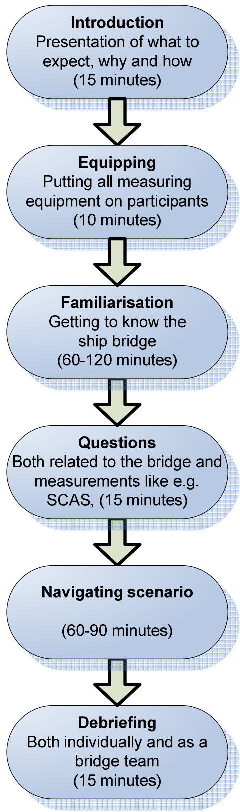

Figure 15. Recommended procedure for simulator testing.

First the participants are to be welcomed and the purpose, background and planned proceeding explained. This is to make the participants relaxed in the environment and to confirm that the procedure is following ethical policies and regulations. Next the participants are to be equipped with instruments for collecting data related to HRV. This is recommended to be done before familiarization so that participants will be trained in the same situation they are to perform the task. Familiarisation aims at making the participants comfortable with the environment and equipment they are to use. The familiarisation is followed by a phase were any uncertainties can be sorted out and questions regarding the measurements of demographic data of the participants and SCAS can be asked. The participants will also be introduced to the statements related to COCOM. This is followed by that the participants will navigate one of the scenarios. Afterwards additional questions of SCAS will be asked and debriefing will be initiated. Initially every participant will be interviewed individually. Afterwards a team debriefing will be conducted, so that observers may ask questions to clarify circumstances that have caused uncertainties during observations related to the task. The same procedure will be repeated the next day when the participants will be back to test the other bridge type. The scenarios should be conducted during the same time during the day so that results will not be influenced by effects that are related to the time of day, for example sleepiness. To avoid carryover effects between the scenarios and bridge types a minimum time limit between the start of the two scenarios has to be established.

4.6 Expected results

In this section the data for analysis and possible outcomes are presented.

4.6.1 Data

We expect the following data to be accessible:

1. Video recordings. The work with the electronic equipment like for instance radar and ENC (Electronic Navigation Chart) will be recorded.
2. Expert evaluations of each scenario trial.
3. Independent performance measures such as:
   Time (average speed)
   Measures of relevant safety margin
   Measures of relevant CPA
4. Heart Rate of participants solving tasks(HRV)
5. Subjective measure of experienced work load (NASA TLX)
6. Subjective measure of experienced core affect (SCAS)
7. Subjective measure of experienced control during the scenario trials

These data will serve as a foundation for comparing the two bridge settings. Having scenarios recorded for analyses afterwards provides possibilities for tracking special situation and questions related to the task.

4.6.2 Possible outcomes related to research question

The proposed study in the simulator has a stated goal of comparing two bridge types. This is a specific question compared to the more probing questions in the field study and task analysis. We expect the results to provide information on the impact of different bridge equipment, for example, regarding experienced workload, experienced work situation, core affects and control. These data, containing subjective measures, physiological measures and expert ratings, render possibilities for comparisons that will state possible differences related to the equipment. This in turn may give new insights and perspectives. We expect to learn more about how the task of navigating in fairway is conducted under given circumstances. We have good possibilities of finding work strategies that can explain how a joint cognitive system including a ship bridge is used.

4.6.3 Possible outcomes related to data collection methodology

During the field study it became evident that it may be difficult to collect data in the natural context, see section 3.6. The proposed composite of data collection methods may answer the additional question of which methods that are appropriate to use when studying the ship bridge and what the constraints of specific methods are.

5 Discussion

In this thesis results from field studies and task analysis are presented. A proposal for how this knowledge can be used for further studies is also presented. By doing this we have studied phenomena in the real world, interpreted them and turned them into research questions that we argue would lead us further to the understanding of human factors related to decision making on a ship bridge.

We set out to study the work on a ship bridge in its natural setting and have several times argued for the importance of ecological validity, which briefly can be explained as the study of phenomena in its natural context. The next step, to further investigate findings from the field study and task analysis is proposed to be conducted in a full mission bridge simulator. This can be understood as leaving the original goal of studying the natural setting. Through the use of a high fidelity simulator we argue that we do not leave the perspective of high ecological validity. We still study the task of navigating in fairway in its wholeness. We do not break down the task into subtasks related to specific instruments and test them individually. Although we may focus on specific details we still observe them in the context of navigating in fairway.

When studying task solving in a full mission bridge simulator, we do risk to be observing task solving that are typical for a simulator but still not representative for the reality. Some aspects, like, for instance, the personal consequences of damage due to a collision cannot be simulated. Other aspects, like cargo planning, paper work preparing for docking or time pressure due to last minute changes of cargo logistics will not be simulated. These are all examples that clearly have an effect on the work on a ship bridge and most often are related to the work of navigating in fairway. This risk of not being able to identify potential effects from some aspects is then a calculated risk, if we want to use proposed data collection methods in a simulator, especially in combination since this demands time for calibration. If we can not control the environment that we study it is difficult to argue that we are actually measuring under the same, or equal, circumstances. As shown, the work on the ship bridge is complex and dependent of many factors. If one factor like weather or one part of an instrument is changed, this may be dependent of many other factors which make it difficult to know the extent of the change if we do not control the environment. When investigating specific questions like the comparison of two bridge types, the proposed data collecting methods in a simulator can give reliable data. We have proposed data collecting methods that are closely related to the aspects that we want to study and that in several cases have been used before. We argue for high validity due to the use of a high fidelity simulator. For instance, one study has shown that there is no difference in heart rate dependent of task performing in a simulator or the real world when professionals are tested in high fidelity simulators (Magnusson, 2002).

We further argue for high reliability in those cases that we propose to use data collecting methods which have been verified before like for instance: NASA TLX, SCAS and HRV. These data collecting methods are to be used in a simulator which provides good possibility for repeatability. Through documentation regarding of the other data collection methods like observations and COCOM, the work can be tracked if needed. Validated data collection methods provide possibilities for generalizing results. During the studies we have to be careful with the analysis of the constraints of the situation, so that we may generalize in a correct manner. One example is a potential constraint due to the ship model used by the simulator. We rely on the functioning technology in the simulator and factors like how well the ships model is programmed and interact with the imaginary sea. This will have an effect on the experience of ship behaviour and has to be realistic. The feeling of "this is not for real anyway" will in some sense be present. However, in a simulator we at least have the opportunity to describe the prerequisite for the scenarios in detail, and play the recordings again and thus learn something, at least from these situations.

Swedish research conducted under the paradigm of Dynamic Decision Making has several times used microworlds and experimental settings (Juslin & Montgomery, 1999). Defending Brunswikian psychology Hammond (1999) criticises the use of microworlds if they are to be chosen indifferently

> "If it is a creation of someone's imagination, someone who merely wanted to create a complex opaque, and dynamic system, then we need more justification: why these arrangements?" (p. 312).

Within the Naturalistic Decision Making there has been an argument that traditional study in experimental settings prone to miss phenomena affecting the real situation (Zsambok, 1997). In our proposed study we argue for the use of a high fidelity simulator. We have shown how we can relate problems from the reality to tasks to be solved in the simulator. This is one reason for why we argue to have better prerequisites than previously mentioned microworlds for studying what participants "actually do". If I would have to place the study of ours in a paradigm, I would, although we use a simulator like to place it under the umbrella of Naturalistic Decision Making due to fundamental similarities. "NDM is the way people use their experience to make decisions in field settings" (Zsambok, 1997, p.4), which is what we did in the field study and task analysis and argue to do in the high fidelity simulator. Another similarity is the fact that we study “experts” working in their natural setting which also is typical for NDM.

By the proposed data collection methods we have a strong prerequisite to investigate the differences of the bridge types. This will probably uncover new questions that can lead us further. The proposed study will render a deeper understanding of the work on the ship bridge and provide good possibilities for learning more of what is central for the task of navigating in fairway. This may be used when considering changes related to the joint cognitive system including a ship bridge, like for instance discussions of buying or constructing new bridge equipment or reasoning about work organization. A deeper knowledge may provide a more nuanced reasoning about how the work on the ship bridge can be supported in a constructive manner. This in turn may give a safer and more efficient prerequisite for navigation.

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Appendix A-D