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EfficienSea
Efficient, Safe and Sustainable Traffic at Sea

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Executive Summary

In the last decade maritime traffic on the Baltic Sea has increased drastically. It is expected to increase even more in the future leading to a traffic situation which is becoming a threat to the safety of navigation and to the maritime environment (Sonninen & Savioja, 2005).

EfficienSea is a strategic project concerned with improving the efficiency, safety and sustainability of the increasing maritime traffic in the Baltic Sea region. 17 organisations from six countries are participating in the project, consisting of six work packages.

The study is part of Work Package 6 concerning “Dynamic Risk Management”. The work package aims to develop and demonstrate different approaches to dynamic risk management. Part of this work is the assessment of decision support tools used for the provision of vessel traffic service (VTS).

The following research questions were considered:

1. What characterizes decision making in the settings of a VTS centre?
2. What decision support tools are used today to provide vessel traffic service?
3. What user needs do VTS operators have today and how can these be included in the decision support system development of the future?

Decision Support for a VTS

As part of the project several decision support tools used today for the provision of VTS were studied. In VTS-centres decision support aids are often subsystems integrated in one large VTS-system. These aids are used to support traffic control and monitoring, information gathering and navigational assistance.

Following decision support tools were examined in the study:

- RADAR
- AIS
- GPS/DPGS
- ENC
- VHF radio
- Cameras
- Internet and mobile phones

Additionally, to highlight that decision support tools are not limited to be a technical solutions, procedures, checklists and training of VTS operators and their impact on the operators’ decision making were studied.

Study visits, expert interviews, a simulation, a focus group interview and a literature study were used to collect data on VTS operators’ user needs. The collected data was analyzed by applying the Recognition-Primed Decision (RPD) Model (Klein, 1993) of decision making in naturalistic settings.

What characterizes the decision making in the settings of a VTS centre?

VTS operators act based on experience, making it hard to actually single out different aspects that influence the decision making. Thus, there is a variation of situations which are seen as typical and

where the operators act on earlier experiences, creating a framework consisting of expectancies, cues, plausible goals and typical actions.

During traffic monitoring the operators look for information that conflicts with their expectancies on the traffic development. They use the information from various data sources to construct a dynamic picture of the situation. Based on their working experience, both on board and on shore, the operators have concepts on what is typical and what is not. As long as all the information is classified as typical, their course of action is to let the traffic flow without interfering actively. Acting on the situation, the operators make the decision on which information is needed by whom and when.

In order to assist a vessel with navigation the operator needs to infer more data from the context. This might, for example, happen through conversations on the VHF working channel in the area where the responsible VTS operator asks the bridge team for complementing information. The communication is used to define what kind of advice or assistance a certain vessel needs. It is also used to derive information on the status of the bridge team.

What makes the decision making process of navigational assistance vary from the one of information service and traffic monitoring is that the operator needs to consider both the bigger picture and the immediate surroundings while assisting in someone else's decision process instead of just matching a response to a typical situation. This means he/she needs to assess the situation without taking over control, matching the advice or assistance to a specific vessel and crew in a specific context.

What decision support tools are used today to provide vessel traffic service?

Through several expert interviews, observations and a focus group interview it became clear that the use of decision tools is highly dependent on contextual factors such as:

- Services offered by the VTS in the specific area
- Traffic density
- Geographical and hydro-meteorological conditions
- Manning levels
- Level of education and work experience of the operator

The results show that the need for decision support tools can differ from one VTS centre to another. In some areas VTS operators also have to take responsibility for tasks not necessarily included in the definition of a VTS. This makes it hard to define which decision support tools are actually used and needed for the provision of VTS in a VTS area.

However, the results of this study show that most essential for a VTS operator is the VHF and the RADAR. These two tools were also found to be indispensible and should always be working. Further, parts of the AIS information transmitted were also identified as important for the provision of good VTS service, e.g. CPA, TCPA, name, course and ETA. But nevertheless, all the experts mentioned that there were problems with the reliability of AIS data displayed in the system.

Finally, the data collected in this study indicates that one of the key elements in the decision making in a VTS centre is not any specific tool, but rather the experience the operators build up and maintain.

What user needs do VTS operators have today and how can these be included in the decision support system development of the future?

Organisational user needs

In the study, aspects concerning the overall organisation of the maritime sector arose. It became clear that a general goal and an overall scope for the work of the VTS must be defined. The main goal should be safety. The organisation of the maritime sector should be aware of the importance of creating a safety framework of guidelines which is VTS-centred. This includes a clear statement of which services are included in the VTS. A VTS centre should not become an overall service centre for all the events happening in a VTS area, e.g. VTS operators should not be forced to take fairway maintenance records, answer to port alarms, organise the berthing of ships etc.

In addition, clear guidelines concerning the VTS education must be stated. A background as a Master Mariner should be obligatory for all VTS operators. Communication skills and navigation knowledge need to be improved and refreshed frequently to guarantee the best preconditions to provide good service to the maritime community.

Technical user needs

The VTS operators emphasized that the right information must be presented at the right time. What type of information this is and when it needs to be presented, depends on the context of use, e.g. traffic density, geographical and hydro-meteorological conditions. The amount of information should be matched to what is needed for the daily work of an operator. Future support system design should bear in mind that decisions are often made based on pattern recognition.

Further, many operators expressed concern with regards to the trustworthiness of the information displayed in the system, in particular with regards to AIS-based information. Operators must be able to rely on the information which they base their decisions on. Doubts on the trustworthiness of a data source lead to a time-consuming process of double checking. The validity and integrity of a data source must be guaranteed or it needs to be removed from the system altogether.

Additionally, the experts stated that problems in the interaction between shore and ship arise by having differences in the information displayed on shore and on the bridge. These differences must be compensated for, or otherwise be managed, to facilitate the work of the VTS operators.

Summary of needs

1. Support familiarity in the information presentation to facilitate pattern matching for quick and effective decision making
2. Support of communication to facilitate the interaction of the different players in the maritime sector.
3. Support the building of trust through better and more effective communication between shore and ship (content is more important than quantity)
4. Re-evaluating and defining the role and tasks of the VTS as service for the maritime community with safety as the main goal
5. Need for a common "situation picture" so that bridge team and VTS operators can perceive the same representations
6. Remember the non-technical resources such as experience, training, co-workers and procedures
7. The validity and integrity of the data presented in the system must be guaranteed

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Abbreviations/Definitions

AIS	Automatic Identification System,a system that transmits certain information about the ship (name, position, speed etc.) and receives the same information from other AIS-equipped vessels in the vicinity.
AtoN	Aids to Navigation
BaSSy	Baltic Sea and Safety project
Boarding point	A position where pilots board or disembark ships at sea.
CCTV	Closed-circuit television, the transmission of signals from video cameras to a specific place (as opposed to broadcast television).
COG	Course over ground, the actual course a vessel follows (differs from heading, which is the direction in which a vessel points).
COLREGS	International Regulations for Preventing Collisions at Sea. The IMO “rules of the road”, to be followed by vessels at sea
CPA	Closest point of approach, an estimated point where the distance between two vessels will be at a minimum.
DAMSA	The Danish Maritime Safety Administration.
DSS	Decision Support System
ECDIS	Electronic Chart Display System, a navigation information system for vector-based digital charts.
EMSA	European Maritime Safety Agency, the maritime safety agency of the European Union.
ENC	Electronic Navigational Chart, term for official electronic charts produced for use with an ECDIS.
ETA	Estimated Time of Arrival, a measure of when a vessel is estimated to arrive at a certain point
Fairway	Fairway in the widest sense of the term refers to the water areas used for shipping. It is however normally used in the sense of a cleared channel intended for navigation.
FMA	Finnish Maritime Administration.
GNSS	Global Navigation Satellite System

GOFREP	Gulf of Finland Reporting System, a mandatory ship reporting system in the Gulf of Finland.
GPS	Global Positioning System, a system for satellite navigation.
GRT	Gross Register Ton
HRO	High Reliability Organisation
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IMO	International Maritime Organisation
ISPS	International Ship and Port Facility Security
MKD	Minimum Keyboard and Display
MMSI	Maritime Mobile Service Identity
NDM	Naturalistic Decision Making, a theoretical framework for decision making research, emphasizing the study of how people actually make decisions in demanding situations.
OER	Operational Experience Review
POS	Pilot Ordering Service
RADAR	Radio detection and ranging, an object detection system.
RPD	Recognition-Primed Decision making, a decision making theory included in the NDM framework.
SMA	The Swedish Maritime Administration.
SMCP	Standard Marine Communication Phrases
SOG	Speed over ground, the actual speed of a vessel relative to the ground (can differ from speed through the water).
SOLAS	International Convention for the Safety of Life at Sea. IMO regulations concerning the safe construction and equipping of ships.
SRS	Ship Reporting System, a voluntary or mandatory reporting system for vessels in a specified area. It collects and distributes information of importance for the vessel traffic safety.
SSN	SafeSeaNet, a European platform for maritime data exchange.

VHF	Very high frequency, a band of radio frequencies used for among other things maritime communication.
UHF	Ultra high frequency, a band of radio frequencies.
VTS	Vessel Traffic Service, a shore-side service for vessel monitoring, navigational assistance and information service.

1 Introduction

1.1 General introduction

In the last decade maritime traffic on the Baltic Sea has increased drastically. It is expected to increase even more in the future leading to a traffic situation which is becoming a threat to the safety of navigation and to the maritime environment (Sonninen & Savioja, 2005). EfficienSea is a strategic project concerned with improving the efficiency, safety and sustainability of the increasing maritime traffic in the Baltic Sea region. 17 organisations from six countries are participating in the project, consisting of six work packages (application form, partner document). The work relates to the concept of e-Navigation, aiming to harmonize collection, integration, exchange, presentation and analysis of marine information (IMO NAV 54). Decision support tools are one part of this, and as is it considered essential that the e-Navigaton architecture is developed in accordance with top-down user requirements (IALA Recommendation e-NAV 101), it is also necessary to assess what the actual user requirements are. The following study is part of Work Package 6 concerning "Dynamic Risk Management". The work package aims to develop and demonstrate different approaches to dynamic risk management. Part of this work is the assessment of decision support tools used for the provision of vessel traffic service (VTS).

1.2 Aim

As part of work package 6 "Dynamic Risk Management" the aim of this study was to identify the user needs that relate to decision support tools used today for providing vessel traffic service. Further, the study focused on examining the overall needs of VTS operators today and in the future.

The following research questions were considered:

1. What characterizes decision making in the settings of a VTS centre?
2. What decision support tools are used today to provide vessel traffic service?
3. What user needs do VTS operators have today and how can these be included in the decision support system development of the future?

1.3 Document structure

The report consists of seven chapters. Chapter 1 is a general introduction and presents the overall aim of the study. A background including the history and definition of VTS as well as an overview on the decision support tools studied is presented in chapter 2. Chapter 3 introduces the theoretical framework used for the analysis of the collected data. In chapter 4 the methods used for the data collection are described. The results of the data collection are presented in chapter 5 followed by an analysis and discussion in chapter 6. Chapter 7 summarizes the overall conclusions and introduces areas for future research.

2 Background

Vessel Traffic Service (VTS) is a shore-side service implemented by a *"Competent Authority to improve the safety and efficiency of vessel traffic and to protect the environment"* (IMO, res. A.852). The VTS operates through VTS-centres with operators monitoring traffic, assisting in navigational matters and providing information with the help of several decision support systems. Through the past years there have been several studies concerning decision support tools for the maritime sector but most of them focused on the technical aspects of such tools including possible enhancements and future applications rather than applying a usability perspective in the analysis (Høye, Eriksen, Meland & Narheim, 2007; Grundevik, Wilske, Huffmeister, 2009; Kharchenko, Vasylyev, 2004; Chang, 2004).

2.1 History of the Vessel Traffic Service

VTS was not implemented in one day; the need for this service arose through decades. All started with the introduction of shore based RADAR stations in the late 1940s. Traffic management was very limited in that time and RADAR stations were introduced to facilitate the effective use of port facilities. RADAR could provide traffic images and it was possible to monitor the traffic to keep it flowing, especially in the port areas and approaches. The first shore based RADAR was installed in 1948 in Douglas, Isle of Man, followed by the ports of Liverpool and Rotterdam (IALA VTS Manual, 2002). The first steps towards what is nowadays known as VTS were taken the 1970s. After several major oil spills, the pressure to protect the maritime environment rose and resulted in a slow, but constant movement towards more organised co-operation between pilots and RADAR chain operators.

On the initiative of the Governmental Maritime Consultative Organisation (IMCO), nowadays called IMO, VTS was defined by adopting a resolution on the implementation of such a service. This resolution was replaced by the IMO Assembly Resolution on VTS (A.857(20)) in 1997. A.857 states guidelines for vessel traffic services (IALA VTS Manual, 2002). There are two different types of Vessel Traffic Services, coastal and port or river services. A coastal VTS is responsible to assist with the safe passage of vessels through coastal waters, especially when there is a high traffic density or if the area is difficult to navigate. Port or river services assist vessels to navigate efficiently and safely when leaving or entering a port or while sailing along a river. Nowadays there are more than 500 operational services worldwide (IALA VTS Manual, 2002).

2.2 Vessel Traffic Services Today

As mentioned above Vessel Traffic Service (VTS) is a shore-side system implemented by a *"Competent Authority to improve the safety and efficiency of vessel traffic and to protect the environment"* (IMO, res. A.852). There are three different types of services included in VTS: information service, navigational assistance service and traffic organisation service. Depending on the geographical characteristics as well as on the traffic density and pattern, the Competent Authority needs to consider which of the three services are going to be provided by a VTS-centre in the area. The Competent Authority is defined by the IMO as *"the authority made responsible, in whole or in part, by the Government for vessel traffic safety, including environmental safety, and the protection of the environment in the area"* (IALA VTS Manual, 2002).

Information service is a service providing the traffic with all necessary information in good time. Information can be any kind data concerning vessels' positions, intentions, destinations as well as any information concerning the VTS-area, e.g. boundaries, radio channels, reporting points, hydro meteorological facts etc. The information service is meant to *"assist the shipboard navigational decision making process"* (IALA VTS Manual, 2002).

Navigational assistance service consists of two parts, navigational advice and navigational information.

Navigational information can contain:

- course and speed of a vessel
- positions identities and intentions of the surrounding traffic
- warning to specific vessels
- position relative to the fairway axis and way-points.

In the case of navigational assistance in form of navigational information the VTS contributes to the decision making on board. In contrast to it, navigational advice includes are more active part for the VTS operator as he/she is participating in the actual decision making. Navigational assistance service is given at request. (IALA VTS Manual, 2002)

Traffic organisation service has the objective to prevent the development of dangerous situations and to keep the traffic fluent, safe and efficient in the VTS-area. It is concerned with proactive planning of vessel movements to avoid accidents and congestions. The traffic is monitored and governing rules and regulations are enforced. In the areas where VTS is authorized to provide traffic organisation, the instructions should be as clear and direct as possible, leaving only details of the execution to the vessel (IALA Manual, 2002).

2.3 VTS- personnel

As mentioned above the VTS is operated by VTS operators. Depending on the geographical area and the traffic density and pattern, an operator is responsible for providing service for either the whole area or a certain sector. As the operator should be capable of providing all necessary information and even navigational assistance and traffic organisation, most of the operators have a marine background (IALA VTS Manual, 2002). Through the past decade IALA has stated guidelines, standards and recommendations for the training of VTS operators, -supervisors and managers (e.g. Recommendation V-103 (1998)). Most focus is on the so-called "On-the-Job Training". After several basic courses the new operator is appointed to a VTS-centre and is trained on the job by a certified VTS operator to acquire a thorough knowledge of the area and the actions appropriate for providing VTS-service (IALA VTS Manual, 2002).

2.4 Support Systems used for Vessel Traffic Services

The following chapter is an outline of available support systems used today to facilitate the decision making process of VTS operators. The outline will include both technical systems such as RADAR as well as non-technical support, e.g. guidelines and procedures. In VTS-centres decision support aids are often subsystems integrated on different layers in one large VTS-system. These aids are used to support traffic control and monitoring, information gathering and navigational assistance. There are several manufacturers, e.g. Atlas Elektronik, Saab Transponder Tech, Sofreglog etc., offering such systems. Design as well as sources of information used in those systems can differ a lot between various VTS-centres depending on the size, the traffic density and the overall needs of the operators to be able to provide VTS (IALA VTS Manual, 2002). A VTS-system is often referred to as a decision support system (DSS).

A Decision Support System (DSS) is an interactive system or subsystem designed to facilitate decision making by combining data, documents, knowledge and/or models to identify and solve problems. In general, DSS are computer-based information systems, which enhance a person's or group's ability to make decisions. (dssresources.com) Although the different decision aids are normally integrated in one VTS-system, each decision aid is going to be presented separately to underline its advantages and disadvantages in use for VTS service.

2.4.1 RADAR

RADAR is one of the most important instruments used for navigation and traffic monitoring. It is short for radio detecting and ranging. RADAR is based on actively measuring the surroundings. It uses high frequency radio waves, which are reflected by objects and other hinders. These reflections are received by a RADAR receiver and are used to identify hinders, objects etc. (www.ne.se). There are both ground based and ship borne RADARs (Koester, Anderson & Steenberg, 2007). RADAR is a robust system and has been in use for several decades. It has the advantage of being independent from other sources, e.g. databases, GPS, not needing any other information input. Other decision aids in the maritime sector require data input from other sources, e.g. AIS which needs a GPS-position. As the RADAR is independent from other sources it is more reliable than other tools. It is a stable system and can be used in various weather types (Grundevik & Wilske, 2007).

However, there are several disadvantages with this decision aid. To have a complete coverage of an area several antennas are needed, which can be quite cost-intensive. Further, distance measurements are not always correct so that it is hard to see how close different objects/vessels are to each other. Even overshadowing, meaning that a vessel is not detected due to objects, other vessels etc. shielding it, is a recurring problem, when vessels are near the coastline. When RADAR is used in bad weather conditions, e.g. snow, rain or high waves, the quality of the information can be compromised. Further, one has to keep in mind that RADAR on its own never can be used to identify a vessel. For identification the use of at least one other decision tool is needed, either VHF radio or AIS (Grundevik, Wilske, 2007).

2.4.2 Automatic Identification System (AIS)

The automatic identification system was introduced in 1995 with the aim of avoiding collisions and assisting the VTS. It provides mariners with on-line static and dynamic data of other vessels' behaviour. It is the first information source in the maritime traffic surveillance which is dependent on information transmitted by other ships. Today it has also become one of the most important tools for traffic monitoring. Via a VHF frequency a vessel's ID, position, course, heading and speed is transmitted to other vessels and/or to receivers onshore. AIS offers the possibility to send important information concerning e.g. a port or dangers to navigation. AIS is mandatory for all vessels larger than GRT 300 (Koester, Anderson & Steenberg, 2007). An AIS-message contains three types of information: static (MMSI-number, IMO-number, call signal, name, ship type), dynamic (position, course, speed, heading, rate of turn, navigational status, time) and journey related (type of goods, actual draft, destination and ETA) information. The interval in which the message is sent differs depending on the size, the cargo and the speed of a vessel. Table 1 shows the reporting interval depending on a vessel's behaviour. AIS is ship borne, but it can also be placed on a non-vessel (Koester, Anderson & Steenberg, 2007).

Table 1:

Ship status	Reporting interval
At anchor or berth	3 min
0-14 kn	10 sec
0-14 and altering course	4 sec
14-23 kn	6 sec
14-23 kn and altering course	2 sec
>23 kn	2sec
>23 kn and altering course	2 sec

The AIS-information is normally presented as digital information either on small separate displays (MKD) or as symbols with vectors overlaid on RADARs or in an ECDIS. Normally the operator can choose which information should be displayed and in what way. Further, the AIS can be used for online presentation of the traffic situation, replay of historical data, statistics, accident investigations, risk analysis and for optimization of the placement of aids to navigation (AtoN). There are some common errors linked to the AIS caused by both operators and the manufacturers. These errors include failures in the man-machine interaction, installation errors, wrong static data (wrong input of IMO- or MMSI-number) and errors in the GPS signal (Koester, Anderson & Steenberg, 2007).

Although AIS offers a faster information update in a better quality than the RADAR and is more independent from visibility and weather conditions, it is highly depending on correct GPS-data. If the data the vessel is receiving from the GPS is incorrect, so is the information transmitted to the VTS-centre and to other vessels. Another problem with the AIS is that it is not mandatory for all vessels, which leads to difficulties in detecting smaller vessels and yachts. However, if AIS was mandatory on all types of ships, it would probably still be hard to detect any vessel as there always is a risk of cluttering screens (Grundevik, Wilske, 2007).

2.4.3 Geographical Positioning System (GPS) and Differential Geographical Positioning System (DGPS)

Today the GPS is the only fully functioning global navigation satellite system (GNSS). It has the purpose to give positioning with a global coverage. It is built up from 24 medium Earth orbit satellites that enable a GPS-receiver to determine its location, speed, direction and time. A GPS-receiver requires signals from at least four satellites at one time to be able to calculate a reliable three-dimensional position. As the GPS can provide a three-dimensional position 24 hours a day and independent of the weather conditions, it is one of the cornerstones of navigation world-wide. There are some limitations to the GPS. As GPS always needs a clear line of sight between the receiver and the satellite, its information can be unreliable if an antenna is shielded by an object. There have also been some problems with the range and the accuracy of GPS. To compensate for these problems, differential GPS (DGPS) is used. DGPS is based on shore-based reference stations sending out signals which are used to correct the position obtained by the GPS-signal (Koester, Anderson & Steenberg, 2007).

2.4.4 Electronic Navigation Chart (ENC) and Electronic Chart Display and Information System (ECDIS)

Electronic navigation charts include information about routes, depths, shoreline etc. ENC is the name for the official electronic charts. These charts are based on vectors and are in digital format, which means the position of each object in the chart is shown individually. ENCs are presented in a so called Electronic Chart Display and Information System (ECDIS). In an ECDIS various navigational tools can be integrated based on the need of the user (Bjelfvenstam, 2007). In the settings of a VTS the information from different sensors such as AIS, RADAR etc. is presented on an ENC in the VTS system.

The ECDIS are complex systems and as different types of information can be integrated in such systems they need an adequate amount of training in order to be operated correctly. Aside from its complexity the system depends on different databases to be able to get access to updated charts (Grundevik, Wilske, 2007).

2.4.5 Cameras

Video cameras are commonly used for traffic monitoring. Normally those cameras are CCTV (Closed-Circuit TeleVision). These cameras are located along the fairways in a VTS-area. A VTS operator can zoom in and out on a spot as well as cameras normally are moveable in different directions. Although cameras are important tools for traffic monitoring, some state (Bjelfvenstam, 2007) that they are only useful in daylight and in good visibility.

2.4.6 VHF-radio

Very high frequency radio is used mainly for voice communication between the VTS-centre and the vessels in the official VTS-area. The VHF is used for distributing information to the vessels in the VTS-are as well as to keep track of the traffic movements (e.g. by calling a vessel when it passes a reporting line).

2.4.7 Internet and mobile phones

During the past years the use of Internet and mobile phones as a communication means between vessels and the VTS has increased. The development of broadband Internet enables the exchange of different kinds of information, e.g. exchange of RADAR pictures (Koester, Anderson & Steenberg, 2007).

2.4.8 Non-technical decision aids: Procedures, checklists and training as decision tools

The decision support tools named above are all based on the idea that such a decision aid needs to be technical, usually based on information presentation on a digital display. This view on decision support tools is very limited. Operators do not simply focus on their computer screens but work interactively with a large system, following guidelines, procedures and checklists during their work (e.g. emergency procedures). Thus all kinds of guidelines, procedures, recommendations and checklists can be viewed as decision aids, too. They all constrain the operator's decision and actions and help to make sense out of the information presented in the VTS-system. Also training can be seen as a tool to shape decision making and is therefore also part of the decision aids a VTS operator has access to. Even experience seems to have a big impact on how decisions are made in such dynamic settings as the working context in a specific VTS-centre.

When focusing on new solutions in the field of decision support systems, one should focus on defining how decisions are made in real life settings instead of deciding which technical solution is appropriate to improve the decision making of VTS operators. Training, changing procedures, implementing new checklists or even the redesign of the workplace can also improve decision making processes (Roberts, Bea; 2001).

Another very important decision making resource can be one's co-workers, as plenty of evidence from other domains shows. Research within the so-called high-reliability organisation (HRO) framework emphasises on the role of individual people and their relations to their tasks and to each other in making decisions and maintaining safety in very complex and sensitive organisations, for example nuclear-powered aircraft carriers (see e.g., Roberts 1990; Weick & Roberts 1993). Extensive field work by Sanne (2003) within the air traffic control domain also shows the importance of working together with people who share a common orientation to the task at hand, in order to reach overall goals. Sanne's results also show the importance of giving people who work together the ability, time and motivation to be attentive to the performance of each other. These are just two of many possible examples highlighting the importance of one's colleagues as a decision support resource.

2.5 Related Projects

During the past years there have been several projects concerned with the development of different approaches to enhance the efficiency and safety of maritime traffic.

2.5.1 BaSSy

The BaSSy (Baltic Sea Safety) project was a research project centred on the importance of safe, well-organised shipping in the Baltic Sea. Within the project there were several focus areas, such as the development of a Formal Safety Analysis (FSA) framework to estimate the consequences of collisions and groundings, a study of the design of ship bridges from a human-machine interaction perspective and, most relevant in this context, a Man-Technology-Organisation profiling of a VTS centre, design of a decision support concept for collision avoidance and an analysis of the risk reducing effects of safety measures such as traffic separation zones. To include results derived and lessons learned in this study an expert interview with Eric Wagner was conducted. Its results will be presented later in the report. Further, as information from the project will be fed into EfficienSea by the project partners involved in the BaSSy-project.

2.5.2 EMBARC

EMBARC was a maritime safety research project with a multitude of different goals and objectives, with the general objective being o demonstrate how the safety and efficiency of maritime transport is improved by the VTMIS (Vessel Traffic Maritime and Information Services). Most relevant for this report is the conclusion that all European waters should be a single reporting area, the introduction of the High-Risk Vessel concept, and the idea that Vessel Traffic Management centres, including both VTS and search-and-rescue functionality, could be beneficial.

2.5.3 MarNIS

A third relevant project is the MarNIS project, which had the general objective of improvement of safety and the protection of the environment. It has many things in common with EMBARC, including the focus on VTM's and the High-Risk Vessel concept. MarNIS also examined the role of AIS and long range tracking in the monitoring of such HRV's. MarNIS also focused on the exchange and dissemination of maritime information.

2.5.4 SafeSeaNet (SSN)

SafeSeaNet (SSN) is a European platform for maritime data exchange between the Member States' maritime authorities introduced on behalf of the Directive 2002/59/EC. The Directive stated the goal of establishing a computerized data exchange system in the Member States. Since October 2004 the European Maritime Safety Agency (EMSA) has been responsible for managing the system and the cooperation between the different members. The political responsibility lies with the Commission (www.emsa.europa.eu). SSN collects and contributes various kinds of data concerning vessel traffic monitoring, dangerous cargo details, results of ship inspections and information related to ship waste and cargo residue. It relies on a tree-like structure out of local Competent Authority, national Competent Authority and the central index (www.emsa.europa.eu).

SSN is based on an internet solution with a distributed database. The core part is an XML-messaging system, which is used to transfer data between the data provider and the data requester. The system itself acts like hub providing information based on references. These references are central indexes which can be compared to links. Instead of storing all information, SSN just safes a reference to where the information is located. SSN can be used 24 hours a day all year long. In January 2008, 21 Member States were involved as well as Norway and Iceland on both local and national level. (www.emsa.europa.eu)

2.5.5 PORTNET

PORTNET is an information system providing a collection of all authority notices required for ships arriving or leaving a Finnish port. It is a telematic system, combining a telecommunication and information system with an internet-based user-interface. PORTNET is a national single window facility that can be accessed through the Internet. PORTNET is also responsible for the distribution of information to all concerned parties. PORTNET is managed by the Finnish Maritime Administration (FMA) but it is owned by the PORTNET-community, a community consisting of the FMA, Custom's and the 20 largest ports in Finland (Bäckström, 2005).

PORTNET is an internet-based application with operative time-table and cargo information concerning the vessel traffic in the Finnish area of the Baltic Sea. It is available 24 hours a day. PORTNET is accessed through a homepage www.portnet.fi which also contains other applications connected to it. Accessibility is based on registration and on the rights granted by the PORTNET-community giving only authorities full access to the portal and all its applications. In 2005 PORTNET had about 2000 registered users. (Bäckström, 2006). One of the parts of PORTNET not needing any registration is the intermodal portal. It contains information regarding the vessels' time-tables, Custom numbers and authority notices. That means e.g. advance notice of arrival of a vessel, security notice from vessels (ISPS), cargo declarations etc. Further, different authority decisions can be downloaded as pdf-forms, e.g. ISPS-notice regarding ship security (ibid).

As PORTNET is owned by a community, all decisions regarding the system are distributed among the responsible parties. All new information is handled using the web-interface. The information is provided by ship agents and captains, pilots, ice-breakers, VTS and the ports themselves. All information is even linked to the SafeSeaNet-index server. On the national level PORTNET is used by FMA, the Frontier Guard, Customs, Marine defence forces, ports and the Ministry of Agriculture. (ibid). The advantage of PORTNET is that it can be used in combination with an AIS-base station network. The AIS is directly being connected and matched to different port calls, which can be used for estimating a vessel's arrival with close to one minute accuracy (ibid).

2.5.6 Gulf of Finland mandatory Ship Reporting System (GOFREP)

Due to a drastic increase of traffic in the Gulf of Finland the Estonian, Finnish and Russian maritime authorities implemented the project of the Gulf of Finland mandatory Ship Reporting System (GOFREP) in 2004 (Sonninen & Savioja, 2005). The purpose of the GOFREP-system is to contribute to safety of navigation through and across the GOFREP-area, increase the protection of the maritime environment and to monitor compliance with regulations for preventing collisions at sea (www.fma.fi). The GOFREP system is operated by three shore-based facilities at Tallinn Traffic, Helsinki Traffic and Sankt Petersburg Traffic. It has primary and secondary tasks, some of them less frequent depending on the difference between summer and winter operations.

Primary tasks are:

- the reception and distribution of relevant information from and to the vessel traffic
- monitoring vessel traffic, e.g. observing dangerous encounters or breaches of regulations.
- providing advice and information about navigational hazards or weather conditions

Secondary tasks are:

- reporting of breaches to responsible authority
- providing information for organisations not directly part of the system, e.g. port operators, shipping agents.

The key element of the GOFREP-system is the communication between operators in the three participating countries, which even has impact on the decision making onboard a vessel (Sonninen & Savioja, 2005). The GOFREP system was developed based on human-centered design principles. During four workshops VTS operators from Estonia, Finland and Russia participated in simulations to test different scenarios (Sonninen & Savioja, 2005).

3 Theoretical Framework

In the following chapter the theoretical framework for this report is presented.

3.1 Naturalistic Decision Making (NDM)

Naturalistic decision making emerged in the 1980ies based on findings from decision research in real life settings. In field studies researchers found that decisions in high stake situations and under time pressure were not made based on the idea of a decision-tree where a single decision maker evaluates different alternatives according to the expected outcome. It was found that people in such situations rather make decisions based on prior experience. (Klein, 2008). Instead of focusing on a certain decision event, containing a moment of choice, considering alternatives and considering consequences, NDM focuses on the situation assessment a decision maker makes in a specific situation. Studies showed that less than 20% of all decisions made by people actually involve concurrent deliberation with more than one alternative or cause of action was considered and contrasted. (Klein &Calderwood, 1991). In the following part naturalistic decision making settings are going to be presented. Each setting will be applied to the VTS domain.

3.2 Naturalistic Decision Making Settings

Naturalistic decision making settings are characterized by eight different features which are hard to explain for traditional decision making strategies: Ill-structured problems, uncertain and dynamic environment, shifting, ill-defined or competing goals, action and feedback loops, time pressure, high stakes, multiple players and organisational goals and norms (Orasanu & Connolly, 1993). Generally these settings are applicable in the shipping and VTS domain.

3.2.1 Ill-structured problems and uncertain and dynamic environment

Normally the problems a decision maker is confronted with are not well defined. They need to be recognized by the decision maker and he/she often needs to take an active part to develop come up with hypotheses to develop options of possible reactions towards a problematic situation (ibid). People often find themselves in situations where information to be considered for the decision making is incomplete. Not all information is necessarily available and as time proceeds the dynamic environment will change, increasing the uncertainty of the situation (ibid).

The settings for the work of VTS operators are dynamic and uncertain. As the traffic image changes so does the information that an operator has at hand to make decisions, creating a constantly changing situation. Further, the information that the operators have at hand, can never completely display every detail of a situation. There are always cases of incomplete or wrong AIS-messages, RADAR overshadowing or simply technical malfunctioning of parts of the decision support systems used at a VTS. The operator therefore needs to deal with both dynamic settings and a certain amount of incompleteness of information. Therefore one can say that VTS operators concerns in the daily work do not normally appear well-structured.

3.2.3 Shifting, ill-defined and competing goals

Outside of a laboratory it is seldom the case that there is just one specific goal or value influencing the decision maker in his/her choices. It is often the case that there are shifting and competing goals, or even goals that are embedded in each other. This is especially tricky when new goal and values are introduced as the situation is constantly changing. Further, there can be discrepancies between individual and organisational goals and/or values providing yet one more level to take in consideration when making a decision (ibid).

In their daily work VTS operators are often confronted with shifting, ill-defined and competing goals, an example is safety as a goal which is competing with the schedule and time-keeping. All vessels in the area have intentions and goals that they are following. It is up to the operator to understand those goals and to organise the traffic so that it is sailing fluently and safely at the same time that all actors need to be satisfied.

3.2.4 Action and Feedback Loops

In contrast to more traditional approaches, naturalistic decision making is interested in series of decision events over time. The focus is on how these series are used to solve a problem or to get more information on it, or even both, e.g. physicians choosing a treatment plan, not just a single isolated treatment. Often the different decision events in such a series are used as feedback loops by the decision maker, changing his/her course of action depending on new information obtained by earlier mistakes. How helpful new information is for the decision maker derives from how tightly actions and situation outcomes are coupled (ibid).

As stated above VTS operators need to take an active part in detecting conflicting or risky situations in the traffic picture. An operator also needs to anticipate possible future accidents to create a safe and fluent traffic situation. As one decision of an operator will probably affect more than just a single vessel, the decisions made by one, should be treated more like a series of actions instead of isolated decisions. That means that the operator uses the changing information as a form of feedback loop for his/her decisions and actions with the possibility to correct the course of action depending on new information obtained from the decision support tools.

3.2.5 Time pressure /stress and high stakes

A core aspect in naturalistic decision making is that nearly all decisions need to be made under conditions where time is limited. This leads to situations in which the decision maker may experience personal stress, increasing the risk of exhaustion and loss of vigilance. Further, to be able to make a decision under time pressure one needs to develop a strategy. Research has shown that people tend to shift their thinking to less exhausting decision strategies when dealing with time pressure (Payne, Bettman & Johnson, 1988 as cited by Klein, 2003), definitely not turning towards strategies based on deliberation. Klein's (1998) research on fireground commanders showed that 80% of all decisions are made in less than one minute which shows that it is impossible to consider several alternatives and to evaluate them. In the field of naturalistic decision making the stakes normally matter for the decision maker which likely leads to a situation where the participant feels personal stress while trying to achieve a good outcome as poor decisions can lead to enormous cost, e.g. economic loss, loss of lives (Orasanu & Connolly, 1993).

In maritime settings a decision maker needs to deal with high stakes most of the time. If a poor decision is made one or more vessels might collide, ground or worse; people could get injured. Sometimes just seconds decide whether an accident happens or whether it can be prevented. This puts a lot of pressure on the VTS operator who is responsible for monitoring the traffic and providing the right information. Additionally to high stakes and stress, there are strong organisational settings for a VTS with goals and norms concerning safe and efficient traffic management in the fairways of the Baltic Sea. Rules and guidelines as well as recommendations for the work stated by organisations like IALA, IMO, EMSA or local authorities generating overall values for the working settings.

3.2.6 Multiple players, goals and norms

In real life decision making it is seldom that just one single individual is engaged in the decision making process. It is rather the case that several individuals/parties are engaged in the decision making together, with people or groups assigned to a specific decision making role in the process. One difficulty with this characteristic of naturalistic decision making settings is that it is important to make sure that all parties have access the information needed to share an understanding of common goals and the situational status (Orasanu & Connolly, 1993).

There are always multiple players engaged in the decision making carried out at VTS-centres. Actors such as a Harbour Master, Lock Master, pilot, VTS operator, captain of a vessel and his agency might all have completely different goals which they act on in a certain situation. The VTS operator then needs to solve upcoming conflicts by planning ahead and trying to satisfy the other parties' needs.

3.3 Recognition-Primed Decision Model (RPD Model)

The RPD model was developed by Klein and associates in the late 1980ies. It is one of several models dealing with the aspects of decision making in naturalistic settings and focuses on the importance of recognizing a situation and applying pattern matching to decide on a course of action. In their research Klein and his associates tried to analyze professionals' decision making, e.g. fireground commanders, nurses (Klein, 1998). Klein defined a decision as *"choice point"* where reasonable options exist and the expert might select another option. The selection is not necessarily a conscious action, but as long as there were different options available, a decision was made. Data from research on fireground commanders indicated further that there was no deliberation about different options; neither were they considering more than one alternative. Commanders could build a "*good course of action*" even from the moment they were confronted with a situation (Klein, 1998).

Due to experience the commanders could focus on familiarities between the situation they were presented with and earlier situations they had been through. These familiarities helped to derive a reasonable reaction without the need to deliberate about different alternatives as the situation was identified as prototypical (Klein, 1998).

The Recognition-Primed Decision (RPD) model focuses on two aspects of decision making, first the way that decision makers identify the situation to be able to choose a course of action and second, the evaluation of the chosen course of action by mental simulation. Klein (1998) identified three different variations of the RPD model. Variation 1 focuses on how the decision maker recognizes the situation as typical and familiar, variation 2 on how a situation is diagnosed and variation 3 deals with how the decision maker uses mental simulation to evaluate the outcome of a possible course of action.

Figure 1: The Recognition-Primed Decision Model

Variation 1 is a simple match. The situation is recognized as familiar and/or typical and the decision maker proceeds to take action. When the situation is recognized the decision maker also recognizes the course of action that is suitable. It is a reaction based on cues and patterns as it is not just the situation which is recognized but also cues, goals, expectations and actions. (Klein, 1998) In the daily work of a VTS operator variation 1 decision making occurs when the operator is conducting tasks like e.g. calling a vessel which is passing the reporting line, informing the traffic about weather conditions or the water level in a fairway or channel.

As named above, variation 2 focuses on diagnosing a situation. This means that the decision maker needs to attend a situation actively as information obtained from it might not clearly fit a pattern. There is a need to acquire more information about the situation to be able to diagnose it and to derive a course of action. Variation 2 also accounts for situations where the outcome does not match the decision maker expectancies. The decision maker will then try to respond by checking his/her interpretation, matching what fits best to the situational features. One could say that the decision maker is "deliberating about the nature of the decision" (Klein, 1998). An example of variation 2 decisions in the daily work occurs whenever a VTS operator is monitoring the traffic and a vessel does not behave as expected. This might include, but is not limited to, situations such as vessels passing very close to each other, ships leaving the fairways or coming close to hot spots. The operator needs to take a closer look and analyze the situation further to be able to react. He/she needs to be active and does not just react towards a situation but needs to evaluate it.

Variation 3 focuses on mental simulation for evaluation of a course of action. The decision maker uses the heuristic strategy of mental simulation to imagine how a specific course of action is going to influence people, objects and the situation itself. This strategy is used to predict the future or to account for events in the past. It is strongly coupled to experience (Klein, 1998). Variation 3 decisions are those which need a closer evaluation in form of mental simulations of a specific course of action. These decisions occur whenever a VTS operator is involved in planning his/her work. Based on the traffic picture presented on the display the operator is using mental simulation to determine how the traffic is going to develop in the nearer future. This includes evaluating the traffic picture by taking into account where vessels are heading, how fast they are, what cargo they are carrying etc.

3.4 Usability defined by ISO 9241-11 "Ergonomic requirements for office work with visual display terminals"

Usability is the "*extent to which a product can be used by a specified user to achieve specified goals with effectiveness, efficiency and satisfaction in a specific context of use." (ISO 9241-11)*

ISO 9241-11 defines usability as something that enables a user to achieve goals in a specific context. It is defined by emphasizing on assessing the whole work system in naturalistic settings. Further, ISO 9241-11 attempts to introduce a framework, which can be used to measure usability of certain system components as well as the usability of the overall system. (ISO 9241-11). ISO 9241-11 introduces three concepts for measuring usability; effectiveness, efficiency and satisfaction. Effectiveness measures the accuracy and completeness with which a user achieves specific goals. Accuracy and completeness can for example be measured by quality and quantity output. (ibid)

Efficiency focuses on the amount of resources used in relation to the effectiveness with which a user achieves his/her goals. Resources in this case might be time, physical and mental energy spent on a task and/or the material and financial cost of it. (ibid). Satisfaction is defined as *"freedom from discomfort"*. It can be measured in terms of attitudes that users have towards a product. It is the user's response to the interaction with a product and it can be assessed by both subjective and objective measures, e.g. observations, questionnaires, attitudes, opinions. (ibid)

Another important aspect in the above definition of usability is the focus on naturalistic setting or what is called the "context of use". It consists of users, tasks, equipment and the physical and social environment and states indirectly that it is not the product but the context of use itself, which influences a product's usability (ibid). In this report the focus is primarily set on the context of use and the user satisfaction defined by this ISO-standard to develop user needs for VTS operators today and in the future.

4 Method

This chapter presents the methods used for the data collection. As the aim of this study was to get insights on VTS operators' user needs different methods were used to obtain data. A literature study, a simulation, a focus group interview and expert interviews were used during the collection.

Figure 2: Data collection process

4.1 Literature study

To get an understanding on decision support tools used today a literature study was conducted. Its objective was to give a state-of-the-art review on existing decision tools as well as to summarize lessons learned and problems identified in other research projects, e.g. BaSSy, MarNis, EMBARC, SafeSeaNet. The results of the literature study are included in the background chapter of this report.

4.2 Simulation "eSim"

During two days in March 2009 a day in the Sound was simulated at the Chalmers University of Technology. The simulation was part of the work package 4 in EfficienSea and aimed to collect data to concerning user needs as well as to analyze and explore communication and information flow among the actors of the scenario. The simulation consisted of two three-hour long scenarios in the Sound between Denmark and Sweden. It took part at the Chalmers University of Technology in Gothenburg and three bridge setups were used. The bridge setups represented different vessels (cruise ship, tanker, coaster). Aside from different vessels, the Port Authority (Port of Copenhagen-Malmö) a pilot (Drogden Pilot), VTS (SOUND VTS/SOUNDREP), Lyngby Radio and JRCC were part of the simulation. All participating actors were professionals and they were asked to act as close as possible to reality. As mentioned above, the simulation had two parts, one baseline normal scenario and one baseline busy. The scenarios were constructed based on a 24 hour AIS recording of the traffic in the Sound (report WP 4.2,).

All radio communication during the simulation was recorded. Additionally every actor had one observer using contextual inquiry. Contextual inquiry is a method used in social science research as well as in software development and aims to understand the real environment people work. Observations are combined with questions giving the observer an opportunity to get insights on a person's daily work and working routines. This method can be used to gain information on peoples' attitudes, needs and problems they face (Kuniavsky, 2003). All observations in the simulation were noted down in a software analysis platform (CITE).

4.3 Study visits coupled with expert group interviews

To obtain deeper knowledge on the actual user needs of VTS operators three different study visits to VTS-centres were conducted (VTS Ymuiden, Traffic Centre Hook of Holland, Sound VTS). Each study visit was coupled with an expert group interview, in which two or more operators answered a set of questions. The questions were openly formulated and dealt with a variety of topics (communication, good/bad service, anomalies and conflicting situations, use of decision support in daily work) concerning a VTS operator's work. Each topic was discussed with the help of one or more nondirected and follow-up questions.

Aside from interviewing experts in their daily work environment, the study visits also aimed to get a better understanding on what technical equipment is used today to provide vessel traffic service in different areas and what needs there are today that have to be addressed in the future. During each visit, the operators' working environment was observed and the operators were asked questions, similar to a contextual inquiry. During the study visit notes were taken while observing and interviewing the experts. On two of the three study visits, presentations by the experts were held. All data collected was evaluated by summarizing the interviewees comments and answers to a specific topic.

4.4 Expert interviews

4.4.1 Eric Wagner

As part of the state-of-the-art review on decision support system used for vessel traffic service, Eric Wagner was interviewed as an expert. He participated in the BaSSy-project and conducted an operational experience review (OER) at the Helsinki Traffic Centre, including an extensive task analysis of the work of VTS operators. The interview was a semi-structured interview with nondirected and follow-up questions. The aim was to get a deeper understanding for the different tasks VTS operators do during their daily work. Further, the interview aimed at gaining more knowledge about the work of the BaSSy-project concerning VTS. During the interview notes were taken which were evaluated afterwards. The answers were summarized in different topics.

4.4.2 Adam Cowburn

To get a better insight on the education of VTS operators Adam Cowburn was interviewed. He has background in behavioural studies and communication and has been working with the SMA concerning the VTS education for several years. The interview was semi-structured and followed an interview guide completed by follow-up questions. It took approximately 30 minutes and was recorded. The evaluation of the interview is based on a verbatim transcription made after the interview.

4.5 Focus group interview

A focus group interview was conducted at the Aboa Mare, the Maritime Institute of Åbo Swedish Maritime School. Focus group interviews are used to collect data concerning firsthand experiences, motivations, values, priorities and desires as the participants state and discuss their opinion on a specific topic. This interview form was developed in the 1930s and is used in various areas from social sciences research to software engineering (Kuniavsky, 2003). In this study the focus group interview was used to gain further insights about the overall user needs of VTS operators concerning decision support tools now and in the future.

Seven men and one woman participated in the focus group. All were experienced VTS operators who were taking part in an education for becoming On-the-Job training Instructors. The participants came from different VTS-centres all over Finland (GoFREP, Helsinki, Bothnia, Archipelago, Kotka, Hanko) and had all several years of experience working as VTS operator. Prior to the interview the participants received information on the project, the aim of the study and were asked to sign consent forms. After signing the form, the participants were presented with three different questions.

1. Rank the following decision support tools according to their importance for your daily work! Which one is most important, which one least?
    - VHF
    - CCTV
    - Telephone/mobile phone
    - GPS/DGPS
    - AIS
    - RADAR
    - ECDIS
    - Hydro meteorological information
    - Databases, e.g. PortNet (please specify which ones)
    - Internet
2. What characterizes a conflicting situation?
3. How would you define “good VTS-service”?

The participants were asked to think about and make notes on one question during five minutes individually or until everyone agreed to be ready. Then the question was discussed openly in the group. During the group discussion the different opinions and comments were recorded by writing them onto a whiteboard. Aside from a moderator, there was one additional observer present taking notes during the focus group interview. All notes taken by the operators were collected at the end of the interview. The notes from the whiteboard were photographed. After the interview all notes were evaluated and summarized according to the questions asked during the focus interview. The notes were evaluated by comparing them to results from the study visits as well as by analyzing them in connection with the RPD model.

5 Results

The following chapter of the report presents the results of the data collection. Data was collected through 3 study visits at different VTS-centres, a focus group interview with Finnish VTS operators and two expert interviews.

5.1 Study visit at the VTS-centre in Ymuiden

The VTS Ymuiden is located in the Harbour Operation Centre (HOC) on the south bank close to the port of Ymuiden. It offers different maritime services for vessels approaching the Sea Ports of Amsterdam (Ymuiden, Velsen-N, Beverwijk, Zaandam and Amsterdam). In the HOC several services have been centralized and can are offered to all traffic within the VTS-area. The VTS-service in the area is managed by the Port of Amsterdam, as it is the largest of the Sea Ports, on behalf of the Central Nautical Management. The Port itself is owned by the municipality of Amsterdam and is part of the Nautical Sector. VTS-services are part of the traffic organisation department within the nautical sector. Beside VTS-services, a lock service, the hydro-meteo advice service Ymuiden (HMAIJ), the pilot service and vessel movement reports and administration are part of this department and are provided by the HOC.

5.1.1 VTS Ymuiden

VTS Ymuiden is responsible for traffic organisation, including planning and coordination as well as monitoring vessel traffic. It also offers information services. All traffic approaching any of the ports needs to pass the locks at Ymuiden and is handled by this VTS-centre. The centre is located at the entrance to the Nordzeekanal which is the channel linking the North Sea with the ports. The HMAIJ is a service part of the VTS responsible for tidal prospects, monitoring high tides and low waters and publishing tide-windows for deep draught vessels. This data is important to guarantee the traffic flow on the entrance to the Sea Ports of Amsterdam. Navigation assistance and advice in the VTS-area is a responsibility of the pilot organisation which is also located in the HOC.

5.1.2 Work environment and equipment

The work environment is unique as it unites pilots, VTS operators, pilots, ship reporting administration and port authorities in one space, the Harbour Organisation Centre (HOC). This centralization of services makes it possible to exchange information on vessels, weather and other facts of concern among all actors and services located in the HOC.

The VTS operators sit in line to each other in the same room as the Chief Pilot, Chief VTS[1] and a shore-based pilot. Although there are a lot of different advantages, e.g. possibility to direct information exchange between organisations and services, it was mentioned by the Chief VTS operator that the level of noise due to communication can be disturbing, especially during dense traffic hours when there is lots of communication on the VHF-radio as well.

[1] Local job description for the officer at duty; VTS supervisor

Figure 3: Three VTS operators and the operator of the Port of Amsterdam at the HOC

Each workstation is height adjustable and has six computer screens displaying information. Two screens show the VTS-area , one the lock status reporting system, one the vessel reporting system, one pictures from the cameras located at the locks and one displays weather and tidal information. Further, a work station is equipped with two keyboards, for entering information into system, a VHF-station with a microphone, a telephone and a pair of speaker.

The VTS operators and shore-based pilots in Ymuiden use RADAR information as main tool for traffic organisation and shore-based pilotage. There is complete RADAR coverage for the VTS-area and RADAR information is fed into a report- and following system. All information is presented the PONTIS system, a system for Port Management. AIS information is also used for traffic organization but mainly in the area of the Port of Amsterdam as there is no complete RADAR coverage.

When asked why RADAR and not AIS information is used in the VTS-system, the answer was that AIS is not reliable enough. Through the last years the experts had experienced several problems with the use of AIS information, e.g. wrong time zone, wrong position or even switched off. Further, the expert said that it might even be dangerous to use the AIS for traffic organisation as the information is updated in different intervals.

"AIS information does not add anything that one does not know through VHF-communication; it is an information system, but nothing more"

When asked about additional equipment, the Chief VTS operator mentioned that there was no need for further technical aids. The information displayed today is already including all necessary information. The core aspect is to learn the system, not to have more information displayed. Further, estimated arrival time (ETA), Cargo, TCPA and CPA were identified as the most important information for a VTS operator and it is already displayed in the system used today. Finally, the windows of the HOC were pointed out as the most important decision aid for the VTS operators and the shore-based pilots. Through the windows the operators have a good view on the area and the entrance to the Nordzeekanal.

5.1.3 Training, experience and good service

During the expert group interview, training was mentioned as essential for both shore-based pilots and VTS operators. They are trained with simulations which recreate the naturalistic environment and are based on data recorded at different VTS-centres in the Netherlands. All pilots at the HOC have a background as Master Mariners. They are trained in a national pilot training program. In comparison to the pilots, not all VTS operators had a maritime background. This is mainly due to problems recruiting new personnel.

"Good service is when no captain is asking questions on the radio"

Concerning good service the operators mentioned the problem that there is no real feedback for when an operator is doing a good/bad job. It is not necessarily good service just because no collisions are happening. When asked about the key element for good service, the experts named experience.

5.1.4 Anomalies and near miss situations for VTS/SRS operators

When asked about anomalies, the experts underlined that there is no clear definition for an anomaly. All situations differ from each other depending on the traffic density, the vessel's characteristics and the mariner's experience in approaching the harbour. It is hard to say when an anomaly is occurring and what triggered it.

Concerning the definition of "near miss situations", the experts' answer was quite similar. Situations differ and it can sometimes be appropriate to pass really close to each other. In general there are short distances in the Dutch waters as there is inland traffic on small channels as well as traffic passing through the VTS-area both north- and southbound. The passing sometimes is close with less than one nautical mile as distance between two vessels.

5.1.5 Problems/needs

The experts mentioned several problems they have experienced in their work. Mainly the competence of the bridge teams was said to be steadily decreasing leading to problems in the ship-to-ship and ship-to-shore communication, e.g. when talking about a vessel's intention. Another problem recognized was that mariners nowadays are less likely to follow the common rules for the traffic at sea. It has been experienced that vessels give way late in a distance of less than one nautical mile.

5.2 Study visit at the Hook of Holland and Traffic Centre Hook (17th April 2009)

The visit took part during daytime at 17th April 2009. There were 6 participants taking part in the study visit, two VTS operators/Shore-based pilots from the Traffic Centre Hook (TCH), three shore-based pilots from the port of Amsterdam and one shore-based pilot from the river Scheldt. The visit started with two presentations on shore-based pilotage and VTS in the Port of Rotterdam. Each presentation was followed by a short discussion concerning different aspects of SBP and VTS in the Netherlands. During the discussions the experts from the different traffic centres acted as a focus group. A question was directed at them starting a discussion between the experts. The presentations and discussions were followed by a visit at the Traffic Centre Hook, where all experts participated.

5.2.1 Services and organisation at the T.C.H.

The Traffic Centre Hook contains three different organisations concerned with pilotage and VTS-services. The administrative staff works with planning and managing the pilots for the incoming and outgoing vessels. Further, there are pilots and VTS operators working at the T.C.H. During every shift there is a chief pilot and a chief VTS operator at the centre to manage and coordinate the work of the operators and shore-based pilots as well as the traffic movements in and out of the harbor. At the T.C.H. the VTS operators are responsible for information service and traffic monitoring, navigation assistance and advice is reserved for the shore-based pilots. They are the only ones allowed to advice vessels during their way into the harbor while the first contact to incoming vessels is normally made by the VTS operator.

5.2.2 VTS operators and workstations

There are four different VTS-areas on the way from the entrance to the Nieuwe Waterweg. The four operators are located in one room each one on at an own work station (figure 3). The work stations consist of u-shaped desks with four computer screens, a telephone with touch-screen monitor, a VHF-receiver, a microphone and speakers. The screens the operators are facing display different kinds of information. There is one screen showing all information on incoming vessels, one with information on vessels at anchor and two RADAR screens showing the VTS-area. AIS information can be displayed on the RADAR. Green lines mark the vessel which has sent the most recent data update. The interface displays information on the landscape and coastlines in dark colours in contrast to vessel which are displayed in light colours.

Figure 4: One VTS operator station at the TCH

5.2.3 Alarms

The VTS-system has different warning systems which are normally not used by the operators. The only alarm function frequently used is one showing vessels at anchor in a circle. In case a vessel is moving but has not reported that, the system alarms the operator as soon as the vessel touches the boundaries of the circle surrounding it. When asked about possible future alarms, the operator stated that he did not think that this would be necessary. The equipment used today is well enough to monitor the traffic and to provide good service.

5.2.4 Collision avoidance and safety margins

During the discussion the experts where asked how they would define a near miss and how such misses could possibly be presented as part of the decision support system they work with it their daily work. Outside the Port of Rotterdam there is dense traffic with vessels lining up for entering port as well as vessels passing on their way north and south. Under these conditions it is important to consider safety margins between vessels to avoid collisions and to guarantee an efficient traffic organisation. When asked how safety margins are determined the experts answered that those margins are made based on experiences. This is why one can say that every person/actor, e.g. captain, pilot, port authority, has his/her own view on the minimal distance a vessel needs to another. Further, safety margins depend highly on different factors, e.g. vessel size, ability to manoeuvre, weather, experience of crew on board etc. so that it is hard to define a general safety margin for a situation and vessels.

5.2.5 Planning – short-term, long-term, proactive

Through the VTS-system the operator gets information on the expected vessels. When the vessels enter the reporting area they are labelled on the RADAR and first contact is established. A first contact normally contains information on the draught and intentions of a vessel. The operators use a passage plan for long-term planning. The data of the passage plan can be found in the information system which delivers information concerning incoming and outgoing vessels as well as those which are at anchor. Through that system the operators can access the estimated arrival time (ETA) for each ship. That makes it possible to follow a vessel making its way to the port as all deviations must be reported.

Proactive actions are often coupled with traffic monitoring. As the operator monitors the traffic he/she also predicts the development of the traffic based on the situation displayed on the screen. One of the experts also mentioned that there is a track-monitoring function integrated in the VTS-system at his traffic centre which gives an operator the opportunity to monitor the predicted track of a vessel, but it is never used.

"One needs to have experiences from both sides"

During the study visit it was stated several time that one needs to have expert knowledge to provide efficient, safe and reliable service for the vessels in the corresponding VTS-areas.

5.2.6 Communication

All operators in the TCH use the SMCP for communication on the VHF and the communication is in either Dutch or English. The experts said that communication is the main tool to implement trust between the operator ashore and the bridge team. To be able to provide good service one needs to trust in the other party's competence.

5.3 Study visit at Sound VTS Malmö

On 23rd April 2009 the Sound VTS in Malmö was visited as part of the data collection process. As during earlier study visits, observations of the operators at work were combined with an expert group interview concerning the daily work with focus on ship-shore communication and VTS decision support systems. After an introduction on the Sound VTS and its background, the pilot ordering service and the VTS-service were visited. During the visits the operators were asked questions concerning their work, equipment and ship-shore communication.

Sound VTS is not a VTS but a ship-reporting system (SRS) offering information service (SOUNDREP). It started in 2007 as a project financed by both the Swedish (SMA) and the Danish Maritime Administration (DMA). The system offers 24h/7d service with two operators in each shift. The reporting system is not mandatory, but is still covering more or less 96% of all traffic passing through the Sound. Besides the SRS, the Sound VTS-centre also administers the pilot service, with 28 pilots at 6 different pilot stations. The pilots are responsible for both long-distance pilotage as well as Sound passages. The area covered by the Sound VTS today is just a small area but an enlargement is planned for 2012.

5.3.1 The operators at the Sound VTS

The operators work 12 hour shift, changing roles (active, passive) every second hour. When taking an active role, the operator is at his work station, providing information service and monitoring the traffic. The operator taking on a passive role is still in the VTS-centre, but he/she is free to leave the work station and can either take care of administrative work or take a break. During each shift, there is one Danish and one Swedish operator. Operators work 2 days followed by several days off. The training for a VTS operator contains an introduction course as well as on the job training. All training corresponds to IALA-recommendations and the operators have a maritime background as Master Mariners. Experience, both onshore and onboard, is seen as the key to good VTS-service. One has to understand the needs of the seafarers to be able to provide good service. Further, it was also stated that it is one's experience which is essential for recognizing anomalies in the traffic situation.

5.3.2 Working environment and equipment

The operators are located on the 13th floor with a good overview of the harbour entrance. There are three desks, two for the operators at work and one for the possibility to raise manning levels if it is necessary. Each station consists of a slightly u-curved desk, which can be adjusted in its height, five computer screens, a telephone with touch-screen, a VHF-receiver and two speakers. Three of the computer screens show RADAR pictures of the Sound, the areas displayed are chosen individually by the operator. The other two displays show hydro-meteorological information and a database containing information on vessels which currently are in the VTS-area.

Figure 5: VTS operator at work at Sound VTS

Although there are RADAR screens the operators still use the paper chart to look up detailed information on specific areas, e.g. on cables, offshore installation etc. The paper chart serves the VTS operators as an additional information source.

5.3.3 Traffic anomalies, near miss and high risk vessels

During the study visit the VTS operators were asked questions concerning the definition and identification of anomalies in the traffic. They stated that it is hard to define anomalies as there is nothing like typical situation. Each day different types of vessels pass the Sound carrying different cargo, having different intentions etc. The traffic development differs from case to case. Therefore it is the operator's experience and training which makes him/her recognize a situation, but still it is impossible to define a general case of anomaly.

As well as anomalies, it is hard to define a near miss situation as it is also strongly related to the situation in which it occurs. Normally there is not such a high risk for collisions but rather for grounding in the area of the Sound VTS. There are alarms integrated in the systems signalling that a ship is leaving the recommended course, but often the operators do not have enough time to help a vessel avoid grounding. The margins in the Drogden channel are sometimes very small. When talking to the chief VTS operator it was mentioned that there is the intention to start marking high-risk vessels on the RADAR screen in a different colour. The category high-risk vessel contains black listed ships, ships with dangerous cargo and large vessels which are hard to manoeuvre.

5.3.4 Good service

During the expert interview the VTS operators were also asked to define "good service". For the Sound VTS good service is defined by the provision of 3 different kinds of information to the vessels in the VTS-area:

- Information to a vessel on possible meetings with other vessels
- Information concerning weather and water level in channels
- Information which cannot be obtained by the information system on the vessel itself, e.g. when a vessel is about to lift the anchor all the surrounding vessels are made aware of a crossing ship

The operators also mentioned that their work has influenced vessels to report to the SRS because of the information one can get. Nowadays vessels that are frequently in the VTS-area, e.g. fishing boats, are much more likely to report themselves than before.

5.3.5 Communication

All operators at Sound VTS use SMCP as well as there are different general procedures which need to be followed while reporting vessels. Although the experts said that SMCP was always used, they mentioned that there are exceptions, e.g. when talking to a "British captain". As communication is seen as essential for the information service offered by the VTS, it is important for the VTS operator to adapt the communication to the different people from different cultures. The working language for the VTS operators is English which is spoken on channel 17 and 16. Even when a vessel calls in Swedish or Danish the operators answer in English to be able to provide important information to the other vessels in the VTS-area. But there is also a working channel, channel 4, which opens the possibility to contact the VTS or the vessel in Swedish or Danish. Communication seems to be highly coupled with the experience a certain operator has.

5.3.6 Problems/Needs

There are several problems that the VTS operators experience during their daily work. For example, there is no possibility to obtain information on the visibility in the fairways. Today visibility is checked by calling the Drogden-lighthouse. But this means that the information is not updated or called in every hour or in even shorter intervals, as it would be required for good service. A solution to this problem would be the installation of CCTV-cameras along the fairways. That would also help to monitor the traffic in the fairways better. On the RADAR passing vessels in dense traffic actually seemed to collide in the picture as their plotting overlaps. Another difficulty recognized by the operators was that the reporting of vessel entering the area is not mandatory. Today all ships passing the reporting line are called and about 96% of the vessels answer, making it sometimes hard to provide complete information to all vessels in the area.

5.4 Expert Interview with Eric Wagner

To obtain more data concerning VTS in the Baltic Sea Region an expert interview with Eric Wagner was conducted. As part of the BaSSy project, Baltic Sea Safety, Eric Wagner conducted an operational experience review (OER) at the Helsinki VTS station. He spent five weeks during late 2005 at the Helsinki VTS and conducted interviews and observation during day and night and high and low traffic density. Further, a task analysis was conducted as part of the OER. The goal of the study was to identify possible human factors design discrepancies in the system. The operational experience review focused on four different areas: the socio-technical system, the control room, the workstations and the software system used for VTS-services. A so called compliancy checklist was used to evaluate the four areas. This checklist was based upon different ISO, IALA and IMO standards and guidelines providing the baseline criteria to be met.

5.4.1 Service and manning levels at Helsinki VTS

Helsinki VTS offers 24 hours of service seven days a week. The operators work in 12 hour shift. There are 38 operators working at the VTS Helsinki. There are two different services at the traffic centre, GOFREP, the Gulf of Finland Mandatory Reporting System, and the VTS sectors which are responsible for traffic organisation, information service and navigation assistance within the Finnish territorial waters and VTS sectors. As VTS-services in Finland were centralized several years ago, the optimal work situation is seven operators working at one time; one chief operator, one for the Kotka area, one for Hanko, one each for the Helsinki east and west sectors, one for the Helsinki approaches (up to berth), one GOFREP operator and one backup operator as well as the watch supervisor. The two operators in the Helsinki area change with one another regularly during their shifts as well as the GOFREP and the Hanko operator who change every fourth hour. This is meant to relieve the operator from fatigue in monitoring high traffic areas by letting them switch to a lower traffic intensity sector for a period of time.

The GOFREP operator at the Helsinki VTS station is responsible for monitoring the traffic entering and transiting vessels within international water on the Finish side of the Gulf of Finland while the VTS sector operators have several tasks in addition to the "primary" traffic monitoring task such as arranging the ice-breaking service within the harbour basin, managing vessel departures and arrivals. Outside of normal office hours the VTS operators also organise the traffic in the port such as where to berth etc., arranging stevedores and receiving the fire and break in alarms for the port authority installations. On top of that the filling in of maintenance request reports for i.e. faulty or malfunctioning aids to navigation, radars etc is a part of the VTS operators' daily work.

5.4.2 The VTS system

The computer system used for monitoring traffic is standardized and it is used for both the sector VTS-services and for GOFREP. It is an electronic chart and information system (ECDIS) with integrated AIS and RADAR information. The electronic chart system displays the VTS sector area approaches on one display and detailed hot spots on another display located at the work station. Additionally there are large screen displays for GOFREP and each sector workstation showing the entire sectoral area of responsibility for that operator. During observations the expert recognized that the amount of information displayed in the electronic chart system was reduced to just the most necessary information, e.g. name of vessel. Extraneous information such as soundings, navigational aids etc. were not displayed. This would otherwise contribute to highly cluttered displays complicating target vessel monitoring.

Further, the system is used in conjunction with other databases, e.g. FMA's vessel database, Lloyds register database, PortNet etc. Eric Wagner found that the frequency of use of the information sources differed depending on the situation and the tasks at hand for an operator. In addition to the electronic traffic monitoring support system the expert recognized that the operators used paper charts to obtain more detailed topographical information if required. When asked about which decision aid was most important for the VTS operators, the expert answered that this was hard to define. Traffic monitoring is of course the primary task. The usefulness and importance of a tool depends on the task situation and the VTS area. For example, it was observed that the VTS operators worked a great deal with the PC based ancillary applications for administrative tasks or in order to obtain further information from different databases regarding a vessel. For the monitoring of traffic the more important functions used included the predictor vectors, TCPA and CPA.

5.4.3 Alarms

The VTS traffic monitoring system at the centre had different alarms function which tended not to be used, mainly because too many alarms would be generated which can be very distracting for the operator. There are many narrow fairways and small islands along the coastline of Finland. This leads to situations in which vessels need to pass close to each other generating an alarm although no serious problem is occurring. There were several other alarm functions; e.g. a CPA/TCPA alarm provided in the system to determine close passage, but it was not often used mainly because it was somewhat difficult to execute. Eric Wagner also mentioned that there were alarms and functions supporting risk assessment of different situations, but that they were too "hard to find" in the menu based interface.

5.4.4 Experience

As during earlier interviews for this study, Eric Wagner also mentioned that experience is essential for the decision making process of a VTS operator. He observed for example that VTS operators could determine if the AIS information displayed such as draught seemed plausible for the vessel's other characteristics. The expert also mentioned that the operators search for patterns in the displays to be able to match the response action to the situation displayed.

5.4.5 Problems/Needs

The operators were missing a function to mark different vessels as carrying high risk cargo. As there was no information coding function to display dangerous cargo, it took extra time to click on each vessel to obtain cargo information manually. Further the expert recognized that the operators at the VTS Helsinki had a number of different tasks which were not necessarily related to the primary VTS task; information service, traffic organisation and navigation assistance.

5.5 Focus Group Interview

Eight VTS operators, seven male and one female, participated in the focus group interview. They all were currently taking a course for supervising new VTS operators during the on the job training. They all had several years of work experience and worked with providing VTS for different areas (Archipelago, Helsinki, Hanko, Bothnia, Lake Saimaa) as well as with the GoFREP.

5.5.1 Questions

Three main questions were asked during the focus group interview. They were presented separately and discussed one at a time.

1. Rank the following decision support tools according to their importance for your daily work! Which one is most important, which one least?
2. What characterizes a conflicting situation?
3. How would you define "good VTS-service"?

5.5.1.1 Question one: Ranking of Decision Support Tools

In question one the VTS operators were asked to rank the decision support tools according to their importance for their daily work. Table 2 shows the result of the individual ranking and the group ranking of the operators.

Table 2: Ranking of Decision Tools

Decision Support Tool	Individual Ranking	Group Ranking
VHF	1, 4	2
RADAR	1	1
ECDIS	2	4
AIS	3	3
CCTV	5	
Databases (PortNet, PilotNet, Lloyds)	5	
Hydrographic and meteorological information	6	
Telephone, GPS, Internet	Not ranked	

When the individual ranking was discussed the group mainly shared the same opinion. A discussion came up when the importance of the RADAR and the VHF was ranked. Both tools were thought of as being very important for the daily work of an operator, although the participants could not agree on which of them was most important.

"Man måste se var de kör" (You need to see where they are going)

"Utan VHF kan man inte göra nåt" (Without the VHF you are not able to do anything)

After the presentation of the individual ranking the group was asked to create a ranking together. RADAR and VHF were ranked most important and the experts stated that those are the tools that are essential for being able to provide VTS. The operators stated preferring ECDIS, AIS and RADAR as an integrated system instead of having the information displayed separately. Internet, hydro-meteorological information and databases were seen as equally important and are used frequently. They are seen as connected to each other as e.g. internet is needed to be able to access databases such as PortNet, PilotNet etc. Cameras (CCTV) were rated as not so important for the provision of VTS. One operator stated that they might be needed when the visibility is low in the areas. Another opinion was that cameras would useful if installed at the pilot boarding points.

As a follow-up the group was asked about which particular information presented by the system, they use in their daily work. Some of the operators stated that all information that can be obtained by the system is used. However, as during earlier expert interviews, the participants in the focus group underlined that the need for information differs depending on local conditions in the VTS area. An example is the use of AIS-data.

- VTS Helsingfors & VTS Kotka: name, speed, course and heading
- VTS Botnia: name, destination
- VTS Archipelago: name, speed, course, heading and destination
- GOFREP: uses all AIS-data which is transmitted

5.5.1.2 Question two: Conflicting Situation

The second questioned aimed to get a deeper understanding of problems and difficulties that VTS operators might experience in their daily work. As before the participants were first asked to work individually and then to discuss the individual answer in a group. A white board was used to take notes for further discussion. There were several different categories of conflicting situations.

- Deviation from the fairways
- Technical problems
- No common language
- Different opinions in a situation
- Tired Staff

5.5.1.2.1 Deviation from the fairway

Deviations from the fairway are normally recognized while monitoring the traffic on the ECDIS. There is no further tool the experts could think of which could be used to facilitate the identification of such deviations.

5.5.1.2.2 Technical Problems

Technical problems were also identified as conflicting. The system used for VTS in Finland integrates different information sources in one system. That makes it hard to monitor if the system is working properly; e.g. it was mentioned that it is hard to know where the information actually comes from. That can lead to situations where RADAR stations are not working properly but it is not noticed by anyone as there is still the AIS information in the system. Technical problems were also identified as hardest for a new operator. When one is not used to the system it is hard to be able to solve any problems with the equipment on his/her own. One needs to have experience.

5.5.1.2.3 No common language

In the Gulf of Finland lots of international traffic passes each day. There have been communication problems as there is a lack of a common language. This is especially a problem if a vessel has pilot exemption certificate. This can result in a vessel e.g. vessels with Swedish manning where no one speaks Finnish where the VTS operator needs to translate information between one vessel and other vessels. The Finnish VTS operators use message makers to facilitate the communication. The lack of a common language was also identified as especially hard for a new operator. There is no part in the VTS education which helps to handle situations where communication is not working due to different languages.

5.5.1.2.4 Different opinions in a situation

There are conflicting situations which occur due to different opinions of the multiple players involved in the maritime sector. One is example are differences between the personnel on board a vessel and the VTS operator. Especially during difficult conditions, e.g. bad weather, both operator and bridge team may have different opinions on the situation and are eager to only trust their own instruments, making it harder to cooperate. Other conflicting situations can occur when pilots and VTS operators have different opinions. Nowadays there is no interpersonal contact between the VTS operators and the pilots which can lead to a loss of trust.

5.5.1.2.5 Tired Staff

There have been problems with tired staff on board of vessel. The experts mentioned that it is possible to identify if a person is tired or not depending on the way he/she communicates with the operators. This is especially hard as the operator cannot do anything. In addition, follow-up questions concerning workload and information load were asked. The experts stated that there are different distractions. An example that was pointed out, were alarm functions. There are a lot of different alarm functions integrated in the VTS system which are either turned off or ignored (also mentioned by Eric Wagner).

5.5.1.3 Question three: Good VTS service

The third question focused on a definition of good VTS service. The operators stated different aspects of good VTS service:

- The technical equipment should be good and working containing the decision tools mentioned in question one
- Satisfied VTS staff
- Clear rules for the interaction between VTS operators and the different clients, e.g. agencies, vessels, ports

- High degree of domain knowledge
    - Operators should have a background as a mariner to be able to handle different kinds of situations
    - The operator should participate in refresh-courses to gain new knowledge
    - On-the-job training
- The traffic is fluent without any congestions
- The personal chemistry between the different players (VTS, pilots, vessels etc.) in the maritime sector is good

5.6 Expert interview with Adam Cowburn

As part of this study Adam Cowburn was interviewed. Adam has a background in behavior science and communication and has been working with the education of VTS operators for the Swedish Maritime Administration. The interview followed an interview guide with focus on the education and communication of VTS operators.

The Swedish VTS operators are educated according to IALA guidelines and recommendations. There is a lot of practical training in a simulator. Additionally there are different educational blocks in which communication, speech and service (attitudes) are trained. When asked about possible improvements in the education of VTS operators, the expert mentioned that there is a need for more explicit guidelines on what should be included in it. Nowadays the recommendations from IALA are quite openly formulated not leading to any specific education but to a system where the education of operators differs from country to country, and sometimes even from one VTS centre to another. Further, the expert mentioned that there is a need to improve the SMCP phrases used in the VTS domain. Today the phrases are too many and they are not as standardized as in similar domains, e.g. aviation. Communication needs to be handled as a process supported by the phrases. Therefore there should be fewer and more directed phrases which are trained thoroughly throughout the education of an operator.

According to Adam Cowburn there are several organisational aspects that can influence the decision making of a VTS operator. There is, for example, no common knowledge of the work of VTS operators in the maritime community. Sometimes VTS is seen as pilot ordering service (POS) or maintenance service for aids to navigation (which has also been mentioned by Eric Wagner). Therefore there is the need to formulate safety as main goal for the VTS so that it becomes clear what functions the operators actually have. However, this change in attitude needs to be built on a better cooperation between the different actors in the maritime sector, e.g VTS operators, pilots and seafarers. Further, there is the need for better briefings and checklist in the daily work of operators based on international standards which make it clear which parts are included in VTS and which are not. When asked about the definition of good service, Adam answered that good service is based on that a positive attitude towards communication and process thinking. An operator needs to monitor the traffic actively combined with having good knowledge and understanding of the maneuverability of vessels and possible actions which can be taken by a bridge team.

As possible improvements of the VTS, the expert mentioned that there is the need for a longer education coupled to a better recruitment. Although VTS operators are supposed to be trained Master Mariners there is a lack of practical knowledge of maneuverability of vessels well as possible actions which can be taken.

Further, the communication skills of the operators need to improve with more focus on how standard phrases can be used as part of a process. Finally, the VTS needs to be defined in one term, eliminating all the different acronyms used today. VTS has to be a service with the main goal to improve the safety at sea, not just something that is seen as pilot ordering service.

5.7 Result eSim

As part of Work Package 4 a day in the Sound was simulated. Experts participated in the simulation acting as close to their daily work routines as possible. During the simulation the expert acting as VTS operator was observed for data collection. The VTS operator was an experienced Danish operator from the Sound VTS in Malmö. He acted as professional and tried to work as close as possible having in mind that there were several technical limitations. The equipment for the provision of the VTS was limited to one ECDIS display and a paper chart. There was no possibility to use any databases or the internet to obtain information incoming vessel. Further, there were UHF used as VHF and the VTS operator had only one VHF to work with. Additionally to the VHF, there was a mobile phone which could be used for contacting any of the other players in the scenario. Several results concerning the work of this work package could be observed.

5.7.1 Planning

There were different activities observed which the operator himself called for proactive actions. These actions were for example to zoom in on hot spots and on the reporting line. The operator motivated his actions by work experience from his daily work. Another proactive planning activity was to confirm the AIS information with the vessels. This is important in the Sound as the maximum draught for the two channels (Drogden, Flint) differs.

5.7.2 Equipment

During the simulation the VTS operator mentioned several times that the technical equipment is essential for the work of an operator. He stated that there is always the need for at least two displays, one showing the whole area, one showing the hot spots, to be able to provide good service for the vessels in the Sound. In the simulation the operator was forced to choose between zooming in on different spots or seeing the area as a whole. Further, the simulation showed the need for the access to different databases. As the operator could not use the internet connect to different databases he constructed his own database on a piece of paper showing all vessels currently in the area including their maximum draught, their intentions for passing the Sound and their destination.

6 Analysis and Discussion

The overall aim of this study was to identify user needs of VTS operators with regards to decision support tools used today for providing vessel traffic service, and to get insights on these user needs for the technical development of future decision tools. Three research questions were formulated and each one is going to be analyzed and discussed separately.

6.1 What characterizes the decision making in the settings of a VTS centre?

The decision making at a VTS centre is characterized by what Klein (1993) named "simple match" (variation 1) and "diagnose the situation" (variation 2) in the RPD model of naturalistic decision making. VTS operators act based on experience, making it hard to actually single out different aspects that influence the decision making. There are different situations which are seen as typical and where the operators act on earlier experiences, creating a framework consisting of expectancies, cues, plausible goals and typical actions.

6.1.1 Traffic Monitoring

During traffic monitoring the operators look for information that conflicts with the expectancies they have on the traffic development. Depending on the contextual setting, e.g. what services a VTS centre offers, the geographical conditions, traffic density etc., there are different cues in the information presented on the display that the operators act on. Based on their working experience, both on board and on shore, the operators have concepts on what is typical and what is not. As long as all the information is classified as typical, their course of action is to let the traffic flow without interfering actively. This was especially obvious when the Sound VTS was visited. As a ship reporting system the Sound VTS calls every vessel that enters the area. In the VTS centre the operators use different screens for collecting information and getting cues on how the traffic is developing. As soon as a vessel passes the reporting line, the operator calls it on the VHF radio. Even if a vessel is not answering, the situation is not necessarily seen as atypical as the system in the Sound is not a mandatory one. In the case of the Sound, the passing of the physical reporting line on the screen by the ship representation on a display is seen as a cue to act on, resulting in the operator calling the vessel. The goal of the call is to get in contact with the vessel as well as confirm information reviewed on the system, e.g. maximum draught.

6.1.2 Information Service

The information service also seems mainly based on simple match decisions. The information from different data sources is used to construct a dynamic picture of the situation. Based on their experience the operators use the information as cues to act on. The information presented is matched against their own expectancies. The goal of the service is defined as giving the right information in good time. Acting on the situation, the operators make the decision on which information is needed by whom and when.

6.1.3 Navigational Assistance

Navigational assistance is based on what Klein (1993) calls "diagnose the situation" (variation 2). As mentioned above, in this variation of the RPD model the operator needs to address the situation actively to determine a course of action, in this case giving the right advice and assistance for the vessel in question.

To be able to assist a vessel with navigation the operator needs to infer more data from the context. This might, for example, happen through conversations on the VHF working channel in the area where the responsible VTS operator asks the bridge team for complementing information. The communication is not only used to define what kind of advice or assistance a certain vessel needs. It is also used to derive information on the status of the bridge team, e.g. shore-based pilots in the area of Ymuiden and Rotterdam use the communication to decide if there is the possibility of giving shore-based pilotage to a vessel.

What makes the decision making process of navigational assistance different from the one of information service and traffic monitoring is that the operator needs to take both the bigger picture and the immediate surroundings into concern while assisting in someone else's decision process instead of just matching a response to a typical situation. This means he/she needs to assess the situation without taking over control, matching the advice or assistance to a specific vessel in a specific context. Further, in the case of navigational assistance and advice it also seems like mental simulation is used to determine the best way to assist the bridge team. Based on own experience the operator tries to derive how he/she would act in the situation of the bridge team. This is done by imagining a course of action.

6.2 What decision support tools are used today to provide vessel traffic service?

There are several different decision support tools used today to provide vessel traffic service. The most common have been listed and described above. Through several expert interviews, observations and a focus group interview it became clear that the use of decision tools is highly dependent on contextual factors such as:

- Services offered by the VTS in the specific area
- Traffic density
- Geographical and hydro-meteorological conditions
- Manning levels
- Level of education and work experience of the operator

This can be explained by the need of information that the operators have at different VTS centres. Through the study it became obvious that the needs for decision support tools can be different from one VTS centre to another due to contextual differences. In some areas VTS operators also had to take responsibility for tasks not necessarily included in the definition of a VTS, e.g. the VTS operator for the Helsinki area is also making maintenance reports on aids to navigation as well as managing the traffic organisation up to berth outside of the port's office hours. This makes it quite hard to define which decision support tools are actually used and needed for the provision of VTS in a VTS area.

However, the results of this study show that most essential for a VTS operator is the VHF and the RADAR. Those two tools were used in a more or less integrated system in each VTS centre that was visited. Additionally, these two tools were also named to be indispensible in the focus group interview and should always be working. Further, parts of the AIS information transmitted were also identified as important for the provision of good VTS service, e.g. CPA, TCPA, name, course and ETA. But nevertheless, all the experts mentioned that there were problems with the reliability of AIS data displayed in the system. Too often experience had shown that the information transmitted through the AIS was wrong. Based on that experience the operators had problems trusting this information and it was therefore handled very carefully in the decision making process. In a worst case scenario, all information derived through AIS needs to be confirmed by calls on the VHF leading to a high amount of additional communication, which might be a problem in areas with high traffic density.

Further, the use of decision tools also seemed to depend on how integrated a certain tool was into the system. Some of the operators mentioned that it was not possible for them to say if they were using AIS or RADAR as both information sources were integrated in an electronic chart and information system displaying all data in one chart without showing where the information actually was coming from. Finally, the data collected in this study indicates that one of the key elements in the decision making in a VTS centre is not any specific tool, but rather the experience the operators have. Experience in this case includes both experiences as a VTS operator and as an active seafarer to be able to determine a course of action for a specific situation. This is especially important when an operator needs to give navigational advice and assistance as well as in cases such as a vessel leaving the fairway or vessels getting too close each other.

6.3 What user needs do VTS operators have today and how can these be included in the decision support system development of the future?

The results of the data collection indicated that there were two different categories of user needs:

- Organisational user needs
- User needs concerning the technical system

The focus of this analysis was on using the definition of usability according to the ISO-standard 99241-11 to develop user needs that might guide future decision support system development. As mentioned earlier, this study focused mainly on user satisfaction and the context of use, not on efficiency and effectiveness of the systems used for providing VTS, due to the big differences between the different VTS centres that were studied.

6.3.1 Organisational user needs

The first category of user needs that could be identified was organisational user needs. This user category contains all aspects that were named regarding the organisational setting in which the VTS operators work including education and training as well as attitudes towards the VTS as an institution.

The maritime sector is an international work environment where people from different cultures interact on a daily basis. For VTS operators this means they need to adjust their behaviour based on service promoting safety at sea. The VTS is often seen as POS or maintenance service for the fairways and aids to navigation. Therefore there is the need to establish a better cooperation between the different actors in the maritime settings taking into account that each person has a concrete role connected to specific assignments. There is a need for international guidelines that define more thoroughly what services are included in VTS and which are not in order to change the attitude towards the VTS. The VTS is an active information source and should not be used as e.g. berth organizing service.

Further, according to our experts, the decision making is complicated by the fact that the competence of the bridge teams seems to be decreasing. The experienced VTS operators especially mentioned decreased navigation and communication skills making the interaction between shore and ship more complicated.

Therefore one can state that there is an urgent need to formulate guidelines to guarantee a certain level of education for both seafarers and VTS operators. Additionally the number of acronyms describing the VTS in the international maritime community needs to be limited. Nowadays there are several acronyms (e.g. VTS, VTMIS, VTMS) describing the services offered. There is the urgent need for a standardization of terms to make a clear statement on what VTS can provide.

6.3.2 User needs concerning the technical system

The VTS operators from different VTS centres mentioned several aspects that can be defined as user needs regarding the technical support systems used in their daily work.

Through observations and interviews it became clear that one problem with the decision support systems used today for providing VTS is that the design did not always take into account how people make decisions under time pressure. As shown above decision making in naturalistic settings is not based on a deductive deliberation process considering different options. Instead, a course of action is chosen based on recognizing patterns and then deriving a course of action based on those patterns. Operators neither consider all possible actions nor the optimization of the outcome. Therefore there is a need to focus on what data is needed to support the operators' decision making in specific contexts rather than presenting much data on a screen.

Further, there is the need to consider the complexity of the decision support systems implemented in the VTS. Some VTS operators commented that there is plenty of superfluous information in the system, and only a minor part of what is available is used on a regular basis. However, unless the system is adequately designed, an increased amount of information tends to also make it harder to access, find, and utilise the most relevant information. It seems that the decision support systems in use today are already complex enough to interfere with the operator's work processes. This implies that only functions that are considered relevant by the users of the system should be implemented or be a subject to testing in a specific context. Another user need is the need to be able to oversee the level of data integration in the support systems. The experts mentioned that they must be able to trust the reliability of the information displayed in their system. This is not possible if one does not understand where the information stems from. An example named was the integration of RADAR and AIS information in one system. The operators could not differ between those two sources, to judge their individual reliability, as the information was integrated in one display.

6.3.3 Indications for future development

When designing a new decision support system for VTS operators, one needs to bear in mind that risk is defined on an individual basis by each operator, there is no such thing as a general description of risk and people can have very different opinions on, for example, risk for grounding or collision. Therefore it does not seem meaningful to compute risk based on parameters such as distance between vessels, speed, course etc. Rather than calculating risk, the risk assessment of the VTS operators should be supported by first defining and then presenting the information that is needed for this kind of assessment. One specific example could be to mark high risk vessels on the display. First, one needs to define the criteria for the identification of high risk vessels. Those vessel included in this category might be vessels that are black listed, vessels with high risk cargo, vessels do not following the rules (e.g. COLREG, SOLAS, IMO regulations), vessels not communicating with other vessels or shore etc.

7 Conclusions

In this final chapter the conclusions and recommendations of the study will be briefly presented.

7.1 Trustworthiness

Many operators expressed concern with regards to the trustworthiness of the information displayed in the system, in particular with regards to AIS-based information. It is very important that operators can rely on the information on which they base their decisions. Concern over the trustworthiness of a data source leads to a time-consuming process of double checking the information, e.g., asking all vessels for their present maximum draft over VHF even though this information is nominally available via the AIS. If the reliability of a data source cannot be guaranteed, it is perhaps more suitable to remove it from the system altogether.

7.2 Information presentation

The VTS operators emphasized on that it is important that the right information is presented at the right time. What information and when this is, depends on the context of use, e.g. traffic density, geographical and hydro-meteorological conditions. The amount of information should be limited to just what is necessary for the daily job of an operator. Future support system design should bear in mind that decisions are often made based on pattern recognition. It is therefore important that pattern recognition and other aspects of the actual decision making processes of the operators and the settings in which this process takes part are taken into account when designing new decision support systems. Additionally, the experts stated that problems in the interaction between shore and ship arise by having differences in the information displayed on shore and on the bridge. There is a need to compensate for, or otherwise manage, these differences to facilitate the work of the VTS operator.

7.3 Organisational needs

In the study aspects concerning the overall organisation of the maritime sector arose. It became clear that there is the need to define a general goal and an overall scope for the work of the VTS. The main goal should be safety, which the organisation of the maritime sector should be aware of this; creating a safety framework of guidelines which is VTS-centred. This includes, but is not limited, to a clear statement of which services are included in the VTS. A VTS centre should not become an overall service centre for all the events happening in a VTS area, e.g. VTS operators should not be forced to take fairway maintenance records, answer to port alarms, organise the berthing of ships etc.

In addition to a re-organisation one should also state clear guidelines concerning the VTS education. The background as a Master Mariner needs to be obligatory for all VTS operators. Communication skills and navigation knowledge need to be improved and renewed frequently to guarantee the best preconditions to provide good service to the maritime community. Further, VTS needs to be part of the process of safety management in the maritime sector. This process is relying on the cooperation of many different players, e.g. agencies, pilots, lock masters, port operators. To accomplish a better cooperation as well as a deeper understanding for each others' work, the different players of the maritime sector should have combined training sessions.

7.4 Summary of needs

1. Support familiarity in the information presentation to facilitate pattern matching for quick and effective decision making
2. Support of communication to facilitate the interaction of the different players in the maritime sector.
3. Support the building of trust through better and more effective communication between shore and ship (content is more important than quantity)
4. Re-evaluating and defining the role and tasks of the VTS as service for the maritime community with safety as the main goal
5. Need for a common "situation picture" so that bridge team and VTS operators can perceive the same representations
6. Remember the non-technical resources such as experience, training, co-workers and procedures
7. The validity and integrity of the data presented in the system must be guaranteed

7.5 Future Research

For continued work within this area, two approaches are suggested. First, more concrete user needs for VTS operators and operations can be determined to further guide the development of new decision support tools. This can be achieved by gaining a deeper understanding of the processes by which VTS operators perform their work, and in particular of how safety is created in day-to-day work. A possible method for this can be to perform detailed task analyses of VTS operator work, together with additional in-depth interviews with operators and scenario-based simulations.

Second, usability evaluations of various suggested decision support tools can be performed. Such evaluations aim to examine to what degree a prototype decision support tool is usable for the work and work context it is designed for, and can provide very valuable feedback to the designers.

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