Abstract

This paper focuses on decision making in the domain of vehicle driving, and the goal is to find out what train-drivers have in common with officers of high-speed ferries in terms of general domain properties. Such properties may be important to identify because they can say something about what constraints these rather diverse work domains may have in common. Consequently, design ideas within one domain can be transferred to another, bearing in mind that tasks, strategies as well as domain-specific knowledge and worker competencies, still have to be introduced in the final design of any artefact. A new information acquisition method called collegial verbalisation is used to study vehicle drivers of trains and high-speed ferries. Central properties of the vehicle operators’ work are identified, and a comparison is made between the two very different types of vehicles. Three specific topics from the results are discussed in detail, and some conclusions are made about the generality of them with respect to other domains in transportation. Two of the topics, operators’ spatial division and temporal perspective, are also discussed in relation to the concept of situation awareness.

Keywords: vehicle operation, work analysis, mental models, verbal protocols, information acquisition

1 Introduction

Based on accident reports from road, marine, railroad, and aviation, the US agency NTSB (2005) has identified aspects of driving in need of change. Some of these aspects apply to vehicles in general, such as crew communication, emergency evacuation, visibility, crew training, and driver fatigue, while other aspects address a specific type of vehicle, e.g. ground proximity
warnings on airplanes and train fuel tanks that withstand derailments. Approaching the issue of vehicle safety from an accident point of view gives a solid ground for finding crucial safety issues that needs direct attention. However, this tends to set focus on passive safety, such as emergency exits, seatbelts and airbags. Fortunately, NTSB and many others also acknowledge the importance of active safety, e.g. avoiding driver fatigue, enhancing braking capabilities, etc. Similar to the cognitive issue of fatigue, we would here also like to suggest situation awareness (SA) (Endsley and Garland, 1999) as another form of active safety measure. Endsley (1988) defined situation awareness as “the perception of elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future”.

With the long-term goal of improving vehicle operators’ work, our research is mainly related to active safety. Instead of focusing on the prevention of casualties when an accident has occurred, our focus is rather to aid the operators so that they have better chances of preventing accidents from occurring at all. For this purpose, we study vehicle operators in their daily work in order to get an understanding of the actual driving task. This knowledge can aid a system development process to produce a driver environment that better supports the operators work, thereby reducing the risk of accidents.

Based on studies of ship and aircraft control combined, Dutarte and Mårtensson (2001) discuss the issue of who is in control of the vehicle. General concepts of automation (Bainbridge, 1987), perception (Gibson, 1979), situation awareness (Endsley and Garland, 1999), naturalistic decision making (Zsambok, 1997), supervisor control (Sheridan, 1997), etc. are discussed. They also address specific issues such as the concept of visual flow (Gibson, 1958) and automation levels related to vehicle control. While the concept of perception is of a rather general nature, the concept of visual flow has a rather specific impact on the task of vehicle control. Similar to Dutarte and Mårtensson (2001), we are interested in properties that are more specific to the task of controlling a vehicle, but still general enough to apply to more than one vehicle domain. Gibson’s visual flow theory might apply well to fighter aircrafts and car rallies, but not so well for navigators of super tankers. In the same way, this paper identifies and discusses other concepts that apply to several vehicle domains. In this particular paper, we focus on train driving and high speed ferry operation. Furthermore, there are many general research findings regarding socio-technical systems (see for example Vicente, 1999) that apply to vehicles, but studies focusing explicitly on general properties of vehicles are not as common. Most research into vehicles is limited to a single domain with sporadic transfer to others.
2 Theory

Our understanding of vehicle operators’ work, is here involving information acquisition using the method of collegial verbalisation (Erlandsson and Jansson, in press) followed by analysis by a researcher. On a higher level, the analysis is based on ideas behind Vicente’s (1999) framework of cognitive work analysis, while on a more applied level we are using control theory to structure and analyse the data (Brehmer, 1992).

2.1 CWA

Here, cognitive work analysis (CWA) (Vicente, 1999) is used as a guide to what kinds of information that is relevant to consider during the work analysis phase, and also in what order this information should be taken into account. CWA is referred to as the formative model, specifying the requirements that must be satisfied for a system to behave in a new way. This can be compared to descriptive models focusing on how the work is done, and normative models stating how a system should behave. The CWA framework is based on five levels, starting with an ecological perspective, and gradually moving towards a more cognitive approach; work domain, control tasks, strategies, social-organizational structure, and finally worker competencies. By interpreting information in this order, environment constraints will be taken into account long before one is concerned with the operators’ mental models. Vicente (1999) exemplifies this by referring to the Three Mile Island (TMI) accident and the operator’s erroneous mental model that contributed to it. He argues that it would be misleading to base the design of a control room on operators’ mental models rather than actual environment constraints, since these mental models can be incorrect. We believe this is a logical and suitable way of performing analyses, when the goal is to achieve a re-design of an information system rather than limited changes to it. In practice, it is necessary to find and adopt suitable methods for all the levels of the CWA framework. However, the CWA analysis is not in the scope of this paper.

2.2 Control theory

To aid the analysis phase, we structure our verbal protocols using control theory. Brehmer (1992) uses control theory, without considering the mathematical framework associated with it. Control theory is useful because it specifies general conditions for control of any system, regardless of whether control is exercised manually or by some automatic controller. The following four criteria have to be fulfilled. First, the operator needs some goals (i.e. keep time schedule). Second, the operator must have a model of how the
system behaves (i.e. turning this joystick increases the thrust of the bow propeller). Third, that it should be possible to determine the state of the system (i.e. observe ship’s distance to dock). Finally, that it should be possible to affect the state of the system (i.e. to successfully manoeuvre a large tanker through a narrow channel). This approach is particularly useful when studying dynamic decision making, something that is rather prominent in vehicle operation. This important property is defined by Brehmer (1992) as “decision making under conditions which require a series of decisions, where the decisions are not independent, where the state of the world changes, both autonomously and as a consequence of the decision maker’s actions, and where these decisions have to be made in real time”.

2.3 Collegial verbalisation

The information acquisition method of collegial verbalisation is here used to study the work performed on high speed craft (HSC) bridges and train cabs. The scientific background and the pros and cons of this method are discussed in detail in Erlandsson and Jansson, (in press). This verbalisation method involves vehicle operators being video-taped while driving, followed by colleagues making verbal reports while watching this video data. The method roughly consists of the following steps:

(a) Observational studies to prepare for the video recording phase.
(b) Detailed audio and video recordings of vehicle drivers on their journeys, including start-up and shutdown phases.
(c) Colleagues to the driver individually watch the audio and video recordings and verbalize the observed actions.
(d) The colleagues also participate in individual semi-structured interviews about certain areas of interest.
(e) Audio recordings made of the verbalisations and interviews are transcribed.

3 Method

Both the train study and the HSC-study was divided into three sequential steps; video capturing, collegial verbalisation and researcher analysis. However, the amount of video data, number of colleagues, etc. differs between the two studies.
3.1 Video capturing

Four video capturing sessions were made during the train study; one from a long distance route, one middle-distance route, and two commuter trains. Each session used three video cameras; one on signals, signs and the surrounding environment, a second one on the hands and the face of the driver, and the final one on the instrument panel.

Video data from a large modern high-speed ferry was captured during a three hour route, using four video cameras; one on the forward view of the ship, one with an overview of the centre bridge console including the two operators, one on instrument panels, conning display, radar screens, and finally one close up on a radar screen.

3.2 Collegial verbalisation

Four HSC-operators and seven train operators performed verbalisations of parts of the captured video data captured from their respective vehicles. These close colleagues were experienced in driving the same vehicle and on the same route. The video data were shown individually to each colleague, and they were asked to verbalize everything happening on the video. After the verbalisation, the drivers were interviewed about some specific topics. One of these topics was concerned with, if the drivers could identify any distinct subparts of a journey, with respect to their work tasks. It was also investigated how operators prioritize work related goals and if they felt there were any conflicts between these goals. Each operator was asked to prioritize five general goals and state if they experienced any conflicts between them.

The verbalisations and interviews were audio recorded and later transcribed. All data put together, the following raw data were gathered for both studies:

(a) Video, audio and transcription data from the trip.
(b) Audio and transcription data from the colleagues’ verbalisations and the interviews.

3.3 Researchers’ analysis

The resulting raw data was then analyzed by a researcher. Initially the control theory framework (Brehmer, 1992) was used to categorise and analyse verbal protocols. The transcriptions from the collegial verbalisations were compared to find similarities, differences, contradictions, etc. both within and between the two different vehicle types. Many topics were triggered by
certain events in the video data, thereby causing most of the drivers to comment on the same matters.

Both the collegial verbal protocols and the transcriptions from the video taped trips were analysed to get an understanding of the operators’ perspective on time. The analysis of the latter was based on the method of qualitative content analysis (Altheide, 1996). Each work related sentence in the transcription were categorized into three categories based on if the content where referring to something in the past, present or future. Both the tense as well as the actual content of the sentences made this distinction possible. Especially since much of the work related events typically proceeds in the same order every time, and is also often triggered by certain events at certain points in time. The reason for making this distinction between the past, the present and the future were mainly to use it as an indicator of when the operators are involved in planning ahead, and when they are occupied with the present, or when they think about the past. Such descriptions could give insights into the operators’ time perspective.

4 Results

The results from the study of high-speed ferry operation are here presented, together with some specific results from the train study (Jansson, Olsson and Kecklund, 2000; 2005) (Jansson, Olsson and Erlandsson, 2006).

Of Brehmer’s (1992) four criteria for control of any system, the abilities to control and observe the system can be examined with rather direct methods. The input and output of both the operator and the controlled system can give rather explicit information about these parameters, while the situation is almost the opposite for the more implicit goal and model criteria. However, the following two subchapters make an attempt to describe how the operators’ mentally organise important work tasks (i.e. parts of the vehicle operators’ model of their work). When concerned with moving vehicles, different parts of a journey consist of different types of work. It is of great value to understand which such parts of a journey that the operators consider worth distinguishing between, and then also to identify which factors that is most important for the operators during each subpart. The following subchapter presents results related to the operators’ spatial division of a journey and the next subchapter presents operators’ temporal perspective. Finally, the third subchapter describes relevant goals on a rather abstract level, followed by details of how these goals are realised by the operators.
4.1 Operators’ spatial separation of the route

The four officers were asked to divide the trip into subparts were each part involves substantially different work tasks. Most officers considered that it was worth distinguishing between the following four subparts (Table 1), while some officers also mentioned start-up, standby and shut-down phases as important. A similar distinction was also made by the train drivers (Table 2).

<table>
<thead>
<tr>
<th>Departure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open sea</td>
</tr>
<tr>
<td>Confined waters (archipelago, narrow fairways, shallow water)</td>
</tr>
<tr>
<td>Berthing</td>
</tr>
</tbody>
</table>

*Table 1 describes the subparts of a journey that the officers identified as worth distinguishing between, with respect to their work tasks.*

<table>
<thead>
<tr>
<th>Leaving a station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out on the route</td>
</tr>
<tr>
<td>Approaching a station</td>
</tr>
</tbody>
</table>

*Table 2 describes the subparts of a train journey, identified during the analysis (Jansson et al. 2006).*

4.1.1 Predefined route / fairway / safe water

Complementing the division of a journey into subparts, several officers also made a distinction between “safe water”, the fairway and the ships predefined route. That is, instead of dividing the journey in respect to the position from start to end, the journey is instead divided sideways in respect to the ships route. They referred to “safe water” as areas where the specific ship can travel safely without e.g. run aground. Safe water areas can often be larger area than just the fairway. They were mainly concerned with safe water areas at open sea, while the fairway was more important in archipelagos and shallow waters. The predefined route was used as the default scenario, since the autopilot was mostly active. Since the studied ferry runs commuter traffic in an area with low traffic, the officers followed the predefined route almost every day.

4.1.2 Officers’ comments on spatial division

From the transcriptions of the collegial verbalisation, it is clear that the officers’ work differs significantly between different subparts of the journey.
Here follows some descriptions of specific work that have relevance to the distinction between subparts.

Radio communication is an important part of the work, especially during start-up, departure, berthing and shutdown phases. At the departure of this particular ship there are much communication, such as radio communication with crew in the stern about distance to the quay, the staff at the quay about the releasing of the ship, the staff at the terminal about the number of passengers, the crew at the cargo decks to know if they are closed, the personnel at the engine room about their status, and VHF communication with the Vessel Traffic Service (VTS) to announce that the ship is departing. Not to forget all the verbal communication on the bridge, the broadcasted messages in speaker systems and VHF-units, as well as all the noise.

Different crews used different steering devices at different stages of the trip, but the general idea among the officers was to let the ship be controlled by:

(a) The autopilot at open sea.
(b) Manual control in confined waters (archipelago, shallow waters, narrow fairways or anything else that might demand large rudder changes).
(c) The captain, on the bridge wing, during berthing and departure.

Some officers also considered using the autopilot in confined waters. They all agreed that the autopilot were more accurate than manual control, but that they could not trust it fully since there might be an error of some kind, e.g. erroneous GPS-data. Two officers mentioned that, except for the joysticks, they mainly use the rest of the instrument panels during start, standby and shutdown phases, or if there is an alarm.

All officers considered radar monitoring as an important task while at open sea. They also commented on the importance of double-checking information, especially concerning the correspondence between real world objects and to the ones found in radar and electronic charts. They argue that they cannot trust electronics to 100 %, but that they have to rely on it when there is thick fog. One captain said that by double-checking radar information when it is good visibility he learns how much he can trust the radar when it is low visibility. There seem to be consensus among the officers, about the importance of direct visual information as compared to electronic information. Furthermore, the usage of direct visual targets is described as being most important while berthing and departure. The officers also men-
tioned that every one had his own landmarks as guidelines, e.g. “stopping when positioned at the welded seam at the quay” or “turning when one is seeing straight through the passenger gangway”

4.2 Operators’ temporal perspective

The temporal perspectives described here are not temporal segments like the previous division into subparts. It is more similar to the predefined route / fairway / safe water distinction in the sense that the time perspectives complement each other and the operators can switch between them as they find appropriate.

4.2.1 Time intervals

The train study found that the train drivers’ work can be divided into three different time intervals (Jansson et al., 2006):

(a) A long-range interval with an interaction between the train and a rather distant environment.
(b) A short-term interval, with an interaction between the train-cab and the visible surroundings.
(c) An immediate sense interval, with an interaction mainly in terms of braking and feed-back from the stopping train.

Different work task identified in the ship officers’ work suggested that a similar pattern could be identified there as well. Here follows some examples of such work tasks found in the HSC-operators’ work:

(a) The long-range interval involves route planning, and observation of radar and electronic charts, etc.
(b) The short-term interval contains things like manual steering that takes place when the officers needs faster manoeuvres, e.g. when giving way to ships, passing through channels or navigating in archipelagos.
(c) The immediate sense interval is found while the officers are berthing. They make slight modifications to the joysticks as a reaction to variations of the sound of the engine, as well as based on the current acceleration or deceleration of the ship.

These different time intervals were also found to have a relation to the different subparts identified. The long-range interval has a close connection to the open sea part of the trip, where not so much is happening and the ship is following its predefined route. The short-term interval is for example related
to confined waters where direct visual information and manual control is crucial. The immediate sense interval is closely related to departure and berthing where ship feedback and control is performed at a much quicker pace.

4.2.2 Past / present / future-categorization
The distinction between different time intervals was partly also supported by the results of the past, present and future analysis. All work related topics in the transcription of the videotaped trip was categorized into three categories; past, present or future. These topics are visualized in their sequential order in Figure 1. The figure show that the officers continuously talk about what is presently going on, but during the open sea part of the trip they clearly also spend much thought on future events.

![Figure 1: Past/present/future-categories in their sequential order. Each entry in the figure corresponds to a single topic discussed by the officers.](image)

4.2.3 Officers’ comments on time
Large vessels typically have long delays from the point in time when a steering command is executed until it makes any significant changes to the ships direction or speed. Ferries, especially smaller high speed ferries, react much faster than cargo ships. The studied ship is a large high speed ferry (1500 passengers), were actions must be taken several nautical miles in advance of a potential collision. This makes it necessary for the officers to predict events and give steering commands long in advance. One officer described that he has the radar set on 20 nautical mile scale with off-centre mode, and that the ship is moving approximately one nautical mile in two minutes. From this, he concluded that he knows where the ship will be in 40 minutes. Another officer reasoned that, if there is another ship that should be giving way but is not, you need consider evasive manoeuvres five to six nautical miles in advance, and this is still not so much time if you have a ship on
collision course. Furthermore, all officers mentioned some general strategies of their own, such as “in the archipelago I consider at what in distance my ship would come to a complete stop, given the current speed” or “if I know that I will catch up with a ship, I plan ahead by altering the course by a few degrees, so that I pass it nicely”.

4.3 Operators’ goals

4.3.1 Ranking of goals

The officers were asked to rank the five goals found in the Table 3. As expected, the results indicate that safety aspects are top priority. Furthermore, the officers argued that it is important to follow the timetable, since it was considered as an agreement between them and the passengers.

<table>
<thead>
<tr>
<th>Ship officers’ goals:</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>Sum:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety for yourself, your crew, and passengers</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Safety for third party (e.g. other ships)</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Following the timetable</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Maintaining passenger comfort</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Minimizing fuel consumption</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 3: Four officers’ ranking of goals. ‘1’ is the highest rank and ‘5’ the lowest rank.

<table>
<thead>
<tr>
<th>Train drivers’ goals:</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6.</th>
<th>7.</th>
<th>Sum:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety for yourself and passengers</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Safety for workers along the rail</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Maintaining passenger comfort</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>23</td>
</tr>
<tr>
<td>Following the timetable</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>Safety for unauthorized people</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>Minimizing fuel consumption</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>41</td>
</tr>
</tbody>
</table>

Table 4: Seven train drivers’ ranking if goals. ‘1’ is the highest rank and ‘6’ the lowest rank (Jansson et al. 2000).

Table 4 show a similar ranking of goals made in the train study, and comparing the two tables show rather similar results between the two different vehicle types. The ship officers’ slightly higher ranking of the timetable as compared to passenger comfort, was discussed by the some officers. They argued that they could not affect the passenger comfort on their large high-speed ferry to any larger extent, rather than just using their stabilizers. They stated that it was the weather conditions that caused discomfort among the passen-
gers. The results of the train drivers instead have a slightly higher ranking of passenger comfort as compared to the timetable. It is not surprising, since their driving style has a greater impact on the passengers. Even though the differences are very slight, the result is supported by the operators’ descriptions of their work.

4.3.2 Officers’ comments on goal conflicts
When asked about any conflicts between these goals, several officers described a conflict between following the timetable and minimizing fuel consumption. One officer also mentioned that it is dilemma to keep the timetable in thick fog. He argued that it is dangerous to go with high speed into a harbour, especially with low visibility, and that the timetable would be ignored in these circumstances. Another officer mention that when they go with 30 knots in thick fog they have to trust the radar image, causing any small boat not visible on radar to be run over. Much like in air and rail traffic, the distance needed to stop a large ship is much longer than the sight distance in low visibility. However, this is a clear example of how the officers realise goal conflicts between safety and efficiency.

One officer referred to the motto: “Safe between A and B, to the least cost possible”. Another captain said “We never put the ships’ safety at risk! I reduce the speed if necessary. If it is bad weather, we get delayed.”

5 Discussion
The results are of a rather explorative and descriptive character, but many valuable insights have been attained. The collegial verbalisation method provided valuable qualitative data which really describes the complexity of the navigation task, and the similarities and differences of between the crew members’ ideas and work procedures. Here follows a discussion of how the results of the three studied aspects relate to other research, as well as a discussion of the limitations of the applied methods.

5.1 Spatial separation
Both officers and train drivers considered their journey to be divided into subparts with respect to what tasks were being performed. Officers from other ships might have different ideas about which subparts that are worth distinguishing between, but the important thing is recognize that there are different subparts each with specific work tasks. By identifying and understanding these differences one increases the chance of creating useful work
support systems. For example, the results indicated that the usage of visual targets in the surroundings was most important while berthing and departure. The fact that the concerned ship is equipped with bridge wings is a good example of how a specific need is supported. However, the major part of the bridge is a multi purpose platform used during many different work tasks. The officers described that they mainly use the instrument panels during start up, standby and shutdown phases, or if there is an alarm. During the rest of the trip, they were primarily occupied with the integrated radar and joysticks. We are not arguing for unique instrumentation for each subpart, but rather to acknowledge the specific properties of the work within each of these sub-parts.

In relation to this, it is important to emphasize the problems related to mode error, described by Norman (1988) as a way of increasing the risk of erroneous actions by simply changing the rules. Sarter and Woods (1995) implies that there are two kinds of contributing factors to mode error; buggy mental models and opaque indications of the status and behaviour of the automation. Even though the bridge wing can be considered a valuable asset, it might still suffer of mode error. Since the bridge wing introduces an additional way of controlling the ship, it also introduces an uncertainty about which way of controlling that is currently the active. Erroneously believing one has control of the ship can have terrible consequences. However, this is not a big problem since the officers can easily test if they have control or not. The problem is worse when a single computer system have several different but similar modes.

5.2 Temporal perspective

The three time intervals that were identified among the train are similar to a distinction made by Loomis and Beall (1998). They study vehicle control, but with an explicit focus on visual perception and optic flow. Each of the three levels has its own timescale. The first level relates to plans of the trip, the second level relates to supervision of the close proximity including any obstructing objects, and the third level relates to direct control of speed and direction. Contrary to Loomis and Beall (1998), we have no explicit focus on visual perception, but rather discuss vehicle operation from the broader perspective of interaction and mental models. Loomis and Beall (1998), also recognize that it is not sufficient to study optical flow, and they argue that research based on Gibson’s (1958) work of visual orientation in animals typically is limited to the study of optical flow. Loomis further state that it is also necessary to study “a variety of cognitive representations, both for short-term and long-term planning”.

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Concerning the three time perspectives identified among the train operators, Jansson et al. (2006) concluded that the future European graphical train control interface ERTMS/ETCS-DMI (Cenelec, 2000) does not support the long-range interval very well. Furthermore, it should be noted that the temporal perspectives in the HSC domain where transferred from the train study, rather than identified in isolation. That is, no explicit study to identify such intervals for high-speed ferry operation was made independently of the train study. It is therefore not clear if the ferry domain also might have additional or different intervals not available in the rail domain. However, such transfer of knowledge is exactly what this paper is suggesting.

As seen in Figure 1, planning ahead seems to be mostly occurring while the ship is at open sea or in the archipelago. The officers on duty typically have a long period of inactivity at open sea, while the rest of the trip is rather intensive. This causes the operators plan ahead, thereby staying active and occupied, but more importantly as a way to prepare for what is to come. However, there are some problems regarding the method. First of all, the data is of course very weak since only a single trip was analysed. Secondly, the relationship between an operator using e.g. the future tense and if that operator is actually planning ahead, is not known. Furthermore, in is not known how often and when the operators choose to discuss work related topics verbally among the crew, and when they keep it to themselves. However, the result that the officers communicate more about planning while at open sea is not surprising. It is also obvious that the officers do plan ahead frequently, and that this is an important part of their work. Their integrated bridge aids the officers somewhat, unfortunately the AIS (Automatic Identification System) is not integrated and therefore not used. Some support is already available in modern radars with integrated electronic charts. Some research and development is currently being done concerning such tools as intelligent predictors and distribution of the routes of other ships.

An important question is how one can support the officers’ work, e.g. by aiding them to plan ahead instead of waiting for some problem to occur before they take action. In relation to this, Hoonhout and Zwaga (1993) make an important distinction between two different operator strategies, management by exception and management by awareness. The former refers to when operators waits for an exception to happen, e.g. an alarm, before they take any action. The latter approach is when operators continuously study the process, thereby being able to minimize exceptions by a continuous control of the process. We also agree with Andersson, Sandblad, Hellström, Frej, and Gideon (1997), that the operator should be provided with good observability as to the systems past, current and predicted future status.

Both the spatial and the temporal distinction of vehicle operation is here used as simple and naïve fragments of how the operators organize their work
mentally. Without arguing about the actual representation in the mind of the operators, we limit ourselves to the saying that the verbal protocols suggest that the operators make distinctions similar to the one’s described here, and that these distinctions are significant in operators’ work.

We further argue that spatial separations and temporal perspectives are closely related to the concept of situation awareness (Endsley and Garland, 1999) discussed earlier. Furthermore, out of the four criteria of the control theory framework (goals, models, observability, controllability), all but the goal criteria are directly relevant for vehicle operators’ situation awareness. With knowledge about operators’ work in relation to models, observability and controllability it should be possible to develop work support systems that better aids the operators to acquire and maintain a high level of situation awareness.

5.3 Goals
The general idea among the officers was that all other goals were inferior to the goal of safety. The fact that operators rank safety highest of all goals is of course always the case in any serious transportation business. However, the rank of any goals subordinated to safety is highly dependent on specific properties of the particular individuals, crew, organisation, work environment, etc. Concerning the lower ranked goals, the officers argued that they could not affect the passenger comfort significantly, other than using their stabilizers. This is reasonable on large high speed crafts such as the one being studied here, but not on smaller HSCs where the passenger comfort suffers more easily.

However, the officers’ ranking of goals shows one perspective, while the actual realisation of these goals in practice is what really matters. The officers’ comments indicate that there is a conflict between safety and efficiency. In a low visibility scenario, the officers argue that they lower the speed somewhat, but they also admit that the distance needed to come to a full stop is further than the line of sight. They also express that the sea clutter function of the radar might remove smaller boats or objects, and even if all information would be visible it might still be misinterpreted, as was the case with the accident of the high-speed craft MS Sleipner in 1999 (Statens forvaltningsstjeneste, Informasjonsforvaltning 2000). Such examples indicate that there is a balance between safety and efficiency. Modern shipping companies trying to optimise profits often have detailed statistics of both fuel consumption and deviations from the timetable. If used improperly this could of course be problematic.
6 Conclusions

Three aspects of the operators’ work were identified in both the train domain and the HSC domain; spatial separation, temporal separation, and the prioritising of goals. Further comparative studies of different vehicle domains could expand and differentiate this form of descriptions to vehicles in general. This could then be used as a description of what Vicente (1999) refers to as environmental constraints. Constraints can of course exist on many different levels, such as the specific vehicle, vehicles in general, socio-technical systems, etc.

Knowledge about environmental constraints of socio-technical systems in general can be used in many different contexts, but the knowledge therefore also becomes rather broad. Environmental constraints of vehicles should, on the other hand, be specific enough to separate them from constrains of socio-technical systems in general, but at the same time also be general enough to apply to more than one type of vehicle. This would then allow for meaningful transfers of knowledge between different vehicle domains. However, it is of course the specific constraints of the particular environment that is important, when involved in design of artefacts that are to be put in use somewhere.

Concerning the three specific topics of this paper, more detailed conclusions can also be made. First of all, the vehicle operators’ individual tasks of each different subpart of a journey should be supported appropriately. However, this does not mean necessarily mean that there should be individual workplace for different subparts, as is the case with the bridge wing of a ship. Hence, by identifying different subtasks we do not aim to normatively define certain work settings or modes for different tasks. The goal is rather to support each work task well, within an integrated work environment that aids the operators.

Secondly, even though the officers rank safety as their most important goal, accident investigations still show that officers sometimes cross the fine line between prioritizing safety and prioritizing efficiency or other goals (Statens forvaltningstjeneste, Informasjonsforvaltning 2000). It is the combined effect of the safety awareness of the whole organisation, individual crews, and specific crew members that form the behaviour that increase the risk of such accidents.

Finally, it is necessary to allow the vehicle operators to work on and switch between the three different time perspectives interactively. On the ship where this study took place, the long-range interval was supported by
several instruments; radar, electronic charts, auto pilot, predefined route, etc. During the less active phase, at open sea, the officers have the possibility of spending more time planning ahead, as a way of staying occupied and reducing future burdens. It is therefore important to aid operators to work by the principle of management-by-awareness.

Within the short-term interval good visibility and enough manoeuvrability is necessary. It is therefore a problem, that ships typically have long delays from the point in time when a steering command is executed until it makes any significant changes to the ships direction or speed. Tools for planning and prediction are of course also important within this time interval. Within the immediate sense interval, manoeuvrability is of course also important. Even very small time delays can be problematic here, causing overcompensation effects. Therefore, it could be of interest to explore if the officers would be helped be reducing such delays, or at least provide feedback and predictions of such instant interaction. Also, this form of tools would aid the operators to plan rather than react to problems (e.g. overcompensation).

One example of when the officers are working by the management-by-exception rather than the management-by-awareness is found in their reaction to alarms. Many alarms occurred onboard the ship, whereof a few frequent and poorly designed alarms affected the operators’ work in several ways. First, that a substantial part of their work was concerned with acknowledging, analyzing, and dealing with alarms, and secondly that they became more ignorant of alarms. One officer commented that ”the first thing you do in an emergency, is to remove the alarm so that the brain can continue to work again. You cannot do anything before this”. This needless problem could be reduced by some straight forward alarm sanitation (Larsson, 2000). However, the real issue here is how to provide the operator with a work environment that advocates management-by-awareness, thereby reducing the triggered alarms to the ones that can not be anticipated and dealt with in advance, and to allow the officer to anticipate and control the process even before the alarms are triggered.

References


