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A socio-technical perspective on the future Vessel Traffic Services

Tore Relling [1]
Gesa Praetorius [2,3]
Odd Sveinung Hareide [4]

Abstract

Autonomy is expected to cause significant changes to the Maritime Traffic System (MTS). The Vessel Traffic Services (VTS) is a control system in the MTS and will be affected by new interactions caused by autonomy. The paper proposes a proactive approach in discussing the future VTS. The paper renders the historical development of socio-technical systems theory and argues for systemic evaluation of internal and external consequences of changes in the design of the future VTS. A democratic process to involve people from the various levels of the VTS organisation with different competencies is suggested. To evaluate the consequences of change, a systemic internal and external approach is suggested. For discussing internal consequences, a levelled socio-technical systems model is adapted and applied. External consequences are suggested to be discussed by applying design principles of system-of-systems to understand the interplay between VTS and the MTS.

Keywords

Vessel Traffic Services (VTS), Maritime Traffic System (MTS), socio-technical systems, autonomy

[1] *Department of Ocean Operations and Civil Engineering, Norwegian University of Science and Technology, Aalesund, Norway*

[2] *Linnaeus University, Kalmar Maritime Academy, Sweden*

[3] *University of South-Eastern Norway, Faculty of Technology, Natural Sciences and Maritime Sciences, Department of Maritime Operations, Tønsberg, Norway*

[4] *Norwegian Defence University College, Royal Norwegian Naval Academy, Bergen, Norway*

1 Introduction

The maritime industry is expected to face major changes in the coming decades. Technology 4.0, referring to the large-scale interconnection of components, systems and infrastructure (1), affects existing services and opens for new types of services. Autonomous concepts are believed to become a reality as emphasized by the International Maritime Organisation's (IMO) regulatory scoping exercise for Maritime Autonomous Surface Ships (MASS) (2). Exactly how these concepts will be realised is still uncertain. The concept closest in time to become a reality is the container vessel Yara Birkeland, planned to go into service with shipboard personnel in 2020 and gradually move to autonomous operation by 2022 (3). Additionally, tests with a self-driving ferry in Finland (4) and a remotely operated tug in Denmark (5) have been conducted, and small passenger ferries to replace bridges are planned (6,7).

A future with autonomous vessels will change the maritime industry in many ways. However, the change is not merely about the autonomous vessel itself. It is also about how it will interact with other actors in the Maritime Traffic System (MTS). One important measure for navigational safety in the MTS is the use of Vessel Traffic Services (VTS) to guide and advise the traffic (8). The VTS is described as a control system in the MTS with interactions within the system (the VTS) and externally with the systems in its environment (9). A future MTS with autonomous vessels will consequently cause changes for the VTS, particularly for the external interactions between conventional and autonomous vessels.

It is possible to approach the discussion of future VTS in two ways, one is reactive, and the other is proactive. The reactive approach is to take a stance that autonomy needs to be developed so it has the same capabilities as conventional vessels. The convenient consequence for the VTS is business as usual, and it is up to the ship designers to solve the challenge of designing technical solutions that respond as a human navigator would do. The proactive approach is to take ownership to the overall objectives of the MTS to be as safe and efficient as possible. However, such an approach is a complex task, since it comes with a requirement to jointly consider the VTS and the MTS. A joint consideration makes it impossible to understand the actors in the system in isolation but requires a holistic approach. This paper suggests that the proactive approach is challenging but necessary, and argues this approach requires consideration from researchers in the maritime industry.

The paper considers the VTS as a socio-technical system (9,10) and explores how a systems perspective and the use of a socio-technical systems approach could guide the early phase of designing the future VTS. The paper aims to answer the following research question:

> *How can a socio-technical systems approach focusing on a democratic process, and systemic evaluation of internal and external consequences, be used in the early design phase of the future VTS?*

2 Background

The regulatory scoping exercise for Maritime Autonomous Surface Ship (MASS) by the International Maritime Organisation (IMO) (2) is a manifestation of the belief of autonomy being important for the future maritime industry. The IMO suggests different degrees of autonomy which are determined by the locus of control of the vessel (ship/shore) and by whether there are seafarers on board or not. In other transport segments, it is suggested not to use the term autonomy, since it is heavily dependent on the opposite of the original meaning of the word, namely communication and/or cooperation (11). The term levels of automation (LOA) has been used to describe the relationship between human control and machine control (12). In the perspective of LOA, the highest level of automation has been described as the computer decides everything, acts autonomously and ignoring humans (13). Hence, autonomy being a level of automation. The paper will consider autonomy as a process where the use of technology implies a significant change to the system's human and technology function allocation (14). Such an approach acknowledges that autonomy could be different from system to system and opens for many different concepts that all could cause major changes in the maritime industry, however, we expect autonomous systems to be able to collaborate with other maritime systems.

2.1 Vessel Traffic Services

The Vessel Traffic Services is one of the measures to meet the governmental responsibility of the safety of navigation and regulation of maritime traffic in maritime waters stated in the United Nations Conventions on the Law of the Sea (UNCLOS) (15). The IMO is responsible for adopting international shipping rules and standards, while the individual nations have jurisdiction for their territorial waters and nominate a Competent Authority responsible for implementing the VTS. International Non-Governmental Organisations (NGO) are a substantial contributor for IMO, and the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) is the NGO closest associated with the development of the VTS (8).

For Norwegian waters, the government executes the responsibility through the Ministry of Transportation. The Competent Authority is the Norwegian Coastal Administration (NCA), hence being responsible for personnel, equipment, facilities, procedures, finance and legal matters (8). There are five VTS centres, four responsible for territorial waters and one for international waters. In addition, Traffic Separation Schemes (TSS) are established for transit traffic in international waters and in two of the most congested traffic areas in territorial waters (16). The individual VTS centres are responsible for everyday activities and in addition responsible for adapting the centrally developed procedures to local procedures valid for their area.

2.2 The Maritime Traffic System

To evaluate changes to the MTS, it is necessary to clarify what is included in the term. The MTS is context-dependent; it will change from one geographical location to another and change over time. The paper discusses the role of VTS, hence, the context is that the VTS is involved in territorial waters where one state has jurisdiction. The term stakeholder is commonly used in systems engineering to identify groups or individuals who affect, or being affected by, the achievement of an organisation's objectives (17). To identify the MTS, systems or stakeholders that affect, or being affected by, the achievement of *safe navigation* is included.

Van Westrenen and Praetorius (18) state that control in maritime traffic is exercised by the bridge team, pilot and VTS. Mansson, Lützhöft and Brooks (19) describe key participants in navigating and manoeuvring ships in port waters to be the shipmaster, maritime pilot, tug master and the VTS-operator (VTSO). Fiaz (20) has analysed stakeholders for navigation and assessed their impact on safety and efficiency. He identified that shipowners, crew, water canals/coastal waters/straits, IMO, Flag State, Classification societies and educational institute/guideline publisher influence safety.

In sum, for the MTS the interaction between bridge team, pilot and VTS is imperative. However, this interaction is likely to be affected by the organisational context, such as identified in the stakeholder analysis where shipowners are mentioned. Consequently, one can assume both pilot organisations and Competent Authorities (for the VTS) being important. There are also several other actors such as IMO, Flag States, Classification societies, educational institutes, and guideline publishers in the stakeholder analysis. The MTS, therefore, consists of the immediate interaction between the operators involved in navigation in the area, and additionally, the organisations and stakeholders affecting their decisions. An example of a future MTS is shown in Fig. 1.

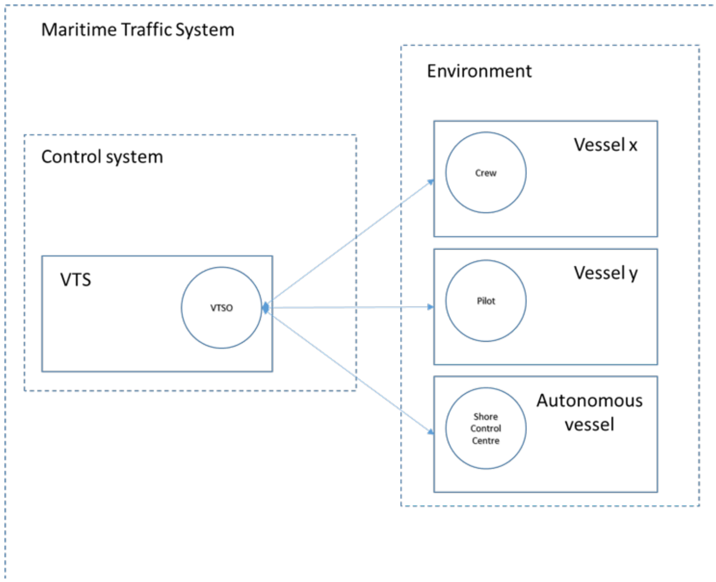

Fig. 1. The Maritime Traffic System (MTS) described as of the vessels in the area (the environment) and the VTS as the control system.

The share of autonomy will be imperceptible for many years since the great majority of vessels will be conventional. However, in some areas, autonomous vessels will have a significant impact on the traffic situation. In these areas, the autonomous vessels will coexist with conventional vessels. Such coexistence implies new interactions between the actors in the industry. To explain the implications of the coexistence in the industry systems theory is applied. The doctrine of expansionism considering objects as a part of the whole is a cornerstone of system theory (21), and the paper presents relevant theory to explain a holistic picture of the relationship between the actors in the industry. Initially, the taxonomic distinction between systems and system-of-systems is presented. Further, the development of socio-technical systems theory that origins from the systems theory is presented.

3.1 System-of-systems

More than 50 years ago Ackoff (22) pointed to the fact that the systems concept lacks a unified set of terms, ironically lacking a *system* for the terms in systems science. Consequently, he presents a comprehensive list of terms, where a system is defined as a set of interrelated elements. Further, he defines an organisation as *a purposeful system that contains at least two purposeful elements which have a common purpose relative to which the system has a functional division of labour* (22). He differs organisations from organisms by stating that the organisms do not contain purposeful elements, and none of the organisms can display will (22). The clarification of terms by Ackoff is important and points to a difference between focusing on an organisation and an organism. It implies a difference between what could be a component in a system and what is a system. However, by zooming out to *more* than one organisation, collaboration and, at least partly, common goals between various organisations is found. Large scale, complex, socio-technical systems (such as organisations) that collaborate are often named system-of-systems, even though not all socio-technical systems are systems-of-systems (23). Similar to Ackoff's abovementioned challenge about terms for systems, there is no widely accepted definition of system-of-systems.

Maier (24) aims to create a distinction between a system and a system-of-systems. He suggests *operational* and *managerial* independence of system components could be used for creating a taxonomic distinction between systems and system-of-systems. Further, he emphasizes that the system must pass both the criteria of operational and managerial independence to be categorised as a system-of-systems. Being independent and at the same time being a system-of-systems could seem contradictory, however; Maier explains that the criteria are to be used for collaboratively integrated systems (24). He does not explicitly define what *collaboratively integrated* means, but he states that collaborative is opposed to directed, and the decision to collaborate is an on-going discussion, further, he uses the synonym 'federated system' (24). Hence, it is possible to conclude that the systems have some common goals, and the systems see a positive effect of collaborating with other systems.

The operational independence considers that if a system-of-systems is disassembled, the component systems *can* operate independently to fulfil their own purposes and they are able to fulfil purposes on their own. Managerial independence considers that component systems *do* operate independently, and even if being integrated in a superset system, they continue their operational existence independent of the system-of-systems.

An important contribution of Maier's work on differentiating systems and system-of-systems, is his work on defining successful design criteria. The independent properties of system-of-systems require a different mindset for the design. Maier suggests designers of system-of-systems need to follow the design principles of *policy triage* (choosing what to control), *leverage at the interface* (between the component systems), *stable intermediate forms* (stability in the time period before the system-of-systems is finalised), and *ensuring cooperation* (voluntary cooperation through incentives) (24).

3.2 Socio-technical systems

The term socio-technical systems origins from the Tavistock Institute research program in the 1950s where the separate approach to either social or technical system was not seen as sufficient. A new approach where organisations were envisaged as socio-technical rather than either social or technical emerged (25). At present, the socio-technical theory is broadly acknowledged to refer to the joint optimisation between social and technical factors (26,27).

Quality of work-life and democratic processes. In the period until the late 1970s, the interest in socio-technical systems theory increased and socio-technical principles were defined to design systems with 'quality of working life' as the desired emergent property (26,28). The Scandinavian countries were pioneering the initiation of socio-technical design by legislating the cooperation between management and workforce, with emphasis on employees to participate in all levels of decision making. Several democratisation projects were initiated and the mindset on humanisation was a significant contributor for the laws on working conditions. The development did not come through without resistance, and in general two types of resistance were experienced. First, a common belief was that any management-initiated change must be for the worse. Second, some engineers and technologists perceived changes to threaten their position and status. Additionally, some unions were negative intintroducing socio-technical principles since this could threaten their power and influence (26). Despite these obstacles, the democratic process and the humanisation of the work situation became important aspects associated with socio-technical systems.

Automation and complexity. During the 1980s the situation for the industry changed drastically and could have become the dark ages of socio-technical theory. From having problems getting enough staff, the increased use of technology reduced the need for workforce. Consequently, one of the main motivations for designing systems for the quality of working life diminished. The new focal point was cost-cutting, and the industry looked to lean production principles where standardisation of work processes stood opposed to the socio-technical systems principles of decentralised control and coordination. Socio-technical systems thinking lost its strong foothold, and the remaining expertise was found in dispersed, small groups (26). Several large accidents in the second half of the 1980s heavily affected the understanding of causes for accidents. The accidents Chernobyl

(1986), Challenger (1986), Zee-brugge (1987) and Dryden (1989) shifted the focus from human errors to organisational factors. Even though Robinson (29) argued for socio-technical systems principles could provide a design tool for safety problems already in the beginning of 1980s, the accidents regenerated the socio-technical systems theory's relevance for safety almost a decade later (30). The interest for organisational causes transferred to cognitive science and human factors and moved these fields closer to the socio-technical field. Literature from organisational psychology from the 1950s influenced new methods and understanding the context became an important aspect (31). Where the focus of cognitive science had been on the individual, the unit of analysis now shifted, and methods considering human and context together (Distributed Cognition (DC)) (32), or human(s) and technology in coagency (Cognitive Systems Engineering (CSE) and Joint Cognitive Systems) (33), emerged. A different challenge also caught attention in the aftermath of the disastrous accidents in the late 80s; systems were becoming increasingly more complex. The interdependence between system components, and between the system and environment, created unanticipated outcomes. Theories such as Normal Accident Theory (explaining accidents as inevitable due to complexity) (34) and High Reliability Organisations (defining characteristics of organisations coping with complexity) (35) became prominent in the safety discussion. Complexity was incorporated in socio-technical systems thinking, and the term complex socio-technical system was used and dimensions for such complexity defined (36). Such development was reflected when the socio-technical systems principles were revisited in 1987; both gathering and analysing data from users were highlighted (37) in the revised version.

Thinking in levels. In the period from the mid-80s to the new millennium, cognitive science, human factors and socio-technical system theory blended and developed the foundation for the new ways of safety thinking. Organisations, as being socio-technical systems, differed between active failures (in the sharp end) and latent conditions (in the organisations), and applied barriers to prevent accidents by managing the risks (38).

Towards the end of the 90s a significant perspective of socio-technical systems theory gained interest; in addition to understanding the system in context, the socio-technical system needed to be understood

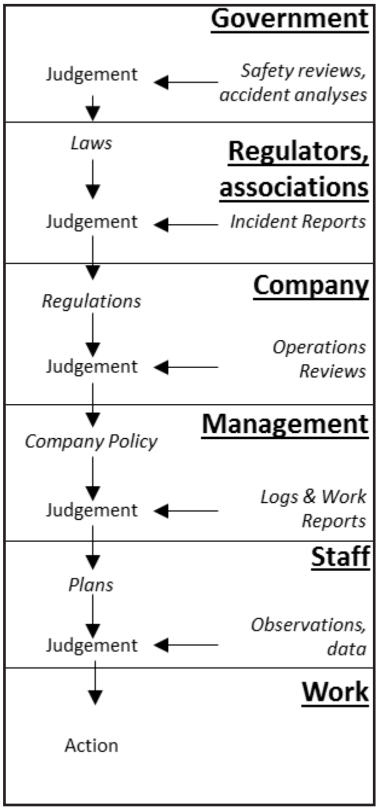

Fig. 2. Rasmussen levels of socio-technical systems (39)

in levels or layers (36,39). This way of considering the socio-technical system was first presented by Trist who presented an evolution from an initial focus on the *primary work station, to whole organisation systems*, and last at the *macrosocial level* (25). The need to engineer for safety, led to a focus between the human and organisation, a concept building on cybernetics where the dynamic communication within systems is emphasised (40). In line with this, an important perspective for the development of socio-technical systems the last 20 years has been Rasmussen's criticism of the research on socio-technical systems being studied separately by individual disciplines and concentrated at one level of the system. Fig. 2 presents Rasmussen's socio-technical system at levels (from operation (bottom level) to top level): *work, staff, management, company, regulators/associations,* and *government*. Further, Rasmussen (41) argued for cross-disciplinary studies vertically across the different levels of socio-technical systems.

Interdepencies and involving users in design. The socio-technical principles were revised for the third time by Clegg in 2000, motivated by the disappointing performance of technology itself and management practices in the development and implementation of new technologies (42). The revised socio-technical principles aimed to again bring the social and technical together to an interdependent aspect of the work system. Clegg (43) pointed to organisations lack an integrated approach to technical and organisational changes, and that users do not have enough influence on system development. The revised set of principles intent was to contribute to *design* new systems, rather than only to understand the human and organisational impact of new technologies (42).

System accident models and resilience. Apparently, the socio-technical systems theory in the field of design of complex systems has made a strong comeback after the moderate interest in the 1980s, and responds to organisations need for being adaptable, flexible, responsive and resilient (44). The perspective of levelled socio-technical systems has been the basis for a system perspective of the performance of organisations. Particularly to understand and learn from accidents, this way of thinking has been prominent since 2000. Accident models such as STAMP (45), AcciMap (46), HFACS (47) have all applied the levelled perspective to move the focus from human error as the cause of an accident to organisational causes. A different, more proactive, application of socio-technical systems thinking is found in resilience engineering. The resilience perspective is focused on how the socio-technical system sustains required functioning in a variety of operation conditions by highlighting how to succeed (rather than fail) by adapting the performance to the environment (9,48).

4 A socio-technical approach to the future VTS

The principles of socio-technical systems theory have been revisited over the last 60 years. From the focus on quality of work-life to focus on system safety, and in the later years a call for socio-technical systems thinking proactively in systems design. Many of the leading methods for assessing safety in complex systems (e.g STAMP, FRAM, HFACS), based on systems theory, share the theoretical framework as socio-technical systems theory. These methods take the necessary systemic perspective that explores the relationships between causal factors within the systems and addresses the complexity known to be important for improving safety in modern organisations (45,49,50). On the other hand, the methods share a challenge of being time-consuming to apply, resource-intensive, and often relying on detailed and high-qualitative data (45,49–51). When designing future systems, the detail level is low and the uncertainty high. Consequently, it is difficult to apply such systemic safety models to support the initial design phase. The comprehensiveness of the methods could, therefore, become a barrier that leads to them not being used before design solutions are chosen. In turn, this shows that the methods might not be the right answer to Clegg's call for including users in the design phase (42). The following section presents a simplified approach to the discussion of the future VTS. It argues that a *democratic* process and a *systemic* evaluation of internal and external consequences of changes reflects a socio-technical systems approach in the early design phase of the future VTS.

4.1 Identifying the future role of the VTS is a democratic process

A democratic focus on the workforce has been a cornerstone in socio-technical systems theory. The democratic focus includes different aspects of emphasising the workers in the organisations. In the early phase of socio-technical thinking, by aiming for humanisation of the work situation, the employees were included to determine the required quality of work life (26). Later, the democratic focus was mainly about *understanding* cognitive activities in man-machine systems (52) and human performance in light of latent conditions (38). *User involvement* has been emphasised to design systems that are capable of self-modification (28), where both *technical and social experts* are needed for joint optimisation (37). User involvement from *all levels of decision-making* (26) and being open for *consulting and informing colleagues* (28) have been underlined as being necessary. Not only to understand socio-technical systems, but also in the *design* of such systems by involving the *responsible for manage, use and support* of the new system (42).

The development of socio-technical systems theory has shown several different aspects to why the democratic process is needed. To identify the future role of the VTS, it is necessary to initiate a democratic process where these aspects are understood and implemented.

The first step is to involve the VTS-organisation in the design phase. It is necessary to come back to the potential technology development in the MTS, and the present attention to autonomous vessels. In this development, the VTS could be a reactive system component that adapts its behaviour to the emerging requirements caused by new technology. The other option is to take a stance that the VTS could contribute to a safe and efficient MTS by a proactive approach focusing a joint optimisation between the VTS and the other system components. Hence, the involvement of the VTS organisation by anchoring the need for discussing the future role of the VTS is the first step.

The second step is to nominate users to be a part of the design process. Implicit in the socio-technical term, both technical and social expert knowledge is needed. As experts in an organisation do not come from either a technical silo or an operational silo, it is necessary to find a strategy to select people with knowledge from various expert areas in the organisation. The selection strategy should also warrant ownership, and people responsible for managing, using, and supporting the future system should be selected. There are several levels in the organisation that manages the VTS (see discussion of internal effects), and the selection of users should be representative for the various levels. The users of the future VTS could be represented as the VTS-operators. However, all VTS-operators should not be put in the same category. As an example, some operators could be more interested in technical solutions and functionalities, while others have their interest in concept development. Consequently, such variety should be reflected when selecting users. The support of the future VTS could be both administrative and technical personnel,and representatives for the support element need to be included. A common quality of all the involved personnel is that they need to be open to communicating and consulting colleagues about assessments from the design phase.

The abovementioned two steps aim to find the people from the organisation with the 'correct' expert knowledge from the different levels in the organisation, with ownership to the design process and being open for sharing and discussing with colleagues. There is no recipe for exactly how to reach such a goal. However, good cooperation between internal organisational expertise and expertise about socio-technical systems theory could be considered beneficial. The internal expertise of the VTS-organisation will provide knowledge about the organisational structure, areas of expertise, and persons with different areas of interest. Expertise in socio-technical expertise could guide the selection process, so no expert areas are over-emphasised. Further, such expertise could make sure that the various aspects of the socio-technical democratic process are understood, and consequently, reduce the risk of just putting some people together and start discussing.

4.2 A systemic approach evaluating internal and external effects

The systems perspective as a foundation for the socio-technical systems theory points to the interactions within the system and between systems. The VTS is a part of the MTS, and as such interconnected with the other component systems. As such, deciding on the future role of the VTS will affect the other systems in the MTS. To understand the interplay between VTS design and the MTS design is therefore crucial. However, as the types and number of interconnections could be infinite, it is necessary to limit what to assess in evaluating how the future VTS would affect the MTS. The following section presents how the use of system-of-systems design principles could guide the discussion of the interplay between VTS and MTS.

Consequently, internal effects for designing the future VTS are important. The perspective in system safety models highlights the connection between the operator and the rest of the organisation. In the last section, a broader perspective on implications for future VTS is suggested, and an adapted version of Rasmussen's levels of socio-technical system is used as a framework for the discussion.

4.2.1 The interplay between MTS design and VTS design

As presented in the background, there is no static MTS. However, the bridge personnel, VTS-operators, and pilots could be considered components of the system. Additionally, the parent organisations of these operators and more distinct actors affect the system. In sum, these components collaborate to achieve a safe and efficient traffic flow, and they are integrated through rules, regulations, and communication. Consequently, one could argue that the MTS is a collaborative and integrated system. The next question is if the MTS is a system or a system-of-systems. Following Maier's (24) taxonomy the components need to be operationally independent and managerial independent of each other to be a system-of-systems. Maier has evaluated the system-of-systems properties of an Intelligent Transport System (ITS) (53) and the similarities to the MTS could guide the assessment.

To decide if the component systems are managerial independent, an evaluation of the components being acquired and operated independently is needed. Shipping companies are owned and run by a variety of actors, and these are most certainly independent of each other. The VTS and pilot service are normally managed by the government, and to a certain degree have some common management. However, in sum, the component systems in the MTS could be stated to be managerial independent from each other. The next criterium is being operational independent. As Maier states in his evaluation of an ITS, the operation is a mixture of individual and government action. In the MTS the vessels could operate independent of each other, and potentially independent without VTS and pilots. The VTS and pilots will have no function without vessels in the area; however, it is possible to claim they are operational independent since they are not relying on another component system to function. In sum, the conclusion is that the MTS, in conformity as the ITS, is a collaborative and integrated system, and further fulfil both criteria of being a system-of-systems.

The perspective of the MTS being a system-of-systems is important in the discussion of the future VTS. The design of VTS will to a large extent affect the design of the future MTS. Consequently, the design principles for successful system-of-systems propose a solid base for discussing the interplay between VTS design and MTS design (24).

Policy triage. The most significant impact is that opposed to systems design it is not possible to fully control the configuration (e.g. traffic flow) or the evolution (e.g. design of vessels) of system-of-systems. A consequence is that even if the VTS is defined as a control system, it cannot fully control the systems in the MTS. The VTS as being a socio-technical system is in *control* when it creates a stable performance output (9,33). When designing the future VTS, it is therefore important to focus on the balance of what to try to control and what not to control, and how the VTS could contribute to a safe and efficient performance in the MTS. Maier (24) warns against over-control (will fail due to lack of authority) and under-control (will fail due to eliminating the system nature in the integrated system).

Leverage at the interfaces. Since the component systems have independent properties, the architecture of system-of-systems needs to consider the interfaces between the systems. One major change is the interface between the autonomous and conventional vessel, and it will basically be an interface between technology (autonomous vessel) and humans (conventional vessel and VTS). This will be a novel situation and requires a different way of communicating than today. The present solution to create a mutual understanding is sharing information and intentions on voice communication, and often relying on informal ways of operating. In a future MTS, it could be expected that autonomous vessel could be great at following formalised rules but poor at understanding informal ways of operating and sharing information and intentions as it is done today. Consequently, different interfaces than the traditional voice communication need to be considered, and the future VTS should consider how it could improve interfaces between future system components.

Stable intermediate forms. Intermediate stability relates to the period until a future MTS is constructed and finalised. Such an approach could be argued to be artificial since an MTS will never reach an end-state. However, *testing and evaluation*, initially as individual components and later as integrated systems (21) is important. For autonomy, this implies that the concept will be tested in parts, but later also as a component system in the MTS.

Ensuring cooperation. The systems being collaborative, and at the same time independent, leads to cooperation in the MTS being to a certain degree voluntary. The cooperation in a future MTS with autonomous vessels will to a larger degree be between unequal actors, with both conventional vessels, autonomous vessels, most likely a shore control centre and a VTS. The development needs to find the right balance where formalised rules and control of the system is considered in the light of providing enough flexibility to users.

Designing a VTS should aim for contributing to stable performance of safety and efficiency in the MTS. The design principles for systems-of-systems are applicable to the design of the MTS, and due to VTS being a control system of the MTS, also applicable for understanding the interplay between VTS solutions and the MTS.

4.2.2 The internal effects for the VTS

An important element in the systems theory is the control system that regulates the behaviour of the overall system. In the socio-technical systems theory this has been reflected since the increasing automation of the industrial processes. The role of humans changed from being directly involved in the action, to decision making and problem solving (52). Even if the technology changed and seemed to take a larger portion of the duties, the human element became more important to control processes. The understanding of the human role in relation combined with organisational causes became important. Initially, this relationship was explained linearly, with latent conditions and swiss cheese (38). Later the relationship was understood by more complex systems models with increased awareness of the multiple connections between the operator and the organisation (45,49,50).

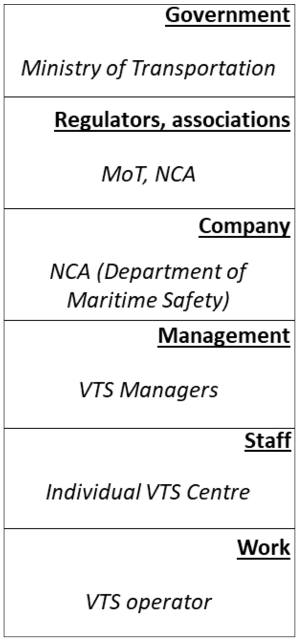

Fig. 3. The Norwegian VTS organization visualized in Rasmussen's socio-technical models

Rasmussen's levelled model of socio-technical systems visualised and formed much of the present understanding of socio-technical systems. In the following section, it is argued that the model could be a tool in the initial design of new socio-technical systems. The democratic process previously discussed, involves personnel from the entire organisation, and the model could initially be used to make sure that all levels are represented in the process. Fig. 3 represents a suggested visualisation of the Norwegian VTS-organisation by applying Rasmussen's model. The governmental level is defined to be the Ministry of Transportation (MoT), who is responsible for the service. Regulators and associations are both the MoT and the Norwegian Coastal Administration (NCA) since they both have responsibilities for the Harbour and Fairways Act. The company-level points to NCA and the Department of Maritime Safety. The management level is the VTS managers of the individual VTS centres. Staff is the crew on duty, and finally the work is the individual VTS-operator.

The essential step of the democratic process is to discuss potential solutions and evaluate the effects of these solutions. The complexity in discussing VTS-roles is the interplay between the VTS and the MTS as discussed in the former section. Further, the consequences for the VTS itself need to be understood. As Rasmussen highlights, the consequences are different on the various levels of the organization. As such, the future roles of the VTS should be evaluated by understanding the consequences for each of the levels in the model as shown in Fig. 4.

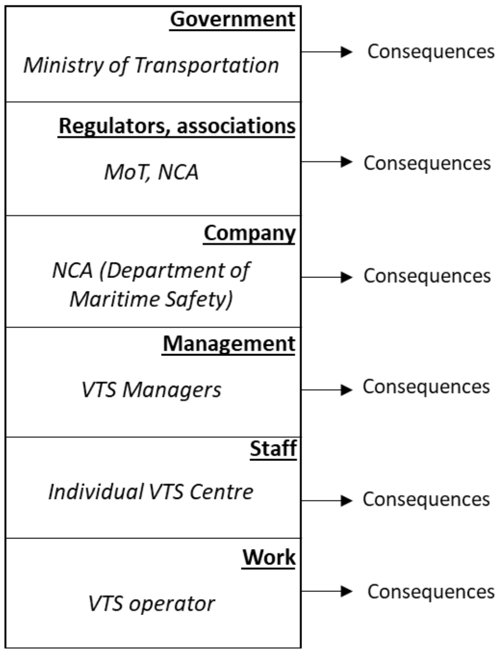

Fig. 4. The consequences of changes to the VTS should be assessed on the various socio-technical systems levels

A benefit of using the model is that it is not dependent on a high detail level. In the initial phase of designing future systems, the granularity is low, the discussion of implications might be on an overall level. However, even with a low level of detail, it is possible to identify obstacles that require attention. As an example, if autonomy calls for different interactions between vessels and VTS-operator, a change of regulations might be required. By only focusing on the VTS-operator, such changes could easily be omitted by arguing it is not possible due to regulations. However, by using the model, it is possible to keep it as an option and raise the argument of changing regulations to the regulator level.

The intention of the model is to understand interaction, *between* the levels. A risk of thinking in levels is ignoring such interaction and focus on the individual level and losing the overall objective. Hence, the process must be goal-oriented, asking what is required to meet the proposed solution. The answer will point to consequences for the levels and for the interaction.

In the initial design phase, the model could provide a good basis for discussion and deciding direction. The visualisation of the model is easy to communicate and to apply as a start of a discussion. Further, it facilitates that everyone involved in the design process are given a voice. However, the pitfall of ignoring interaction is a major risk that must be addressed before and during the process.

5 Conclusion

The future MTS with autonomous vessels will be different from the present. The differences will not be merely about the autonomous vessel itself; it will also be the changes in the interaction between all actors in the MTS. This understanding calls for a holistic approach to discussing the future MTS. The VTS is a control system that contributes to a safe and efficient MTS, and consequently, the VTS is essential in the discussion of autonomy in the MTS. The VTS could take a reactive stance, perceiving autonomy being a designer challenge of making autonomous vessels that have the same capabilities as the conventional vessel. The other option is a proactive approach, where the VTS takes ownership to the overall objectives of the MTS and assess how the VTS could adapt to the future need.

The paper has suggested a proactive socio-technical systems approach to discuss a democratic process and evaluate the systemic internal and external effects of changes for the future VTS. The history of socio-technical systems theory shows a development affected by societal trends and being affected by, and merging into, other approaches.

The paper has argued the *democratic process* has several aspects, ranging from understanding users to user involvement in design. However, the focus on workers has been common denominator through history and is consequently perceived as a cornerstone of the socio-technical systems theory. The paper has proposed a democratic process involving people from the entire VTS organisation with a variety of competencies is necessary to find solutions and to warrant ownership in the design phase.

Further, the paper has argued for the systemic perspective being another cornerstone of the socio-technical systems theory. The history has shown the importance of understanding human performance in a broader perspective than the individual operator. Consequently, the paper has suggested to applying a levelled socio-technical model to understand internal consequences to potential changes. Such an approach aims to provide an insight of the consequences at the various levels, but additionally, for the interaction between the levels.

The proactive approach calls for a holistic evaluation of the future VTS. The paper suggests considering the MTS a system-of-systems and apply the system-of-systems design principles. Subsequently, the VTS as a control system needs to consider how it could contribute to positively affect the design principles of the MTS when discussing the future role of the VTS.

In sum, the paper has presented a complex challenge of taking a systems perspective of discussing the future role of the VTS. The paper has argued that a simplified socio-technical approach could support the discussion in the early design phase of the future VTS.

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