The HTO-concept used as a tool when designing a new VTS center in Sweden

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Abstract. Vessel Traffic Service (VTS) operations are defined by highly qualified personnel supported by advanced technology; an environment that exposes operators to a high cognitive workload. In 2009, Swedish VTS had to increase efficiency with maintained safety and quality. Through the HTO concept, all dimensions that affect the operators' performance were considered – human, technological and organizational aspects had to be balanced. The article discusses the experiences from using the HTO concept in the VTS domain, presents the results of this specific project and suggests some important principles needed to be in place to guarantee successful outcomes of reorganizing projects.

Keywords. VTS, HTO, user-driven, ISO 11064

1. Introduction

Traffic is intensifying in all modes of transportation. Increased quality and complexity of traffic, combined with necessity to optimize traffic streams and logistics in airports and harbors make traffic control ever more needed. In maritime transportation, traffic control is carried out by Vessel Traffic Services (VTS). VTS operators are responsible for safe and efficient handling of traffic in harbors, rivers and approach areas. They guide traffic in and out of harbors, provide information on requests and coordinating movements of ships in emerging conflict situations.

In this article, the result of using an HTO-concept (Human, Technology and Organization) in the design of a VTS centre instead of the more traditional engineering approach is presented.

1.1 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" (IALA, 2008). It is a service that operates through VTS centers, from which operators monitor the traffic, assist in navigational matters and provide information to all vessels in a designated area. In many sensitive sea areas and areas with a high traffic density, VTS centers have been established through the past decades (IALA, 2008).

In 2009, the Swedish Maritime Administration decided to improve efficiency in its services. The VTS was one of them. Re-organization of Swedish VTS has been done before, but the prevailing approach has been to place overall responsibility for the implementation phase on the engineering side of the organization. This time it was done differently using a concept taking Human, Technological and Organizational aspects into account, further referred to as the HTO-concept.

1.2 VTS

The purpose of Vessel Traffic Service (VTS) is to assist ships and make navigation safer – it is safety critical and quality must be consistently high. The operators use established procedures and interact closely with ships throughout the voyage from sea through archipelago and into port. VTS operations are defined by highly qualified personnel supported by advanced technology in an environment that exposes operators to a high cognitive workload. The VTS framework is regulated internationally but the Competent Authority in a country (e.g. the Swedish Transport Agency in Sweden) decides on national VTS areas and service levels. The role of the national VTS Authority in turn, is to assist, monitor and organize maritime traffic in accordance with the national legislation. There are three different types of shore-based services connected to VTS; information service (INS), navigational assistance (NAS) and traffic organization (TOS) (IALA, 2008).

Information service (INS) is a service offering all essential information to the vessels within the VTS area. Essential information may either contain facts on the VTS area, e.g. intentions, boundaries, procedures, radio channels, reporting points, or information concerning variables influencing the navigation and maneuverability of a ship, e.g. upcoming vessel meetings, status of aids to navigation, traffic congestions, meteorological information etc. (IALA, 2008).

Navigational assistance (NAS) is a service with the aim to support the navigational decision-making on board followed by monitoring its effects. NAS consists of two parts, navigational information and navigational advice. Navigational information may contain the course and speed made by a vessel, warnings to specific vessels and positions of other traffic as well as positions relative to fairway axes and waypoints. Navigational advice is an active participation in the on board navigational decision making of a ship. It is up to the Competent Authority to decide whether and under which circumstances the VTS can and may assist the navigational decision making of vessels in the VTS area (IALA, 2008). However, IMO (the International Maritime Organization) states that in case of navigational assistance, the instructions given to vessels should be result-oriented; leaving all details of execution to the master or pilot on board the vessel (IMO, 2000).

Traffic Organization Service (TOS) is a service with the objective to keep the traffic movements safe, fluent and efficient within the VTS area. Furthermore, TOS is concerned with the proactive planning of traffic movements, especially in the case of congestions or other aspects, which might impact on the traffic in the area. Monitoring the traffic and establishing compliance to the prevailing rules in the area are a part of this service.

1.3 The HTO-concept

The VTS-domain constitutes a highly complex working environment where the operators continuously interact with charts and various other sources of information in their effort to interpret the current and future situation, being able to support the vessels in their surveillance area.

When dealing with such working environments or Socio-technical systems, different approaches emphasize different aspects as important focus areas (Haavik, 2011). One example of such an approach is the normal accident theory (Perrow, 1984) where the focus is on human operators, dealing with tightly coupled and highly complex technical systems; another example contrasting the normal accident theory is the perspective of high reliability organizations (Weick and Roberts, 1993) where the focus is on how the inherent qualities of such organizations successfully are able to control highly complex techno-structures.

When designing the new VTS-center as described in this article there was a need for a holistic approach embracing all aspects considered as relevant to optimize the design.

Hence the HTO concept (Rollenhagen, 1997) constituted by the three interlaced entities Human, Technology and Organization was used as a tool in the design work. It must be emphasized that the relations between the entities rather than the entities in isolation was in focus. This means that each entity shall not be interpreted as a homogenous component constituted by static properties, rather it is shaped by the relational context in which it occurs (Haavik, 2011).

2. Method

The pilot study has been implemented in the form of a combined situational and functional analysis where visits were made to the existing VTS centres. During the visits, observations were performed to understand the operators' work situation and the various tasks carried out at the VTS. The observations were also combined with interviews of relevant personnel at the various centers. In addition, a complementary workshop was conducted with a focus on presentation of the results and with the purpose of analyzing the results from a functional perspective. The analysis methods used in the pilot study follows the international standard ISO 11064 "Ergonomic design of control centers" (ISO, 2000), with adjustments made for the maritime domain.

A similar approach was also used during the Design work that followed on the results from the pilot study (Christofferson et al., 2009). The design work was divided into two phases, A and B, where phase A covered design of the overall workplace’s thought usage of function and task analyses and CRIOP scenario analyses in line with ISO 11064 and NORSOK S-002.

The second phase B covered the local operator environment and the principle design of the new operator workstations with associated information handling and user-interface, though user-driven concept evaluation workshops.

3. Results

3.1 *Pilot study*

The results from the pilot study (Christofferson et al., 2009) indicated that the VTS centers, with regards to organization, work environment, competence, workload and the user interfaces for the different systems worked as they should. However a number of potential improvements were identified, such as that the workload on several VTS chairs was perceived as high, also the perceived lack of clarity about what is expected from the VTS operators was noted as well as deficiencies in systems support to operators and the risk of human errors due to occasional heavy workloads.

3.2 Design work

The project delivered successfully, in methodology as well as in figures; the number of VTS centers was reduced from four to three, 35 VTS operators were able to deliver the same service as 42 did in the former organization and outsourced services worth 1,5 MSEK per year were insourced and absorbed within the VTS organization. The total production costs for the delivered services decreased by 15 %.

The task of the design work was, within a relatively fixed layout of an existing building; distribute four operator stations with an option for a fifth station for future needs.

One important goal in the design work was to create ownership of the solutions among personnel – the VTS operators. To achieve this, as many persons as possible that were going to work in the new environment were involved in the project activities concerning analysis and design. Equally important was that managers were participating in the activities to establish and explain the overall objectives – the “Why’s, What’s and How’s” of the project.

The design work was divided into two phases, A and B, where phase A covered design of the overall workplace and phase B covered the local operator environment. Obviously, results in one phase affected and provided input to the other, meaning there was a need for an overlap and iterative approach to an extent that the project timeline allowed for. Hence, some project activities encompassed both phases.

In phase A, focus was on how the operator stations where distributed in the room, partly to meet the needs for interaction between operators and in the same time minimize audial disturbance. A balance needed to be struck between wanted and unwanted overhearing. Another factor, which became obvious during the run of the design phase, was what came to be called “social situational awareness” (Kramer, et al., 2013). In the building in question, entrance was placed on the short side of the room. As noted by Hua, et al (2010), it is inevitable for an operator on duty to pay some attention to other persons entering or exiting the room. If this was going to take place behind the back of the operators, an increased cognitive load was anticipated in order to keep up their social situational awareness. Hence it was concluded that operator stations should be placed with the backs towards the walls, facing the centre of the room. As need for interaction between operators in this project was identified mainly between pairs of operators, it allowed for a layout where the operators could be placed in pairs shoulder to shoulder and across the room from the other pair (Figure 1). Also from an human-organisation (HO) perspective it was noted that the decisions on how to distribute the VTS areas across the four operator positions were based on the analyses of traffic intensity for different areas at different times of day, in order to obtain the best possible level of workload on all positions.

Figure 3 The VTS center in Södertälje, Sweden, in a virtual representation used to verify the distribution and proportions of operator stations in the room

In phase B, the IT-support (including the specialized VTS system) was not going to be renewed, constituting a non-changeable factor in the design of operator environment. However, screen layout with number, size and orientation of screens could be altered within the technical limitations of this system. It became clear in the design work, that the needs for representation of traffic information for VTS operators is challenging, especially for VTS areas in archipelagos like Stockholm. The main challenge lays in the need for detailed information over a large geographical area. The possibilities for simplified representation, for instance “subway maps” is limited. In the previous solution, this had been achieved by placing a number of windows side by side across the screens, each covering its own geographical area. The drawback of this was that it took a certain amount of cognitive workload for operators to "paste" these images together to a complete mental model of the traffic situation (Porathe, 2006). From a human-technology (HT) perspective, the project design resulted in placing four large standing screens next to each other, creating a large common visual display. This allowed for a more complete representation of the entire VTS area, with overlays of detailed maps for certain relevant passages.

Another important area of the design-work in phase B was the ergonomics of the workplace, with an analysis of which tools where most frequently used and how these could be placed for maximum availability. In part these needs conflicted with the large screen area in front of the operator. In order to find solutions and optimum compromises, a low-fidelity mock-up was built and operators were asked for input based on their experience from the existing workplace.

Furthermore, the large screen area needed to be placed as low as possible; to keep the visual areas within limits for the operator's vertical line of sight, according to identified ergonomic criteria (EN-894-2, 2008).

An attempt were also made fro an technology-organization (TO) perspective to introduce pre-recorded radio transmissions that allowed the operator's to make recordings when workload was relatively low and minimized the amount of work needed at the fixed transmission times.

4. Discussion and Conclusion

Despite the successful use of the HTO concept, not all project goals were fully achieved. The organization was designed for highest possible efficiency, in line with the prevailing priorities in the organization at the time of analysis and decision to implement the new VTS structure. During the run of the project, the organization's priorities shifted towards stronger emphasis on external benefits and needs and opinions of the customers/clients/users. In this shift, not enough sustained support for the selected organizational solution was secured internally. When external stakeholders criticized the project, it was decided to change path, leading to some potential effect in terms of internal efficiency being lost.

The parts of the project that were being finalized and put in production were deemed successful. In addition to the concrete economic benefits, the operator environment in the new VTS center was significantly improved. Earlier discussions and complaints in relation to air quality, light conditions, insufficient or non-ergonomic desk were also significantly reduced.

It can thereby be concluded that the present solution, based on the HTO methodology as described in this article, has provided a more satisfactory workplace with less focus on issues connected with work environment and satisfaction than the more traditional engineering approach.

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