Scientific Journals
of the Maritime University of Szczecin

Zeszyty Naukowe
Akademii Morskiej w Szczecinie

2016, 45 (117), 168–173
ISSN 1733-8670 (Printed)
ISSN 2392-0378 (Online)
DOI: 10.17402/101

Received: 31.08.2015
Accepted: 22.02.2016
Published: 25.03.2016

Methodological analysis of reliability assessments for vessel traffic service operators

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Key words: VTS, VTS operator, MWL, Sagat, SATEST, HRA

Abstract
The vessel traffic system (VTS) operator is an important role in the monitoring and supervision of maritime traffic. The main objectives of the VTS is to improve security in the coastal areas. VTS efficiency depends on the quality of the operators. Certain conditions of work should be provided if the system service is to be reliable as this facilitates proper and effective task performance. This article analyzes the factors affecting the performance quality of VTS operator's. The aim of this study is to examine the methods that indicate negative factors affecting the efficiency of the VTS operator. The result of the study is primarily a reliability analysis of VTS, which underlines the importance of a thorough understanding of the factors associated with human reliability. These methods are crucial to determining VTS operator errors, and gaining an understanding of the consciousness of the operator's actions in the workplace. Future negative factors can potentially be eliminated by answering questions about the guiding forces, actions and reactions of the operator to external stimuli in a specified scenario.

Introduction

In accordance with IMO Resolution A.857 (20), vessel traffic system (VTS) is defined as a "service provided by the competent authority, designed to improve security and streamline the movement of the ship, as well as environmental protection. The service should be able to interact with the traffic and to respond to situations developing in the VTS area". In contrast, the main document defining training of VTS operator is defined by the document IALA V-103 \ 1.

The continuous development of technology enables man to aspire to improve the system reliability. The need to improve the security of the system has created a reason to analyze the relationship between man, his action in a working process, and the environment (Figure 1).

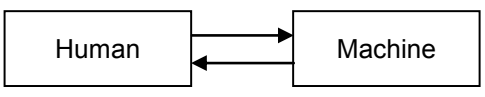

Figure 1. Man-Machine relationship

During the analysis of HRA (Human Reliability Assessment), it is indispensable to define those human activities that can affect the reliability of the system. The subject of this assessment is not only the man, but also the relationship of the man and the machine.

VTS Operator and his work environment

Vessel Traffic System is defined as a system based on vessel traffic control, providing simple informational messages, such as weather warnings and traffic assistance. The vessel traffic control service was established in order to improve the safety of navigation and for the protection of the environment. Most importantly, is was established to improve vessel traffic in the areas where the concentration of a large

number of vessels poses a serious risk of collision or grounding (e.g. in narrow channels).

IALA V-103 recommendations require that personnel are adequately qualified and trained to act as VTS operators in accordance with IMO guidelines. The VTS operators should have sufficient knowledge and skills to work in this rank. They are responsible for coordinating the movement of all vessels in the harbor, and they must ensure safe passage without risk of collision with other units or navigational objects. The field of operator's tasks includes the use of operational equipment, which is located in the control center.

The VTS operator contributes significantly to the monitoring of maritime traffic. The quality of his work depends on the efficiency and effectiveness of the system. VTS efficiency depends on the quality of his work. To ensure the reliable operation of the system, working conditions should be provided that will allow an operator to meet his duties and correctly detect incidents. The operator remains in seated position while performing the minimum number of movements and executing the continuous observation of several screens. Therefore, the workplace should be designed so as to ensure the proper execution of the tasks necessary for monitoring VTS area.

Methods used to evaluate the situational awareness and mental workload (MWL) of VTS Operator

Effectiveness of VTS Operator act examined by means of SATEST

The study was conducted on the simulator Int. Marine Safety in Rotterdam (MSR), which consists of a full VTS operator panel. It allows the selection of multiple scenarios of vessel traffic in both real and imaginary areas. The SATEST method was used to measure the operators situational awareness. This method was based on the Sagat method (Wiersma & Mastenbroek, 1997). The Sagat method is a well-known tool for measuring situation awareness in military aviation. Pilots go through a number of scenarios in Flight Simulator. After certain time periods, the simulation is stopped, and pilots provide answers to questions about the situation in specified time. The analysis includes system status, as well as relevant aspects of the external environment. The results are compared with the results logged in the simulator. The SATEST method was established based on this methodology. A fundamental

Figure 2. Form 1 of SATEST method (Wiersma & Mastenbroek, 1997)

requirement of this method is to ensure appropriate conditions. The operator must forget that he is taking part in a simulation. The experiment lasts long enough to allow the VTS operator to create his/her situational awareness.

SATEST method scheme consisted of two parts:

- The first part of the assessment is the VTS area map, used to indicate the exact position of all ships and their velocity and heading vectors (Figure 2).
- The second part of the assessment is used separately for each ship (Figure 3a). This is done by selecting a single vessel each time (with the click of a mouse). This form must be completed, among others, with ship information (name, destination, type of vessel, speed, special considerations). The study takes into account the potential for emergencies. The details of these situations can be identified in a separate form (Figure 3b).

An analysis of the results obtained using the SATEST method was based on the fact that the operators were getting points after completing the task. Each individual result was compared to that of an operator with the maximum result (score

Figure 3. Form 2 used in SATEST concerning individual information of ships (a), Form 3 used in SATEST indicating increased attention (b) (Wiersma & Mastenbroek, 1997)

expressed as a percentage of the maximum). In this way, the collected information is a mental picture of the operator in various situations. It also covers all conflicts and potential conflicts such as ship-to-ship and ship-to-infrastructure. The information obtained through the SATEST method helps to predict the places where such an emergency is likely to happen.

Mental workload of the VTS operators estimated by the HEART RATE

A study was carried out (Kum et al., 2007) to examine the psychological burden of VTS operator using the Heart Rate method. The main objective was to determine the stress level of the audited entity. The operator could not have committed any human error in the performance of his watch. To characterize the stress index, an apparatus for measuring blood pressure, a Heart Rate Monitor (HRM), was used.

The experiment was carried out in the responsibility area of the VTS Center in Istanbul. This area consists of four sectors: Türkeli Sector, Kavak Sector, Kandilli Sector and Kadikoy Sector (Duru et al., 2005). The study was conducted on 8 of 32 VTS-operators. Persons were randomly selected to participate in the study with no specific criteria used.

The experiment was carried out in different conditions depending on:
- vessel traffic;
- weather conditions;
- type of VTS sector;
- night or day watch.

Using the Polar Precision manometer version 4.03.044, pulse characteristics of VTS operator were received. Table 1 shows the results obtained with manometer.

Using this method most of the factors that caused increased mental strain (MWL) were characterized:
- the size of ships (above 150 meters);
- level of traffic;
- presence / absence of a pilot on board;
- ability to communicate with the ship;
- work overload.

VTS Operator reliability testing with Eye Mark Recorder

This research was conducted in the center of Istanbul Strait Head of VTS (Kum, Furusho & Fuchi, 2007). The research focused on determining VTS operator eye movements during their watch. The primary objective of the study was to increase human reliability during heavy traffic of ships. Eye movement of VTS-operators was registered by EMR8 device.

The results were used as an indicator to assess:
- physiological point of fixation (fixation point);
- durations of fixation (fixation duration);
- change the point of view of VTS-operators.

There were three experimental studies carried out. These studies were conducted in different conditions and in different sectors of the VTS watch keeping responsibility. For the analysis, the field of view was taken into account. This is important in determining the fixation points. This study helps to understand what basic information is used by the operator. It also determines the most important factors in the decision-making process of the operator. The acquired data was then analyzed utilizing a "frame by frame" method.

FRAME BY FRAME is a method used to analyze the results of eye movements. The data obtained from the EMR include 18,000 situations covering five minutes in the data recording period. The operator's field of view consisted of two computer screens (6, 7), two monitors displaying video from the camera (1, 2), the camera's driver (3), VHF (4) and space for administrative work (8) (Figure 4).

Figure 4. Operator's field of vision classification (Kum, Furusho & Fuchi, 2008)

Table 1. Characteristics of VTS operators pulse (Kum, Furusho & Fuchi, 2007)

Data 353	Unit	VTS-01	VTS-02	VTS-03	VTS-04	VTS-05	VTS-06	VTS-07	VTS-08
Duration	H:M:S	02:11:55	01:44:45	02:12:10	02:07:05	01:00:50	01:18:15	01:02:35	01:00:45
Number of Heart Beats	Beats	10.824	8.281	11.505	8.520	5.421	5.326	4.574	5.353
Minimum Heart Rate	Bpm	66	66	72	54	80	57	66	73
Average Heart Rate	Bpm	82	79	87	67	89	68	73	88
Maximum Heart Rate	bpm	111	99	121	99	110	81	85	104
Standard Deviation	bpm	7.1	5.9	6.9	6	3.7	3.5	25	4.8

The study verified that the significant impact of psychological stress on VTS operator's is caused by:

- specification of ships, particularly vessels with great LOA and located in critical areas;
- workplace ergometry.

Concept of simulation method to assess the VTS operator reliability

Human Reliability Assessment is an assessment which is based on the human behavior analysis. Using the human reliability analysis, it is possible to assess the human impact on certain operating conditions (normal and emergency conditions). The most common use of HRA is the evaluation of human activities in terms of system performance.

The essence of VTS operator reliability test is consideration of workplace characteristics, as well as his duties and responsibilities. HRA is most commonly used to evaluate human activities as part of the system. Analysis is based on the estimation of the impact of human activities. Errors could affect the efficiency and/or safety of the system as a whole. The subject of the study is the relationship of the configuration man – working environment. It has to ensure the safety and reliability of the VTS. VTS for the purpose of this work was presented in the form of two components. On the one hand, man as a system operator and on the other hand – his operating environment. The concept of operating environment shall be understood as the tools necessary for the proper functioning of the system (the system devices). Between these two elements, processes take place which are a result of their interaction.

The main purpose of the research is to develop a model of human behavior in terms of VTS reliability and safety assessments. The leading point is the evaluation of the reliability of a VTS operator (Human Reliability Analysis). In order to make a comprehensive analysis, it would be necessary to apply multiple complementary measurement methods. These methods allow for the identification of factors affecting the efficiency of the operator (to estimate the probability of human error) Figure 5.

The research will aim to identify the sources of threats resulting from human activities as a part of VTS system and human error analysis in terms of reliability and safety of the system.

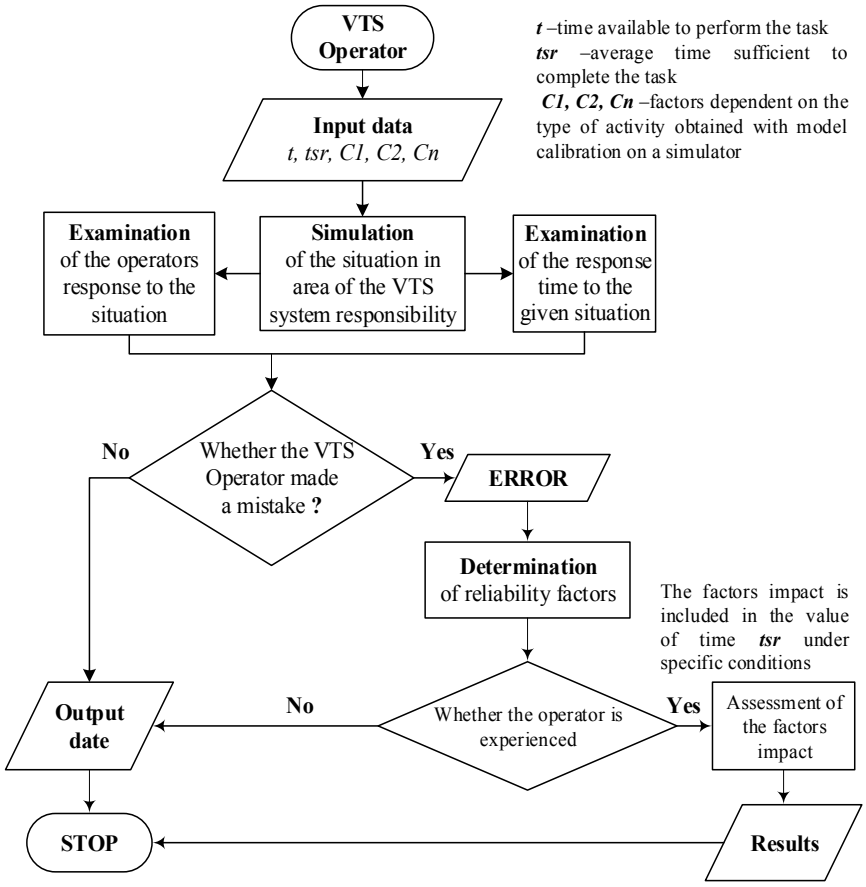

Figure 5. Block diagram of the simulation method

The use of Transas VTS Simulator as a tool for VTS operator reliability assessment

The studies will be carried out on the Transas Harbour Nav-5000 SIMULATOR, which is one of the best VTS and is designed to enhance safety of navigation and for traffic planning. This system allows to:

- receive information about the navigational situation from different receivers;
- generalization of target data and its presentation in tabular and / or graphic form combined with electronic map;
- monitor and to arrange the vessel traffic;
- analysis of the navigation situation and to generate alarms in accordance with criteria specified by the VTS operator;
- digital recording of data with the possibility of its restoration.

The main menu contains a full list of features that enable the proper implementation of VTS tasks. It contains many additional features that allow the adjustment of the operator's environment to a given scenario.

Using the Navi-Harbour company Transas 5000 simulator it is possible to simulate various conditions, e.g. the amount of traffic, emergencies, etc. (Figure 6). This simulator allows the examination of the response time of the object (the operator) to a stimulus. It does this by assessing the level of psychomotor skills being used by the operator.

Figure 6. Simulator Navi-Harbour of Transas 5000

The future research will include the following steps shown in Figure 7.

Conclusions

To meet the growing requirements for more efficient and safer monitoring of vessels traffic under the area of VTS responsibility, enhanced attention is paid to studies that focus on measuring the situational effectiveness of the operator. The article describes a study that focused on measuring the performance of the VTS operator. The concept of operator reliability is introduced as a means to describe and assess the performance of VTS personnel. The scoring system for the execution of tasks by the VTS operator is based on special characteristics of his work, such

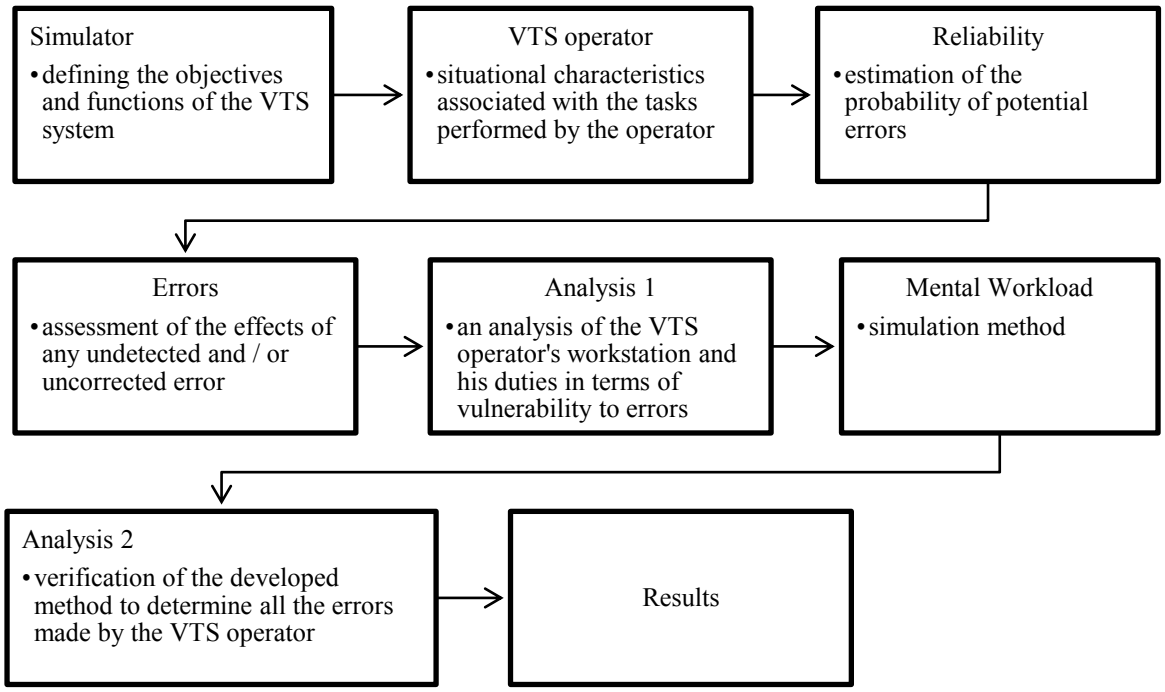

Figure 7. The scheme of the planned research based on the Navi-Harbour of Transas 5000 simulator

as accuracy and processing information obtained through the system. This work systematically analyzes the factors affecting the behavior of workers and the safety of the entire system. It especially takes into account the characteristics of personnel, work environment, responsibilities and liability for performance of tasks under conditions of stress and emergency. Reliability of the VTS operator is used to assess the risks resulting from potential human errors. It is aimed at minimizing the vulnerability to the system errors.

Acknowledgments

Article is a part of study inside the RepSail project and has been co-founded by EraNET in decision: ENT III/Future_Traveling/2/2014.

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