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A STAMP-based approach for designing maritime safety management systems

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ABSTRACT

Designing maritime safety management systems commonly follows basic processes which focus on fulfilling the demands of the regulations in the industry. This provokes designing systems with limited application which are not capable to efficiently use the guidance contained in regulatory demands, and more importantly, creating systems which are not capable of representing, evaluating, and improving the dynamic management of safety-critical organizations. This article proposes a safety system engineering process for designing maritime safety management systems which is based on the Systems-Theoretic Accident Modelling and Processes (STAMP). This process is applied for sketching the safety management of the Vessel Traffic Services in Finland. The aim is to systematically represent the function of the utilized controls for ensuring the internal VTS safety management and the safety of navigation in Finnish sea areas. The outcome of this study provides a descriptive process of analysis for designing maritime safety management systems. In this process, two other concrete elements are included for supporting the functioning of the safety management system to be designed. First, the adaptation of an identification process for determining key performance indicators for planning, monitoring and evaluating the functioning of the safety management system. Second, the constitution of a performance monitoring tool capable of executing the monitoring, measuring, and updating of the determined key performance indicators and the general functioning of the designed safety management system.

1. Introduction

Maritime navigational operations are commonly categorized as one of the most complex and dangerous industry within the large industrial sectors globally (Celik, 2009; Hetherington et al., 2006). For this reason, the International Maritime Organization (IMO) continuously attempts to ensure the safety of maritime operations by providing international conventions such as the International Convention for the Safety of Life at Sea (SOLAS) and particular safety management guidelines such as the International Management Code for the Safe Operation of Ships and Pollution prevention (ISM Code). These and other regulations have brought a gradual improvement of the safety of maritime operations and maritime organizations in general (Kristiansen, 2013). However, the effect of these safety regulations and guidelines on having an actual proactive approach to maritime safety is still being questioned (Schröder-Hinrichs et al., 2013). Hitherto, in certain sectors of the maritime industry, the design and implementation of their safety management systems (SMS) are still influenced by a common limited approach which focuses on fulfilling the demands of the regulations applicable to the organization (Schröder-Hinrichs, 2010).

This issue can be extended with the identified lack of processes for designing and implementing safety management systems capable of representing and constantly improving the management of safety-critical organizations (Dekker, 2014; Hollnagel, 2014; Leveson, 2011; Oltedal and Wadsworth, 2010; Reason, 1998; Reiman and Oedewald, 2007). Studies done for the establishment of a framework to design safety management systems in the nuclear power industry represent few of the available examples for this purpose (Falk et al., 2012; Wahlström and Rollenhagen, 2014). Another issue is the common disregard of the guidance already available in safety regulations and guidelines which can efficiently support the actual organizational safety

Abbreviations: BN(s), Bayesian Network(s); CMO, Context-Mechanism-Outcome; EA, Environmental Assumption; IALA, International Association of Lighthouse Authorities; IMO, International Maritime Organization; ISM Code, International Management Code for the Safe Operation of Ships and Pollution Prevention; KPI(s), Key performance Indicator(s); PDCA, Plan-Do-Check-Act; Req., Requirement of the SMS; SC, Safety Constraint; SMS, Safety Management System(s); SOLAS, International Convention of Safety of Life at Sea; STAMP, Systems-Theoretic Accident Model and Processes; STPA, Systems-Theoretic Process Analysis; UCA, Unsafe Controlled Action; VTS, Vessel Traffic Services

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management and therefore demonstrate their fulfilment (Reese, 2015; Valdez Banda et al., 2016b).

In the context of maritime navigational operations, the need for SMS capable of representing and actually supporting the development of the operations have also been detected in (Boström and Österman, 2016; Ek and Akselsson, 2005; Flin et al., 2000; Hänninen et al., 2014; Lappalainen et al., 2014; Oltedal, 2009; Reason, 2005). A clear example is presented in Valdez Banda et al., (2016a). The analysis of determined actions to reduce the risk of winter navigation operations has pointed out that, in practice, there is lack to translate the actual operational needs into the functioning of the organizational SMS.

In this study, a STAMP-based approach for designing maritime safety management systems is presented. The proposed process is guided by the application of a methodology for integrating safety into system engineering which is based on the design of the organizational safety intent specification included in the Systems-Theoretic Accident Modelling and Processes (STAMP) presented in Leveson (2011).

A case study for the application of the process is presented in the analysis of the safety function in Vessel Traffic Services (VTS) in Finland. VTS is one of the main actors responsible for monitoring and controlling the safety and smooth development of maritime traffic (Praetorius et al., 2015). Thus, the objective is to systematically represent the functioning of VTS Finland and the controls utilized to ensure their internal safety management and the safety of the navigation in Finnish sea areas. The analysis covers the functioning of aid services provided by VTS all year around, making distinctions between services provided during spring-summer-autumn season and winter ice season.

The application of the proposed process culminates with a defined SMS for VTS Finland and the provision of a performance monitoring tool that implements a set of identified Key Performance Indicators (KPIs) which are created to support the planning, monitoring, evaluating and updating of the requirements of the designed SMS for VTS Finland.

2. Safety management perspective

The general notion of safety management has been discussed and various concepts have been developed and applied in different industrial sectors. In the context of safety-critical organizations, the actual management of safety must understand the nature of the aspects influencing how an organization ensures the safety of the operations (Reason, 1997). For this, the top management commitment, the proactive involvement of all personnel in the organization, and the provision of skills, appropriate guidance and tools are essential to obtain the safety management targets (Grote, 2012; Leveson, 2011). The combination of these elements is essential to execute the required tasks to achieve the organizational safety goals and simultaneously fulfil the demands of regulations (Hollnagel, 2014).

A SMS is the commonly utilized vehicle to achieve the safety objectives of an organization. Therefore, SMS must effectively understand the nature of the internal functioning of the organization while also effectively implement and comply the applicable safety regulations. This creates evidence that safety, in general, is a system property, and therefore it must be managed at the system level (Leveson, 2011). Thus, the main of objective of any SMS is to prevent accidents, therefore SMS has to be able to understand, monitor and improve the safety performance of the organization (Dekker, 2014).

Commonly, the performance of SMS is monitored and measured by implementing KPIs (Reiman and Pietikäinen, 2012). These measure the current levels of operational and organizational safety represented in the performance of the SMS. At the same time, KPIs should capture and represent organizational safety trends and developments (Øien, 2001). Moreover, the use of KPIs increases the knowledge gathered in the SMS and proactively improve the management of safety (Swuste et al., 2016). Fig. 1 presents the foundation behind the elements interacting in the dynamics of any SMS. First, the actual functioning of the organization, the internal managerial and operational practices. Second, the demands included in the safety regulations applied to the organization. Third, the external influence affecting the two previous elements, the influence from the acting of customers, industry, economy, society, and regulatory organizations. These three elements influence the actual performance of the SMS. Finally, the SMS performance is commonly measured and guided with the use of KPIs.

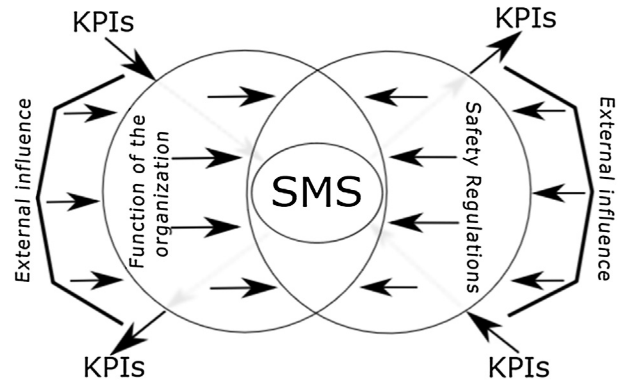

Fig. 1. Elements influencing and interacting in the function of SMS.

3. Research methodology

Fig. 2 presents a flowchart describing the steps of the research methodology. First, the description of the study methodology foundations. This includes the STAMP methodology and the STAMP safety intent specification. Second, the methodology for establishing the process for designing maritime safety management systems. It includes the design process and the method to define the KPIs of the SMS. Third, the methodology of the monitoring tool. The practicalities of the tool to implement the KPIs and monitor the performance of the SMS.

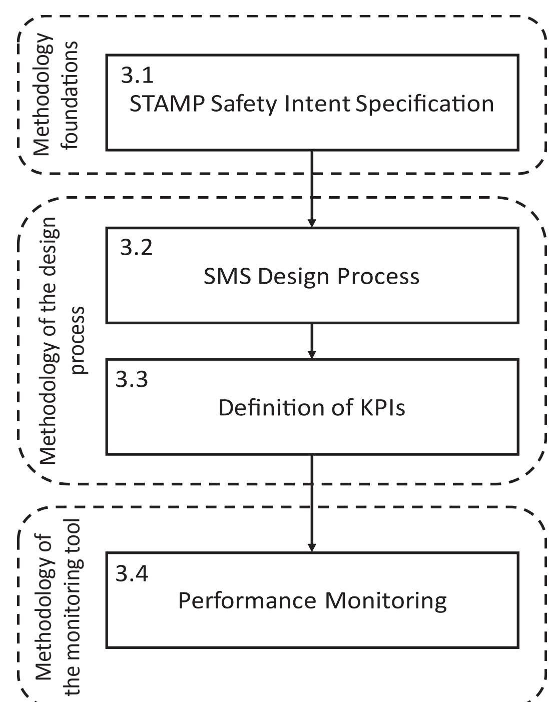

Fig. 2. Description of the methodology applied in the study. At each component in the figure, the reference to a section which describes the utilized method is provided.