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Safety related key performance indicators for securing long-term business development – A case study

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ABSTRACT

An application of the Bayesian Belief Network (BBN) modelling is presented as a support in establishing process safety related key performance indicators (KPIs) for business management purposes. A relation to the managers' trust into results of risk analysis results is made. The case study deals with a possible spill, ignition, and explosion of methanol during a ship tanker unloading operation at the liquid cargo terminal at the port of Koper, Slovenia. Considerations of business impacts of such a major accident proved to be of particular relevance to the top management. Besides direct financial costs indirect economic impacts, like longer business interruption and impact to reputation, caused stronger concern due to their possible overall financial scope. This finding triggered a management requirement for establishing new, direct, measurable KPIs in association with multiple organizational safety improvement measures. Despite their small individual contribution to overall risk reduction, they are altogether effective in better understanding of the benefits of risk analysis for business. The BBN modelling assisted in identifying dominant contributors to key failure events, which was the guidance for proposing the meaningful, measurable business relevant KPIs. Benefits of such KPIs rely on regular monitoring by mid and top managers.

1. Introduction

The paper provides a description of the process in which key performance indicators (KPIs) for business management purposes have been established at the Port of Koper, Slovenia. In the introductory section, the issue, background information, and basic info about the port are presented. The approach and method section lists contributing components to deriving contextual Key Performance Indicators (KPIs) and provides a detailed description of the methodological steps. Section three discusses Bayesian Belief Network (BBN) modelling, as applied in the case study. The discussion part deals with three aspects of the case-study - the analytical part, the trustworthiness of risk analysis and results, and the managerial use of the results in business related decision-making. The conclusion underlines small steps in building trustworthiness of risk assessment towards securing long-term operation and business development.

1.1. Issue

In risk research, there is a continuous attention towards issues of how risk analyses results are actually used in decision making, which features are important for different stakeholders, how performance indicators are developed, and what are the key contributors to trust in the decisions made. In this paper we focus on demonstrating one of the possible ways of how risk modelling results may be perceived as trustful and therefore taken into account when developing Key Performance Indicators (KPIs). There are different guidance and initiatives for making safety performance indicators effective in decision-making, for example, those which use Deming's loop approach as a framework (HSE, 2006; OECD, 2008; Pasman and Rogers, 2014). Recent publications, however, suggest that additional systems for checking the effectiveness of existing KPIs for the purpose of their application in safety management systems are useful. Such systems are, for example, monitoring and reviewing measurements of the most relevant

Abbreviations: ALARA, As Low As Reasonably Achievable; ALARP, As Low As Reasonably Practicable; ARAMIS, Accidental Risk Assessment Methodology for IndustrieS; BBN, Bayesian Belief Network; GDP, Gross Domestic Product; KPI, Key Performance Indicator; RTC, Risk Tolerability Criteria; VAR, Value At Risk – costs of direct damages (utility node in BBN model related to the average monetary value of assets at risk (in €) per operation); VAR2, Value At Risk – costs of indirect damages (utility node in BBN model related to the average monetary value of assets at risk (in €) per operation); Volume, utility node in BBN model related to the average amount of spilled methanol in m^3 per operation.

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components of maritime safety management (Valdez Banda et al., 2016), or the application of an IT system for the safety management, as demonstrated by the BBN modelling (Hänninen et al., 2014).

1.2. Background information

Within the EU 7th FP project iNTeg-Risk (http://www.integrisk.eu-vri.eu) a specific approach for selection and implementation of the KPIs was prepared (named "ERRA D1 - Definition of KPIs for emerging risks for selected industry case studies, including corporate social responsibility aspects of emerging risks"). The purpose of the project was to transparently and consistently connect the underlying risk model results and its related information on the safety related performance of a hazardous activity with the effective management decision-making aimed at monitoring (based on the effective KPIs), maintain, and improve overall safety, as necessary (iNTeg-Risk, 2011). Following this approach Bayesian belief network modelling (Kjaerulff and Madsen, 2008) has been applied in a case study at the port of Koper, Slovenia. The case study concerns a potential spill and subsequent ignition of methanol during a ship tanker unloading operation at the liquid cargo terminal. The approach and modelling results (a summary is provided in Appendix A) have been approved by the port's safety experts and the top management (iNTeg-Risk, 2012) with a question raised about the possibility of improving safety performance monitoring. In this relation, a need for transparent, direct KPIs, which would meet both the ALARP principle[1] (HSWA, 1974; Malekzadeh and Bate, 2014) and long-term business decision needs, was recognized. Despite certain shortcomings of the ALARP principle (Allen et al., 2006; Baybutt, 2013; Redmill, 2010; HSE, 2014), the top management of the port of Koper decided to apply it as a reference tool (i.e. the motivation) that triggers a safety improvement process (iNTeg-Risk, 2012). In this context, it has been decided to check which safety improvements could be reasonably achieved at the liquid cargo terminal in order to further secure its long-term operation. The existing situation, as described in an actual safety report for port of Koper (Luka Koper, 2008), the maritime threat assessment (Luka Koper, 2010), and the associated BBN risk modelling (Gerbec and Kontić, 2014), has been recognized as having the potential for major interruption of business of the port. For better insight into this issue a more detailed analysis has been scheduled, i.e. second stage BBN modelling, aimed at clarifying the following two managerial aspects: first, the scope and severity of such a business interruption (i.e. direct financial, and subsequent economic and reputational consequences), and second, the possible application of additional safety monitoring (i.e. indicators) at the liquid cargo terminal in order to further reduce the possibility of a major accident. The updated modelling involved consideration of specific secondary damages arising from the major accident (i.e., cost of repair of the terminal, duration of operation shutdown, lost reputation with loss of clients, cost of compensations and fines, etc.). The results were then considered in the development of KPIs that are operational, direct in terms of measurement, easy to apply, and transparent for management decision purposes.

[1] ALARP — As Low As Reasonably Practicable; A wider understanding is applied here: risks should be made as low as reasonably possible by using the optimisation approach, comparison of alternatives for reducing risks and selection of the best one, application of BAT — Best Available Techniques – facing both development, health, and environment protection interests. In making a judgement as to whether an ALARP position may have been reached, the Australian National Committee on Large Dams (ANCOLD), for example, suggests the evaluation of the cost of saving a statistical life, good practice, level of existing risk, social concerns, affordability and duration of risk. In this view, regulation, per se, does not provide the best, state-of-the art solutions in longer timeframes but rather a compromise adopted at a particular point in time (Kontić and Kontić, 2012).

1.3. Short description of the port of Koper

The Port of Koper is situated at the north Adriatic Sea. Its net revenue in 2016 exceeded 200 million €, with a total throughput of 22 million tons. More than 1000 people are employed at the port. Specific data are available in the 2016 Annual Report (Luka Koper, 2017), and at https://luka-kp.si/eng/.

2. Approach and method

2.1. Approach

The proposed approach to derive risk based key performance indicators consists of using a socio-technical risk model (iNTeg-Risk, 2011), implementing the main steps of the quantitative risk assessment (QRA) using BBN modelling (e.g., Haugom and Friis-Hansen, 2011; Villa et al., 2016), combined with external & organizational influences in a predictive risk assessment (Øien et al., 2011), as well as the consideration of direct and indirect damages and costs in corporate social responsibility model (iNTeg-Risk, 2011).

2.2. Method

A method for the identification of KPIs is graphically illustrated in Fig. 1 - part D (developed from parts A to C).

The steps are as follows:

1. Step one is related to the collecting and compiling of information and data about the system (organization), site and related activities under analysis. This step does not differ from the common QRA approach, however, considering the relevant damage categories (step 5), additional info about the organization's value chain and economy are needed.
2. Step two is Hazard identification (as in QRA), and shall result in a list of major accident hazards.
3. Estimation of likelihood of potential major accidents – step three - has the same purpose as in QRA, however, in addition to the standard methods like fault tree and event tree analysis, or bow-tie diagrams, the dynamic risk assessment (Villa et al., 2016, section 4) principles are to be applied. Specifically, basic (initial) events need to be linked to the expected contributing qualities, as well as the potential complexity of events within the accident propagation path to be considered. Adequate tool for this purpose is BBN, since it deals with complex relations among the model events and event nodes with multiple mutually exclusive states (Haugom and Friis-Hansen, 2011; Villa et al., 2016).
4. The consequence estimation in step four involves identification of relevant dangerous phenomena (fire and explosion) with their consequences (e.g., intensities, impact distances, casualties, financial loses, etc.) and the likelihood of their occurrence, taking into account results of step 3.
5. Next, the damage risk model is prepared based on the result of the consequences and likelihood model. For the purpose of integrating different damage categories, monetary values can be used as a common nominator (Gavious et al., 2009; Ronza et al., 2009; Gerbec et al., 2016). A breakdown of the cost categories is graphically presented in Fig. 2. The purpose of using monetized damage costs is to enable their summation and the calculation of direct and indirect values-at-risk in the specific risk context and the BBN model.
6. In step six the contributors analysis is made. The BBN tool allows adding the evidence, thus enabling the model to update the nodes states probabilities using the "max-propagation" functionality (Kjaerulff and Madsen, 2008; HUGIN, 2015). The