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A Resilience Engineering -related approach applying a taxonomy analysis to a survey examining the prevention of risks

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ABSTRACT

The aim of this study was to devise a way of applying a taxonomy based on the concepts of resilience engineering and to demonstrate the feasibility of this taxonomy on survey data. An online internet questionnaire was administered to over 6700 OSH managers; their response rate was 22%. The corresponding values for workers' OSH representatives were 5300 and 27%. The present study developed a qualitative taxonomy based on a Resilience Engineering approach. This study applied a combination of both qualitative and quantitative research methodologies. For both managers and workers, 'Commitment of management', 'Cooperation' and 'Systematic improvement of OSH' had positive influences on 'Decreasing accident risks'. Furthermore, 'Obligations', 'Decreasing accident risks', 'Improving ergonomics', and 'Training' exerted a positive influence on 'Development of the work conditions'. The classification of resilience with the present taxonomy helped to clarify an intangible quality like resilience and in this context also helped to develop proactive safety measures. The key constructs of the present taxonomy helped in providing a deeper understanding of the commonalities, differences, and relationships in their sub-categories. The main implication is that the present resilience taxonomy can be applied by managers and employees for determining the future intervention process in improving OSH. When applying the present resilience taxonomy with a participatory approach, the organizations may acquire new perspectives on the working life and learn how they can collectively ensure the successful outcome and fulfilment of needs in OSH.

1. Introduction

One of the basic principles of Resilience Engineering (RE) was defined by Hollnagel (2011, p. 273) i.e. he defined resilience as the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can continue to perform the required operations under both expected and unexpected conditions. Woods (2009) defined that 'resilience' is a system's potential for adaptive action when information varies, conditions change, or new kinds of events occur in order challenge the viability of previous adaptations, models, or assumptions. The concept of resilience would seem also to incorporate two dimensions as follows: First, the capacity to anticipate and manage risks before they become serious threats to the operation (McDonald, 2006, p. 172). Second, the ability to cope with situations in which the operation has become compromised, i.e. the organization's survival is dependent on the adequacy of its response to the threat or challenge (McDonald, 2006, p. 173).

With respect to resilience Woods (2015) argued that "The lines of inquiry have progressed to tackle the following questions: (1) how adaptive systems fail in general and across scales; (2) how systems can be prepared for inevitable surprise while still meeting pressures to improve on efficiency of resource utilization; (3) what mechanisms allow a system to manage the risk of brittleness at the boundaries of normal function; and (4) what operational architectures allow systems to sustain adaptability over long times and multiple cycles of change." By adopting a cognitive strategy, the controller should be able to mount an appropriate response to interruptions and distractions so that the organization's core activities are not put at risk (Malakis and Kontogiannis, 2011, p. 109). The institutional level of the system must be responsible for collecting suitable information for the training about potential problems that threaten resilience (Tjeirhom and Aase, 2011, p.169): (1) Development of guidelines and requirements for addressing cross-scale interactions; and (2) The training tools should be provided to participants from different levels and professions.

Woods (2015) stated that "The process of adapting to disruptions, challenges and surprises over time changes the system in question in multiple ways; even when adapting to preserve, the process of adapting transforms both the system and its environment." Leveson et al. (2006, p. 116) indicated that once the combined model has been adopted by an organization and integrated into its procedures, the amount and quality

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of learning achieved through the investigation and resolution of safety problems impacts on the effectiveness of system safety efforts and the quality of subsequent corrective actions, which in turn has a significant effect on the technical risks present in the system. Resilience cannot be engineered simply by introducing more procedures, safeguards, and barriers (Hollnagel and Woods, 2006, p. 348); instead, RE requires a continuous monitoring of system performance as well as an awareness of how tasks are actually done. The concept of resilience would seem to require both the capacity to anticipate and manage risks before they become serious threats to the operation, and the ability to survive situations in which the operation has become compromised. One important aspect of RE is that it strives to clarify the organization's model of how it creates safety, in order to determine when the model is in need of revision (Woods, 2006a, p. 22). From some points of view, quality and safety management are concerned with maintaining stability - assuring that a constant standard of work or output (process and product) is maintained (McDonald, 2006, p. 169).

Little research has been carried out aimed at gathering evidence-based data in occupational safety and health (OSH) to validate the scientific theories that underpin the RE approach, especially research involving a joined quantitative and qualitative analysis. The present taxonomy in the qualitative study shall specify which fundamental dimensions and processes are involved in these relationships, then define their integrative dynamics, and finally clarify the stages at which these dimensions take on greater or lesser significance in quantitative terms.

The focus of this work was to develop and apply the OSH taxonomy to data obtained from a survey concerned with decreasing the risks of accidents by adopting a systems thinking approach. The present systematic view utilizes the theories inherent in RE (Hollnagel, 2006) but applies these concepts in the framework of this analysis. Better understanding of systemic structures can then facilitate the design of more effective safety culture interventions and application of systems thinking concepts will improve the overall effectiveness of safety management (Goh et al., 2010).

2. The aim of the study

The main objectives of this study are as follows: (1) Introduce a procedure for applying the developed taxonomy based on RE using data from a survey and adopting a socio-technical approach; (2) demonstrate that a taxonomy based on the RE approach makes it possible to interpret the OSH survey's data; and (3) show that a RE-based taxonomy is able to extract OSH domain knowledge from data collected in an internet questionnaire.

3. Materials

The questionnaire survey was carried out in September-October 2008. The employer respondents were selected from the occupational safety and health manager (OSH) register (consisting of private business and municipal sectors) of the Centre of Occupational Safety and from a similar register compiled by the State Administration consisting of public servants. The survey was conducted via an online Internet questionnaire sent to 6710 employers' OSH representatives (OSH managers), with 1478 responding, i.e. response rate of 22%. The corresponding figures for 5306 workers' OSH representatives were 1416 (27%). Among employers' respondents the occupations were according to the Finnish Standard Industrial Classification as follows: Manufacturing 26%, Human health and social work activities 17%, Public administration and defence 17%, Wholesale and retail trade; repair of motor vehicles 9%, Construction 7%, Education 6%, Transportation and storage 6%, Electricity, water supply, sewerage and waste management 4%, Agriculture, forestry and fishing 2%, Mining and quarrying 2% and others 5%. The occupations of workers' respondents have similar types of distributions. Although this data was collected in 2008, the survey was conducted under a similar regulatory environment as exists today; thus it is not believed that responses would differ significantly if collected in 2017. In the present research sample, both employers' and workers' respondents had the similar distributions according to the different size-classes of the organizations and their branches.

4. Methods and analysis

4.1. Joined qualitative and quantitative methods and analysis

This study applies a joint qualitative and quantitative research approach and a taxonomy was developed based on the RE concept. Onwuegbuzie and Leech (2005, p. 381) postulated that methodological pluralism should be promoted in order to help as many investigators as possible to become pragmatic researchers. According to Onwuegbuzie and Teddlie (2003, p. 352) instead of utilizing terms like quantitative and qualitative methods, exploratory and confirmatory methods should be preferred since this would make it possible to unite the quantitative and qualitative data analysis within the same framework. Creswell and Plano Clark (2007, p. 9) defined the background used in mixed methods research in the following way: (1) The voices of participants are not directly heard in quantitative research; (2) Mixed methods research helps answer questions that cannot be solved by qualitative or quantitative approaches alone; and (3) Mixed methods research is "practical".

4.2. Quantitative methods and analysis

The following indicator values of the Likert scale were used: 1 = strongly disagree, 2 = somewhat disagree, 3 = not disagree/not agree, 4 = somewhat agree and 5 = strongly agree. The statistical analysis was done with SAS software (2005). Hypotheses **H1–H10** were tested using regression analysis. The coefficient of determination (R-squared) is calculated in regression analysis to indicate the percentage of the dependent variable that can be predicted by the independent variables; this level of accuracy in prediction of the dependent variable will change based on which independent variables are included in the model. For the statistical consistency of the responses, Cronbach's alpha was estimated as a coefficient of reliability or consistency (SAS software, 2005). It will be noted that the alpha coefficient is included as one of the statistics reported with differential decisions, and not with absolute decisions (Cronbach and Shavelson, 2004). A commonly-accepted rule is that an alpha of over 0.6 is 'questionable,' over 0.7 'acceptable' and over 0.8 'good' and over 0 0.9 'excellent' (Reynaldo and Santos, 1999).

4.3. Qualitative taxonomy of the RE approach developed for this study

Hollnagel (2011, p. 273) stated that resilience can be defined as the intrinsic ability of a system to adjust its functioning. One can make a joint qualitative and quantitative analysis of what happens when an organizational, human and technical system is stretched to accommodate new demands; this offers opportunities for studying aspects of system resilience. The role of qualitative indicators is crucial when developing RE, in fact this is an area which has not received as much attention as other aspects of measurement.

For this reason, the present study has developed qualitative taxonomy indicators. The purpose of the present method is to provide qualitative information about what is happening in intermediate stages of the processes of the RE. Starting from the level of the whole system, the present qualitative approach leads to the development of operational details and specific steps that can be taken on a concrete level. The developed taxonomy techniques place a strong emphasis on the analysis of the relationships between strategy, process, procedures and function within the inherent features of systems.

The present study is being focused on the following characteristics (Wilson, 2014): (1) Systems and Organization; (2) People and