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Technique to identify and characterize new and emerging risks: A new tool for application in manufacturing processes

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A B S T R A C T

The application of advanced automation technology in manufacturing process has increased manufacturing flexibility tremendously. The reasons to automate manufacturing processes include increased quality and efficiency demands, as well as improve the occupational safety and health. However, the fast pace of innovation and the rapid roll-out of new technologies and new products, as well as the creation of new jobs or modification of traditional jobs, requiring new skills, mean that a wider working population faces new risks.

Thus, besides traditional occupational risks, automated manufacturing processes can generate others, referred to as "new and emerging risks" (NERs).

These NERs may be linked either to the manufacturing process as a whole (system) or to specific components. This connection presents at least two complex problems in the field of occupational safety and health.

Firstly, there is currently no technique aimed at identifying and characterizing these risks in order to explain the features that confer them the status of new and/or emerging. Secondly, it is not possible to study the complex interrelations between the features of the system NERs and its components.

With the aim of resolving these problems, with the present work a technique in order to identify and characterize the NERs generated by a system and its components has been developed. This technique has been applied to a case study in the context of automated manufacturing processes.

1. Introduction

Since industrialization began, machine capabilities have increased to such a degree that human control of processes has evolved from simple (with mechanization) to cognitive (with computerization), and even emotional (with semi/full automation) (Pacaux-Lemoine et al., 2017). Now, the twenty-first century's digital revolution has unleashed a new wave of advanced machines, further automating complex tasks and jeopardizing skilled workers in positions once considered difficult to automate (Chang and Huynh, 2016) Even in jobs where physical presence is required, such as in manufacturing and computer control, increased automation and the use of robots are changing the nature of work (Stacey et al., 2017).

Automation is the growing phenomenon of human labor being replaced by machinery and robotics (Euromonitor International, 2013). Industrial automation is a vast and diverse discipline that encompasses processes, machinery, electronics, software, and information systems working together toward a common set of goals (Mehta and Jaganmohan, 2014). An automation system will include different components, in addition to the robot, to provide a complete solution. The basic requirements for system control, including networks and human machine interfaces (HMIs), are introduced along with basic safety and guarding principles for automation systems (Wilson, 2015).

The reasons to automate the manufacturing processes include increased quality and efficiency demands, as well as the presence of hazardous working conditions and the high cost of specialized manual workers (Botti et al., 2017). Granell et al. (2006) conducted a survey on the most important factors when making decisions about automation. The results were (percentage "high degree and very high degree"): Quality (95.2%); Work environment (88.7%); Rationalization (85.5%); Financial (83.8%); Production capacity (79.1%); Risk analysis (74.2%); Volume (69.3%); Time perspective (66.1%); Available workforce (42%).

Thus, one of the objectives of process automation is to improve the safety of plant operations. Manual operation, it is often argued, provides too many possibilities for operator error (Ogle et al., 2008). However, despite the use of advanced automation, the implementation of more sophisticated management systems and increased training,

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many organizations are still finding that their approaches to reducing incidents are failing (Chidambaram, 2016). In the Sixth European Working Conditions Survey (EWCS) developed by Eurofound (2016), plant and machine operators are most likely to feel that work affects their health negatively, with 40% reporting this.

The application of advanced automation technology in manufacturing systems has tremendously increased manufacturing flexibility. However, this creates significant mental pressure for operators who must deal with a series of decisions that decrease their job satisfaction (Choe et al., 2015). In a buoyant economy, funds are available for investment in safety, but the high pace of innovation and the rapid roll-out of new technologies and new products, and the creation of new jobs requiring new skills mean that a wider population faces new risks over shorter timelines (Ellwood et al., 2014).

Thus, besides traditional risks (TR) in the workplace, industrial processes can entail other risks, described by the European Agency for Safety and Health at Work (EU-OSHA) as "new and emerging risks" (NERs) (Brocal and Sebastián, 2015a). The Agency's first step was to identify specific NERs via the publication of four reports containing expert forecasts, covering physical (Flaspöler et al., 2005), biological (Brun et al., 2007a), psychosocial (Brun et al., 2007b) and chemical risks (Brun et al., 2009). The reports were followed by numerous literature reviews and detailed reports designed to explore the main risks identified in these projections. In the context of the present paper, the expert forecast on emerging physical risks related to occupational safety and health (Flaspöler et al., 2005) identified automation-related NERs. A multifactor emerging risk that a majority strongly agrees with was the complexity of technologies and work processes with complex HMIs. This report thus led to another study published by EU-OSHA, whose objective was to investigate the HMI as an emerging risk (Flaspöler et al., 2010). In addition, the increasing complexity and increasing use of information and communication technologies (ICT) in automated manufacturing has led to HMI issues (Ellwood et al., 2014). ICT, including ICT-enabled technologies (ICT-ETs) such as robotics and artificial intelligence (AI), are likely to have major impacts on the nature and location of work over the next ten years (Stacey et al., 2017).

Thus, the automation of manufacturing processes can produce NERs, linked both to the process as a whole (system), and to specific components, such as robots, HMIs and ICT. This relationship reveals at least two emerging and complex problems in the field of occupational safety and health.

Firstly, there is currently no technique aimed at identifying and characterizing these risks in order to explain the features that confer them with the status of new and/or emerging. Consequently and secondly, it is not possible to study the complex interrelations between the features of the system NERs and its components.

From a general viewpoint of risk, standard ISO 31000:2009 sets out general risk management principles and guidelines. In addition, standard ISO/IEC 31010:2009 supports ISO 31000:2009, providing the guidelines to select and apply systematic techniques to assess risk. As both standards detail, the risk assessment process is the complete process to identify, analysis and evaluate risk.

Thus, starting with the theoretical framework proposed by Brocal et al. (2017) an objective of the present study is to establish a technique that is compatible with standards ISO 31000:2009 and ISO/IEC 31010:2009 and permits the NERs generated by a system and its components be identified and characterized. In turn, this would allow for the establishment of the foundations for the future development of other techniques that could entail the static and dynamic study of the complex interrelations between these NERs.

The organization of the present work is: first, the technique to identify and characterize NERs in manufacturing processes is described. Secondly, this technique is applied to a case study in the context of automated manufacturing processes that generate NERs linked to technological and human complex variables. Finally, the results obtained are discussed, and a series of conclusions are set forth, along with suggested future works.

2. Technique to identify and characterize the NERs

This section describes a qualitative and structured technique that aims to identify and characterize the NERs generated by a manufacturing system. This technique is called TICHNER (Technique to Identify and CHaracterize NERs) and it is based on the theoretical framework proposed by Brocal et al. (2017), with special consideration given to their definitions and risk models (1–4).

Risk identification is the process by which risks are discovered, recognized and recorded (ISO/IEC 31010:2009). A structured technique is likely to be more comprehensive than an unstructured or semi-structured workshop and be more easily used to demonstrate due diligence in identifying risk (ISO/IEC/DIS 31010:2017).

Risk characterization is the process of defining the risk components that provide it with the new and/or emerging characteristics of interest according to the theoretical framework of reference. In this framework, a risk (R) is a structure consisting of five components: the source of risk (SR), causes (C), events (E), consequences (CO) and likelihood (L); where this, as a whole, can be expressed as (1).

Next, TICHER is described. To do so, we use the scheme employed by the ISO/IEC 31010:2009 standard to describe its different techniques: (a) overview (already given in the previous paragraphs); (b) Use; (c) Inputs; (d) Process; (e) Outputs; (f) Strengths and limitations.

2.1. Use

TICHNER can be considered part of the risk assessment process described by standard ISO/IEC 31010:2009. This process consists of the stages of identification, analysis and evaluation of the risk. How this process is applied depends on the context of the risk management process, and also on the methods and techniques used to conduct the risk assessment.

The application context of TICHNER will be configured by a manufacturing process. Said manufacturing process may have a generic or specific nature. In the first case, the general characteristics of the manufacturing process of interest will be considered. In the second case, the specific characteristics of the manufacturing process will be considered. This process will be integrated into a real industrial environment.

TICHNER can be applied at any stage of the lifecycle of a manufacturing process. It may also be used in conjunction with other risk identification techniques.

2.2. Inputs

The input elements may include one or more of the aspects set out below. These aspects are part of the general criteria of the risk identification techniques included in Section B.2 of standard ISO/IEC 31010:2017 (Currently, ISO/IEC 31010 is under review. At present, ISO/IEC/DIS 31010: 2017 is published under development):

- Evidence based methods, such as literature reviews, and analysis of historical data;
- Empirical methods, including testing and modelling to identify what might happen under particular circumstances;
- Perception surveys, which canvas the views of a wide range of experienced people.

2.3. Process

TICHNER consists of the sequential application of the following stages:

- *Stage 1. System analysis:* following the method proposed by Brocal