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An innovative prognostic risk assessment tool for manufacturing sector based on the management of the human, organizational and technical/technological factors

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ABSTRACT

The article deals with an innovative methodology for risk assessment concerning human, organizational and technical/technological (HOT) factors, based on fuzzy set theory. The aim of this paper is to propose user-friendly prognostic risk assessment tool (PgRA) by obtaining reliable results and supporting further decisions of the safety managers. The HOT factors are introduced with associated sub-factors. The user-friendly interface developed in Matlab environment provides multiple opportunities for further improvement. The settings presented in this article are strictly applied for, but not limited to manufacturing sector. Flexibility of the PgRA tool allows adjustments and customize model regarding the group of the companies. With introduction of fuzzy set theory in the risk assessment process, level of subjectivity is reduced to the minimum. Practical applications: Possibilities of the practical application are modeled to assist in decrease of identified risks during daily work. This is a useful visual management tool, helpful to all safety managers in planning workplace improvements. The safety managers are in position to predict risk level before the real measures are taken. They are able to show the possible realistic results and risk trend behaviour to their supervisor/director, without spending any financial resources.

1. Introduction

Recent standards and regulations (e.g. ISO 9001-2015) are shifting the decision-making paradigm towards a risk-based approach, even in domains such as quality where this approach has not traditionally been applied. On the other hand, many misconceptions remain even in the field of occupational safety and health (OSH), where a risk based approach is usually adopted, predominantly, the idea that a risk assessment introduces factors limiting system functioning, burdening financial management, and great commitment and obligation. Taking into account wide range of different factors influencing safety management system (Nordlöf et al., 2017) and possible costs of industrial accidents (Gavious et al., 2009), a deeper and systematic approach is needed. There is a need for implementation of the appropriate safety management system (Bragatto et al., 2015). In contrast, Sawacha (1999) stated that reducing the number of accidents leads an important goal, which is the reduction in the number of unwanted and unplanned events in the workplace. Establishing an effective OSH management system at work allows this objective to be attained, but it requires a suitable risk assessment exercise to support it. Nowadays, there are models developed to measure how effective an implementation of the OSH management system is (Vredenburgh, 2002; Walker and Tait, 2004; Bianchini et al., 2017).

Considering the whole safety management system framework, the new comprehensive standard (ISO 45001) is approaching to its final stage, to be published. The risk based objectives are the crucial part of the standard. Risk based approach is strongly discussed at international level, setting the rules for deeply understanding and determination of the OSH issues at the organization level, and resolving it using PDCA model. This type of approach allows to organisations to plan what could be the best way to tackle risks identified and to provide safer and healthier workplace. However, it does not give clear and precise methodology for every organization, but it has to be adapted for every specific company to meet their own needs. Risk identification gives platform for preventive and/or proactive measures, rather than measures implemented based on prescriptive thinking.

The fundament of the industrial safety is risk based approach predominately. Introducing risk based approach (Bragatto et al., 2012), companies will decrease risks and protect their people, but there is possibility to rise overall costs. The main challenge is balance between

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various parts of the company to stay competitive, to reduce costs and increase effectiveness but not at the expense of safety precisely (Abrahamsen et al., 2013). Risk assessment as inevitable part of any decision making process and it is still insufficiently clear if it gives how should risk has to be treated or not. There are many papers on risk assessment in different fields promotes its importance (AlKazimi and Grantham, 2015; Davies, 2002; Van der Hoorn and Knapp, 2015; Pittiglio et al., 2014). In addition, some researchers agreed that risk based approach has its shortcomings and has to be considered in detail (Aven, 2011), related to the associated uncertainties mainly (Aven, 2013). However, it remains the most useful and the most appropriate method for risk reduction.

In order to support the competitiveness of the manufacturing companies, above all the SMEs, there is a need for appropriate risk assessment tools which can provide good and reliable results and are both easy and quick to use. This paper presents a discussion of what makes a risk assessment tool suitable for manufacturing sector (SMEs predominately) and then proposes a tool based on fuzzy logic and prognostics along with a case study of its implementation in a manufacturing company in Serbia. In addition, developed tool could and should be used to predict potential risk level before implementation of the planned measures. A strong emphasis is given in the tool to the human, organizational and technical/technological (HOT) factors, which are recognized to be precursors, but also barriers in safety and health management, particularly in an automatized environment. The tool is based on quantitative risk assessment, as defined in McDonald (2004), and uses fuzzy set theory to minimize uncertainties in experts' judgments, manage risk level and using prognostic to predict potential risk level after implementation of measures. All abovementioned fact are in a line to European Union (European Commission, 2014) primary objective to ensure as much as possible safe worker at safe workplaces.

The paper is divided into five sections. The initial section consists of a literature review and brief analysis of potential risk assessment issues in manufacturing sector, followed by the model description and presentation of the algorithm model and its detailed stages. The "Case study" section describes the application and verification of the prognostic risk assessment (PgRA) tool.

2. Analysis of manufacturing companies needs

This paper is focused on providing a reliable assessment/prediction tool, incorporating a user-friendly interface, which can facilitate the application of a methodology for managing HOT factors in the workplace, particularly in manufacturing SMEs. Considering the fact that SMEs are the vital and an indispensable part for country economic growth and employment boosting, more attention is needed to reach sustainable development goals (Ali Gopang et al., 2017). The same authors gave literature review on how much SMEs are important and how contribute to the country improvement in general. Taking into account that SMEs operate in a highly variable environment, the management is expected to adapt the organization to the changing operational conditions, and to secure a high level of readiness in hazard prevention. In such sense, overall OSH should play a decisive role to the SMEs' survival on the global market (Ali Gopang et al., 2017). Cagno et al. (2014) noticed that safety conditions and management in SMEs are poorer than in large companies. This results in higher accidents rates and more serious consequences in SMEs in comparison to larger organisations (Cagno et al. 2011). Moreover, Guido and Cagno (2010) stated that methods for risk assessment and management developed specifically for large companies cannot be simply transposed to smaller companies; they need to be adapted to the needs, characteristics and resources of SMEs, and this forces the development of methodologies devoted to SME application. The manager of an SME is often the owner, has a very small number of people in his team to deal with OSH, and becomes overloaded with large number of duties (Guido and Cagno, 2010). In addition, if it is harder to motivate and convince the employees that safety is important part of their working habits it will be harder to motivate employers to prioritize safety (Jørgensen and Duijm, 2011). Although recognition of the importance of safety management (Lenhardt and Beck, 2016) has dramatically increased along with the existence of noticeable social and environmental effects caused by the injuries at work, the adoption of the risk assessment methodologies is still often driven by economical and time constraints, more than by effectiveness considerations (Grass et al., 2009). This results in the use of methodologies that are inappropriate, complex and unsuitable for recognising hazards and reducing the corresponding risks, instead of simple and objective approaches (Fera and Macchiaroli, 2010). A number of approaches to tackle these problems have been developed by scientists and researchers, with the help of practitioners (e.g., Tixier et al., 2002; Demichela and Camuncoli, 2014). In particular, according to Pinto (2014), there is no general and unique set of parameters and rules able to describe occupational safety and to assess the risk, as this strongly depends on the context in which the risk is undertaken. This contextualisation passes through the human and organisational factors, that strongly characterise different work environments. The idea of introducing the HOT factors has arisen from aviation (International Civil Aviation Organization, 2012). Researchers and practitioners have attempted to apply this concept in the OSH field for other industries. Monferini et al. (2013) presented a methodology based on human and organizational factors and their impact on the risk level in complex, hazardous industrial plants. Cacciabue (2000) presented risk analysis of modern plants based only on human factors while Mohaghegh and Mosleh (2009) incorporated organizational factors in a probabilistic risk assessment of complex systems. The same issue was challenged in the models of Wang and Elhag (2007) and Monferini et al. (2013) which both incorporated human and organizational factors. More recent papers confirm the necessity and strong willingness of researchers to cope with this problem (Farcasiu and Prisecaru, 2014; Aras et al. 2014). Numerous researchers in the OSH field deal with the issue of factors that influence the risk level (e.g. Djapan et al., 2015). Pinto (2014) also highlighted how the use of general (not specific) risk assessment methodologies forces the analyst to use estimations based on their own experience and perception, limiting the objectivity and repeatability of the analysis carried on. To deal with the uncertainties, a fuzzy approach is proposed, that has been embraced also in the present paper. The literature is rich in theoretical developments and practical applications of fuzzy logic to risk assessments in different domains. Mure and Demichela (2009) highlighted the importance of using and introducing fuzzy logic in the risk assessment process. The paper presents a literature review of fuzzy logic applications, and its ability to achieve significantly better and more accurate results. Fuzzy risk assessment and its variations is used in different fields: project risk assessment and analysis in construction (Carr and Tah, 2001; Pinto, 2014), food systems (Davidson et al., 2006), civil engineering (Wang and Elhag, 2007), railway (An et al., 2007), aviation (Hadjimichael, 2009), oil and gas offshore wells (Miri Lavasani et al., 2011), SMEs (Djapan et al., 2015), transport of flammable substances in pipelines (Jamshidi et al., 2013), and maritime operations (John et al., 2014). In addition to providing an explanation of modelling, some researchers made a step forward by presenting achievable software and interface solutions. Some examples can be found in Groen et al. (2006), Majdara and Nematollahi (2008), Groth et al. (2010), Qu et al. (2011), Stefanovic et al. (2012), and Aras et al. (2014).

In order to fully understand the safety condition in a specific situation, Ren et al., (2008) stated that it is necessary to consider all the aspects that influence safety. The initial step must be to define the HOT factors and sub-factors using a systemic approach. Once the factors to be taken into account for the risk characterisation have been defined, the risk level will depend on the relative importance of the factors, sub-factors, and their current values; these are described with predefined linguistic expressions. The theory of fuzzy sets supports the human way of thinking because it uses approximate information and uncertainty to