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Appraisal of a new risk assessment model for SME

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ABSTRACT

The identification, assessment and reduction of the risks is among of the most important issues of the safety at work. This paper's goal is to demonstrate the effectiveness of a new risk assessment method proposed by the authors and presented in the past (Fera and Macchiaroli, 2009). In general, one can deal with risk assessment using different methods: quantitative, qualitative or a mix; however, the typical models proposed in the literature are difficult to implement in SMEs. The method proposed in this paper is a mixed one whose effectiveness is demonstrated through an application study carried out in different industrial systems, like a steel industry or a logistic services provider.

1. Introduction

The injuries statistics (Table 1) released by the International Labour Organization (ILO) for 2007 are very significant.

They show how health and safety problems are very far from being solved. It is well known that an effective approach to health and safety at work needs a suitable risk assessment phase, the adoption of prevention and protection actions and the implementation of a severe "safety audit" phase. However, less attention has been paid to these phases in the practice, using non-appropriate tools and methodologies which are either too complex to manage or too simple and subjective, thus not suitable to recognize hazards and reduce the corresponding risks.

The aim of this paper is to assess the effectiveness of a new and reliable assessment model presented in Fera and Macchiaroli (2009), able to face the aforesaid applicability difficulties of the models developed so far and to show, through its application to several industrial plants, how an improvement in safety condition can actually be achieved. The proposed model is based on known techniques, such as Failure Modes and Effects Criticality Analysis (FMECA), Scenario Based Risk Assessment (SceBRA) and Italian standard UNI 7249:2007. These techniques are integrated within a procedure composed by seven steps, some quantitative and some qualitative. This model also includes the Analytic Hierarchy Process (AHP) decision making technique, which – as well known – is useful to minimize inconsistencies in experts' judgments, within the subjective phases of risk assessment.

The paper is organized as follows. After discussing the main features of relevant models presented in the literature and the open issues in risk assessment, Section 3 contains a brief overview of the AHP technique in order to underline its importance in the proposed model. Afterwards, the proposed model is described in detail, including a discussion about its main features and advantages. Before concluding, we also report the results from an experimental campaign carried in three manufacturing and services firms.

2. Literature review and open issues

The identification and choice of a suitable risk assessment model has been felt as a crucial issue for decades. So far, models used in the practice were developed for different applications and adapted for health and safety at work. A possible classification is presented in Table 2.

Please note that qualifying methods as "quantitative" or "qualitative" does not mean they are objective or subjective. So, in this paper we refer to quantitative or qualitative to indicate whether a method makes use of numerical data or not, while we refer to a subjective method when it mainly relies on experts' judgment. Since the judgment, in turn, can be qualitative or quantitative, in the last case we also refer to the corresponding method as quali-quantitative.

Thus, subjective methods are focused on the experts' contribution. Experts are responsible to predict the possible interactions between workers, machines and work environment. Subjective models cannot be implemented in all kind of firms, because of their intrinsic uncertainty which makes them not suitable for several applications; think, in example, to risk assessment in the chemical

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Table 1
Worldwide 2007 injuries and deaths.

Type of injury	Number of injuries
Workplace injury	250.000.000 inj/year 8 inj/s
Children workplace injuries	12.000.000 inj/year
Deaths	1.300.000 death/year

Table 2
Methods for the health and safety risk assessment.

Qualitative
"What if?" analysis
Safety review
Check lists
Quantitative
Fault tree analysis
Events tree
Bow-Tie model
Quali-Quantitative
Hazards and Operability Study (HAZOP)
Failure Methods and Critical Analysis (FMECA)
Formal Safety Assessment (FSA)

or oil & gas industry, where generally sophisticated reliability models can and must be applied, and normally lead to a wide extent of success. Instead, subjective models can be used with good results in the non industrial environments. In the international literature there are some contributions about risk assessment for fishing vessels (Piniella et al., 2009), using a check-lists method, or for large transport networks and urban systems (Chen et al., 2009). Other authors (Van Duijne et al., 2008) developed a subjective assessment model based on the European guidelines RAPEX, used for food quality and safety assurance. Another subjective method example is the DELPHI analysis, which is a structured method that gives a hierarchy of the decisions to be evaluated and achieves a final decision through verbal experts judgements. These models are often used in SMEs due to their simplicity, although in some cases their application can be misleading, as underlined by many authors (Hetherington et al., 2006; Wirth et al., 2008; Lingard et al., 1997).

Quantitative models, both objective and subjective, are widely used in many fields, like in large industrial firms or in the oil and gas industries. These models make an extensive use of reliability analysis and, thus, are based on process decomposition techniques and failures likelihoods knowledge. Indeed, several works are based on the Bayesian approach for fault tree analysis or for event trees analysis (Martìn et al., 2009; Doytchev et al., 2008). The statistical approach is also used for other types of risk assessment models, as for the Bow-Tie ones (Ale et al., 2008). The Bow-Tie models are based on the identification of a link between causes and effects of events, and identify a direct quantitative relation between risk sources and risk consequences. A likelihood is associated to all possible paths from a cause to an effect, that is, an expression of the relative importance of a specific risk as connected to a risk source. Objective methods are used to assess risks in the chemical industry (Glickman et al., 2007; Brito et al., 2009) or in the coal mines (Sari et al., 2009); in these sectors safety is often related to specific possible accidents, whose severity justifies the adoption of quantitative evaluation techniques.

Existing literature reports some works using mixed quali-quantitative methods. Some authors apply typical techniques of knowledge analysis, as fuzzy theory (Grassi et al., 2009), trying to formalize and quantify subjective aspects, treated as fuzzy variables. Other contributions on this issue are given by the application of techniques such as the well known HAZOP method and the FSA, that was developed and suggested to be applied in the maritime field by International Maritime Organization (IMO) (IMO, 2002). The FSA is a structured and systematic approach to assess complex situations. Examples of its application are reported in the literature (Hu et al., 2007; Wang, 2002; Ventikos and Psaraftis, 2004). The FSA method is a structured and costly method, therefore – as underlined by several authors – it was mainly used in the maritime sector, but its application to other, less capital intensive sectors, is not easily justifiable. Among the works appeared in the literature, it is worth to mention the contribution by Hu et al. on 2007, who propose an integration between the FSA and fuzzy methods.

Starting from our first need, i.e., to create a model suitable and effective for SMEs, that goes beyond the objective and quantitative models complexity and the non-effectiveness of subjective models, we explored the possibility to create a model for this kind of firms based on an approach which represents a compromise between the different models. The absence in the existing literature of a such a model and the need for an improvement in existing safety assessment tools for SMEs, convinced us that there is space for working on mixed quali-quantitative methods. The lack of such approaches can be due, in our opinion, to the little attention paid so far to safety in the small and medium enterprises (SMEs) by researchers and practitioners. This fact, in turn, might be due to the higher interest paid by them to larger industrial firms, which – in a first analysis – could be identified as a major risk source, while all statistics show, instead, that most part of injuries and deaths are more likely to occur in SMEs. For all the reasons mentioned so far, the purpose of this work is to propose a mixed risk assessment method, able to overcome the practical difficulties generally found by SMEs in the application of objective and quantitative techniques (also due to the higher skills required to this aim) and to fill the gap between the results obtained by the application of subjective approaches, generally employed, and the need for a reliable risk assessment.

One of the foreseen advantages of the proposed method is that, without using costly objective or mixed methods, it allows to achieve a good match between the results of the risk assessment and actual risk relevance. In other words, this means that the proposed method achieves better results using similar resources.

3. The Analytic Hierarchy Process (AHP) framework

The AHP (Saaty, 2000) is a technique used in decision making. Based on the contribution of different experts, it aims at the creation of a unique priority index for each possible decision, that summarises all expert's judgments, minimizing their inconsistency. In general, the procedure, given an objective and given a set of possible choices and/or decisions to achieve that goal, calls the experts to express a relative judgment of relevance of each choice, when compared to all the others.

The main difference between AHP and the DELPHI method, mentioned before, is that the AHP technique is not simply based on verbal judgements but also makes use of quantitative evaluations.

So, given a set of possible decisions, $D = [D_1, D_2, \ldots, D_n]$, the expert has to indicate a relevance judgment of each decision compared with all the others, examined one by one. Each expert gives a relevance judgment, that could be named j_{kil}, where k and i are the counter of all the decisions belonging to the set D and l is the counter of the lth expert. All judgments for each couple of decisions (D_k, D_j), will be synthesized using a geometrical mean through (1).

$$j_{ki} = \sqrt[n]{j_{ki1} \cdot j_{ki2} \cdot \ldots \cdot j_{kin}} \tag{1}$$