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Occupational risk of building construction

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ABSTRACT

This paper presents the quantification of occupational risk of a building construction project. Risk assessment is based on the Occupational Risk Model (ORCA) developed under the Workgroup Occupational Risk Model project (WORM), in the Netherlands, for quantifying occupational risk. This model assesses occupational risk of a worker, by taking into account his various tasks, activities and their hazards. Risk is evaluated for three types of consequences: recoverable injury, permanent injury and death. The occupational risk model is based on a set of 63 bowties, which assess risk owing to different hazards such as fall from ladder, scaffold, roofs, falling object, struck by moving vehicle, contact by moving parts, etc. ORCA calculates the risk profile of a building construction site, consisting of thirty-eight workers in different job positions, such as operators of excavators, loaders, compaction equipment, workers in excavation and framing phases, etc. All risk profiles of workers have been quantified and jobs have been ranked according to their risk. Workers installing timber formworks have the highest fatality risk (1.57×10^{-3}/yr), followed by the workers installing reinforcement (1.52×10^{-3}/yr).

1. Introduction

Occupational health and safety is a major concern to many countries since occupational accidents represent a major source of risk. In 2007, accidents at work killed 3782 workers in Europe (EU-15) and 5527 in EU-27, while 3882435 workers were injured in EU-15, with absence of work more than three days [1]. The building and construction industry has a high contribution to overall occupational accidents, since in 2007, 703389 accidents occurred in EU-15 among which 1083 were fatal, out of 29% of total fatal accidents [1]. The construction section is very hazardous worldwide [2–4], owing to its unique dynamic nature [5], poor conditions and tough environment. The International Labour Organisation recorded 60,000 fatalities in the construction section, out of a world total of 355,000, (nearly 17%), while one in six fatal accidents at work occurred in construction, in 2003 [6].

Traditional occupational safety methods are legislation, regulation, standards, safety guidelines, collection of best practices, accident statistics, investigations and inspections, analysis of safety management systems and personal behaviour. Various accident studies have examined the causes of occupational injuries and fatalities such as those performed by the National Institute of Occupational Safety [6] and OSHA [7,8] This research investigated accident reports, analysed the epidemiology of accidents, recommended elements for an effective accident preventive programme and identified common risk factors such as technical, organisational and managerial. Researchers have analysed several types of accidents in the construction section such as falls from height [9–12], electrical accidents [13,14] and crane related accidents [15,16] and in various countries, such as in the US [17,18], the UK [19], the Netherlands [20], Spain [21], Taiwan [22], China [23] and Kuwait [24]. The main focus was on types of accidents, injuries, age of victim and the major causes of accidents in terms of technical barrier failures. Statistical methods have been extensively used to analyse injuries and fatalities in the construction sector using descriptive statistics [9], factorial analysis [25], variance analysis [26] and multiple regression [27].

In occupational safety research, root causes influencing safety performance have been analysed, by interviewing site managers and safety officers [28], safety professionals [29], project managers [30], workers [31], accident victims [32] in the construction industry or by analysing accidents [33]. A number of factors have identified a number such as historical, economical, psychological, procedural, organisational, environmental and technical factors [28]. Statistical methods have been used in most analyses, but recently data mining techniques, including Bayesian networks, decision rules, classification trees and support vector machines, have modelled accident data and identified factors underlying accidents [34,35]. In more detail the most important risk factors influencing safety performance in the construction industry are the following [2]: poor work and organisation, company size, lack

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of coordination, economic and time pressure, poor communications, poor involvement of workers in safety matter, constantly changing worksite, inadequate training, bad equipment selection, use or inspection and poor safety awareness.

Best practices in the construction section have been selected from various sources, such as safety design manuals, checklists, interviews and various publications addressing the design phase of construction projects [36]. Designing for construction safety is a factor, which may reduce hazards at work and improve safety and health of construction workers, since it has been demonstrated that 42% of fatal accidents may be linked to the design of construction safety [37,38]. Finally, policy may also contribute to occupational safety and accident prevention. It has been claimed that the European Directive 92/57/EEC, of implementing safety and health requirements at temporary or mobile construction sites, has decreased the number of accidents by 10% in many European countries, within the period 1996–2004 [39].

Recently a new tendency has emerged trying to quantify occupational risk and by doing so to strengthen the basis for occupational risk management. In addition to the identification of causes of accidents in the workplace, this new approach is striving to quantify the extent to which various working-environment-shaping factors are present in the workplaces and combine them with workers' exposure to hazards to arrive at quantified assessments of risk. Two semi-quantitative risk assessment methods for occupational risk assessment consists of [40,41] (a) risk matrices with two dimensions, the frequency of occurrence and the severity of consequences with semi quantified scales; (b) the proportional risk-assessment technique or the so called "RSPE" method based on the function R=SPE, where R is the risk, S is the severity of accident occurrence, P the frequency of the accident and its consequences and E the frequency of employee exposure to hazard. The scales of RSPE method are arbitrarily chosen and formed on a qualitative basis.

A number of attempts to a more systematic and consistent approach to quantitative occupational risk assessment have appeared in the literature. A model has been developed to predict the frequency of occupational accidents in offshore oil and gas industry, based on direct, corporate and external factors [42]. Quantified risk for various occupational groups in Sweden based on the number of accidents and relevant exposure has been calculated [43]. A Construction Safety Analysis method has been proposed for assessing risk for construction activities, based on information provided via interviews among construction superintendents and safety experts, for hazard identification, probability and severity assessment of loss of control events [44]. A method has been proposed for risk assessment of several trades in the construction industry, based on estimating the overall frequency and severity from historical data of accidents in Hong Kong and their consequences regarding injuries, days lost and compensation cost [45]. Fuzzy methods have been used for risk assessment of occupational accidents in a steel company [46], at construction sites [47] and workplaces [48]. Artificial neural networks and a fuzzy inference system have been proposed to assess occupational injury risk indexes and predict number of injuries [49]. Finally an exposure–damage approach for occupational risk quantification in workplaces involving dangerous substances is proposed in [40].

The Ministry of Social Affairs and Employment in the Netherlands developed Workgroup Occupational Risk Model (WORM) project, a large scale project during 2003–2008 to improve the level of safety at workplace, by introducing quantitative occupational risk. This project had four major parts: assembly and analysis of accident and exposure data, generalisation of these data into a logical risk model, deriving improvement measures and their costs and developing an optimizer that supports cost effective risk reduction strategies, as described in [50–52]. The results of WORM are presented in [53] and its main achievements are (a) construction of logic models (bowties), which allow for the quantitative assessment of risk of 63 activities of workers, such as fall from ladders, scaffolds, roofs [54,55], hit by falling objects [56], etc., built on the detailed analysis of 12500 accident reports in the Netherlands extracted from the Occupational Accident Database GISAI (Gemeenschappelijk Informatie Systeem Arbeidsinspectie), and data concerning the exposure of the Dutch population to various hazards, as reported in [57] and (b) the development of the probabilistic occupational risk model (ORCA), which performs risk calculation of workers performing various tasks and exposed to several hazards.

The objective of this paper is to demonstrate the features and capabilities of the WORM occupational risk model through the application on a specific site, located in Greece. Occupational risk is performed for the construction of a one storage building with total surface 1100 m^2 and serves for recreational activities of patients of a hospital. This paper is organised as follows. After the introduction of Section 1, Section 2 presents the methodology of occupational risk, Section 3 a short description of the building construction project and Section 4 presents data collection for the occupational risk analysis. Section 5 presents the job positions of all workers, Section 6 the occupational risk quantification results and finally Section 7 presents the conclusions of this analysis.

2. Occupational risk

In the framework of the WORM project a model for the quantification of occupational risk has been developed. According to this model occupational risk in a company is calculated by assessing the hazards the workers in this company are exposed to, the duration of the exposure and the integration of the risk to all hazards and all workers.

A tree-like structure is used to develop the composite model of ORM as depicted in Fig. 1.

The top level of the tree corresponds to the entity under analysis.

The second level provides the type of "Company-position" corresponding to a specific type of job along with the number of people in each position type. There are $i=1,2,\ldots,n$ company positions each occupied by $E_1,\ldots,E_n$ employees, respectively.

The third level of the tree describes for each position-type the activities required to perform the corresponding job along with

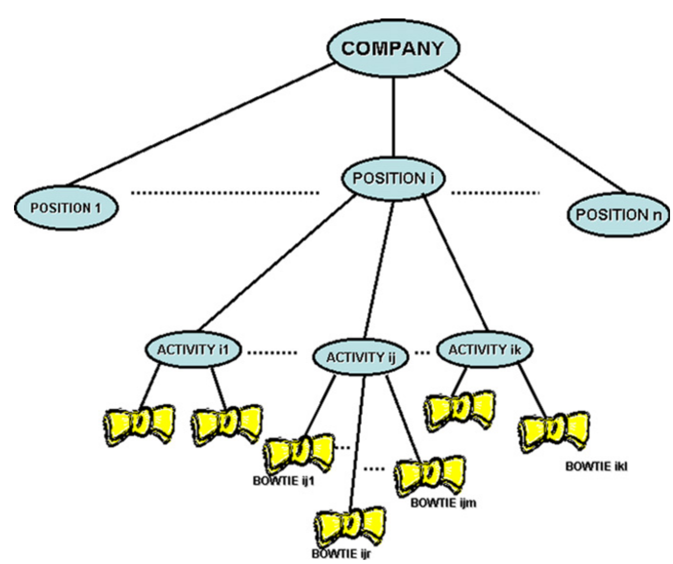

Fig. 1. Composite occupational risk model structure.