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Assessing reliability of design, construction, and safety related decisions

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ABSTRACT

Currently there is no approach which would help to comprehensively ensure occupational safety. Many scientists perform researches and calculations, create new methods related to safety and health, but most of them analyze separate aspects of safety in the field of construction. The authors of this paper present a new complex view on ensuring occupational safety and health during construction. The selection of safety solutions is performed based on complex evaluation of structure, technology and safety. In their previous works, the authors offered a new method for multiple attribute decision synthesis, SyMAD-3, which helps to choose an effective construction project alternative from multiple alternatives by assessing various construction, technological and occupational safety solutions, based on a set of quantitative attributes. However, the integration of these solutions may cause doubts, since decision making in construction is always associated with uncertainty. The investment projects in construction are characterized by the large accuracy variation (from 15 to 50%) of some attribute values. Although the SyMAD-3 method is mathematically grounded, it does not answer the question if the error of attribute values impacts the final decision and if this decision can be reliably assessed.

In the present paper, the authors supplement the SyMAD-3 method with decision sensitivity analysis (SyMAD-3 with SA) to improve the reliability of the SyMAD-3 method and assess the reliability of the obtained decision. The SyMAD-3 with SA method allows us to choose an effective alternative of a construction project by assessing three stages of construction, based on a set of attributes given the error of their values, and determine the reliability of the final decision. The proposed method is implemented in a software package created by the authors with the aim of analyzing decisions and performing experimental calculations in the field of construction.

1. Introduction

Since occupational safety and health (OSH) is a major part of social relations, it experiences the same changes as those taking place in the national as well as international social and economic context. Any new hazards, impacts and risks can be attributed to the dynamics of demographics, changes in employment and work organization, gender differentiation, the size of enterprises, their structure and life cycle as well as rapid technological advances. Occupational safety is also affected by psychological climate which was investigated by Meardi et al. [1] and Lopez-Araujo and Segovia [2].

Not much attention is paid to secondary risk factors and the interaction between various hazards. The inability to predict the operation of a system, even if major factors have been identified, demonstrates the lack of knowledge about the impact of every factor on the system [3]. Villanueva and Garcia [4] performed a research with the aim to determine the factors affecting risk which is associated with workplace accidents having tragic consequences. The authors determined that for men and temporary workers the risk of fatality due to workplace accidents increases with age. There is also a heightened injury risk when working in unusual environments or performing non-standard tasks at agricultural or construction enterprises [4]. Lopez et al. [5] analyzed accidents occurring due to the use of ladders. Different accident related factors were identified for the purpose of developing a pattern of those factors that had the greatest influence on the seriousness and the fatality rate of such accidents [5]. The authors concluded that occupational accidents involving ladders usually happen to older workers and those working in unusual environments. Hasle et al. [6] carried out a research investigating the views of management on occupational safety and health. The authors determined that not every manager pays attention to occupational hazard prevention. Some of them shun responsibility in case of any workplace accidents [6].

There is a need for solutions which would allow us to account for safety and health principles in all stages of work organization and convert them into practically feasible measures. Shiplee et al. [7] emphasize that the more attention is paid to ensuring occupational safety and health the more injuries are prevented. Sukys et al. [8] analyzed the health and safety of construction workers as well as the economic consequences of work-related accidents and the financial value of investments made into OSH. Badri et al. [9] base their work on the analysis of the literature related to the topic. The authors focus on occupational safety laws, management systems, OSH risk management throughout

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project life cycle and efforts to integrate OSH risk management into industrial safety practices, including approaches that use historical data and industrial conventions [9]. Aneziris et al. [10] state that occupational safety and health is ensured by performing workplace risk assessment. This paper presents the quantification of occupational risk of a building construction project [10].

Researchers propose various risk management models to address the problems of workplace safety. Zeng et al. [11] think that the main purpose of risk management is to keep the risks at an acceptable level by maintaining the tolerable risks and following the programs in moving unacceptable risks to an acceptable level. An interesting safety management model is given by Hallowell and Gambatese [12]. Three main aims were identified in their paper: 1) introduce a risk-based construction safety and health analytical model; 2) validate relevant data used to populate the model; and 3) illustrate the applications of the model in practice [12]. Bena et al. [13] offered a new occupational healthcare system based on work records and statistics on occupational injuries. S. Zhang et al. [14] propose a developed automated safety checking platform, which automatically analyzes a building model to detect safety hazards and informs construction engineers and managers what safety measures are needed for preventing fall-related accidents before construction starts. J.P. Zhang et al. [15] propose a new approach for conflict and safety analysis during construction through the integration of construction simulation, four-dimensional construction management, and safety analysis. Chan-Sik and Hyeon-Jin [16] proposed a framework for a construction safety management and visualization system (SMVS) that integrates building information modeling (BIM), location tracking, augmented reality (AR) and game technologies. The SMVS has a potential to improve the identification of field safety risks, increase the risk recognition capacity of workers, and enhance the real-time communication between construction manager and workers [16]. Aguilar and Hewage [17] proposed a system that transmits safety related information of multiple construction projects into a centralized database, where real-time safety indicators are generated. This system is intended to manage and monitor safety during construction [17]. Aminbakhsh et al. [18] proposed a safety risk assessment framework, which is based on the theory of cost of safety (COS) model and the analytic hierarchy process (AHP). This framework provides a decision tool for decision makers to determine the adequate accident prevention investments while considering the funding limits [18]. Perez-Alonso et al. [19] discuss a preventive management model in their work. The results indicate that by not adopting any preventive management model for internationally recognized work hazards the prevention is very poor. The authors concluded that companies and their workers have insufficient information and training in preventive matters [19].

To ensure sustainable management in construction enterprises, scientists constantly conduct research to discover effective solutions and methods, which could help to create a sustainable workplace for the whole period of the project. When dealing with these problems, the accumulated collective knowledge and successful practical experience related to the topic should be considered.

A global OSH strategy is based on creating and sustaining a national preventive safety and health culture as well as a systematic approach to OSH management. The national preventive safety and health culture is a culture, each level of which is characterized by respect towards the right to safe and healthy working environment and gives the highest priority to the principle of prevention. All available measures should be taken for creating and sustaining the national preventive safety and health culture in order to raise general awareness, knowledge and understanding of the concepts of hazard and risk as well as the ways to avoid or control them. Therefore, based on the above statement and the related methodology, sustainable safety and health encourages the use of a systematic approach to the management of national OSH systems.

By using the newly created methods or creating more reliable decision support systems (DSS) scientists search for effective solutions to the problem of occupational safety. Although much research, concerning DSS, has been carried out and many methods and algorithms have been suggested, some questions about various aspects of safety in the field of construction remain unanswered. Among the analyzed literature, there were no scientific papers devoted to multicriteria evaluation of construction projects from the perspective of structural, technological decisions, taking into account the safety requirements.

Occupational safety during various construction processes may be ensured not only by using personal and collective safety measures, assessing occupational risks and educating personnel on the issues of safety and health, but by the proper organization of work and the creation of the appropriate working conditions as well [20]. The organization of work directly depends on the decisions made with regard to construction, technology and safety. Therefore, one of the possible strategies that can be employed in construction sector is the integration of construction, technological and safety solutions. Then, only a single object with its main components related to three key areas, e.g. structural elements of a building, the technology of construction processes and construction process safety, has to be considered. Each of the solutions is also uniquely affected by the integration of solutions and their interaction with each other. The operation of the system allows us to assess the effects of interactions of each attribute with other attributes, which helps to choose the effective structural, technological and safety solutions. This choice will determine if human lives are saved and a number of health problems avoided.

While searching for a global solution in DSS management to the problem of creating a sustainable workplace in the field of construction, scientific papers related to the synthesis of decisions were analyzed. There are not many papers investigating the synthesis of multicriteria decisions in construction. One of them is written by Šarka et al. [21] where the authors propose a method of multicriteria decision synthesis. The method aims at synthesizing several interrelated technical decisions by selecting two (default value) or more best alternatives at each stage [21]. However, by selecting only two alternatives at each decision stage, we lose the possibility of seeing all the available combinations. Multicriteria decision synthesis was also researched by Srdjevic [22]. The authors proposed an AHP (Analytic Hierarchy Process) synthesis of the best local priority vectors taken from the most consistent decision makers [22]. Based on the above-mentioned works it can be observed that, when searching for a complex solution, multicriteria decision synthesis should be used.

In the case where a set of possible alternatives to solving the problem is known in advance and the information about the attributes is provided in quantitative measurements, it is recommended that multiple attribute decision-making (MADM) methods are used. These provide quantitative evaluation of each alternative on the basis of which ranking of the alternatives is carried out to solve the problem. In 2012, while searching for a global solution to the problem of creating a sustainable workplace in the field of construction, the authors in two of their papers presented a new idea, based on the synthesis of structural, technological and occupational safety solutions. The model of this synthesis was illustrated in the form of a decision tree, while the synthesis of solutions was performed, using the SyMAD-3 (Synthesis of Multiple Attribute Decisions by three methods) method. The SyMAD-3 method is intended for combining multiple stage and multiple attribute decisions into a single common decision [23,24]. In the algorithm of this method, the methods of multiple attribute decision-making (SAW—Simple Additive Weighting [25], TOPSIS—Technique for Order Preference by Similarity to Ideal Solution [26], and COPRAS—COmplex PRoportional Assessment [27]) were used. The final result was a new multistage multiple attribute decision synthesis method called SyMAD-3, which can help select an effective alternative of a construction project by taking into account the available structural, technological and safety solutions. However, the synthesis of these decisions may lead to doubts since decision making in construction is always associated with randomness, uncertainty and human errors all of which influence the success and economic effectiveness of a construction project. A similar conclusion was reached by Lopez and Love [28], who