

## INNOVATIVE APPROACHES TO SAFETY RISK MANAGEMENT IN CONSTRUCTION PROJECTS

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**Abstract:** *Almost in the world over the construction industry accounts for a disproportionate number of occupational related injuries. Many different approaches to safety should be implemented to achieve the goal of fewer injuries. Safety risk management is a foundation upon which occupational safety management is built. As digital technologies become widely used in designing buildings, question about their impacts on safety risk management in construction project arise. The paper deals with development of skills for safety risk management through unconventional teaching techniques. The techniques apply multimedia educational tools based on digital technologies that are by architects and contractors in common use for tasks related to buildings designing and visualization.*

**Keywords:** *educational program, safety training, safety risk management, safety education, construction sector*

**JEL Classification:** *I25, M12*

### 1. INTRODUCTION

The construction sector is one of the largest industrial employers in European Union. Unfortunately, it also has almost the most problematic occupational safety and health records [4]. The poor health and safety records in construction are influenced by many factors. As well, it is definitely concerned the low level and absence or malfunction of safety management and control systems in small construction companies and tradesman and low knowledge and a lack of construction safety risk awareness of persons involved in construction projects. Going around building sites, we can see insufficient using of personal or other (collective, technique, etc.) protection equipments, what can be known as high gambling with workers health and lives. All the same, it is routine that people at the site are not able to recognize the occupational safety risks covered in the building project. Even though, workers and managers from these sites have passed some “occupational safety trainings”, usually based on many rules memorizing.

### 2. METHODOLOGY

In the paper is mainly presented and discussed the multimedia educational program centred on development of construction safety awareness through unconventional teaching techniques. It is addressed to designers and is focused on implementation of the concept of Prevention through Design. In order to the mentioned concept implementation is inevitable to create the supporting tools to effective skills development for detection of construction safety risks through virtual building modelling and for relevant building design revise or protective equipments planning. Moreover, the brief estimation of safety education effectiveness in Civil Engineering students is presented. The estimation acknowledged that the perception of construction safety risks is higher in students educated by innovative non-formal teaching techniques.

### 3. OCCUPATIONAL SAFETY RISK MANAGEMENT IN CONSTRUCTION AND PREVENTION THROUGH DESIGN

Almost all injuries in construction sites are predictable and preventable. Many different approaches to safety should be implemented to achieve the goal of fewer injuries. The conventional approaches to occupational safety improvements in construction projects involve in particular: occupational health and safety regulations, occupational health and safety risks management and occupational health and safety management systems. The occupational safety risk management is a foundation upon which safety management is built and risk assessment is a critical task which forms a part of safety management systems. In any industry, the risk of a task derives from the hazards associated with performing the task, namely the materials, equipments, work procedures and organization and other workplace conditions that workers have to face, when perform their job [5]. The process of occupational safety risk management generally includes three main stages:

- identification – choosing specific activity and breaking it down into sequence of stages and identification of all possible hazards that may cause some accidents at the workstation during activity performance,
- assessment – evaluation of relative risk levels for all identified hazards,
- action – controlling the risk by taking sufficient measures to reduce or eliminate it.

However, unlike other industries, it is not easy to undertake risk assessment on construction site, due to its complexity and diversity in job tasks. The work nature of site is quickly changing and workforce is highly dynamic; the production environment changes in time and place, and work crews change frequently. Moreover, workers commonly endanger other workers, who may be performing a different activity at a different location. The standard occupational safety risk analysis method is not designed to

reveal these dangers. It focuses on production activities at predetermined workstations. In construction are needed different, innovative approaches to identify hazards and risks and prevent accidents.

Application of the Prevention through Design (PtD) concept in the construction industry is challenging. The PtD in construction implies: a) explicitly considering construction safety in the design of a project, b) making design decisions based in part on a project's inherent safety risk to construction workers, and c) addressing worker safety in the constructability review process. The good one situation for the safety of the construction workers is to make this an important parameter for the planners and designers of the conceptual and preliminary design phase [1].

The European Union have appreciated the beneficial impacts of PtD and is leading the way through the Council Directive 92/57/EEC on the implementation of minimum safety and health requirements at temporary or mobile construction sites. In the directive, the role of the building planner, be it the client as well as the architects and designers, is emphasized as having the responsibility for taking account of the general principles of prevention concerning safety and health during the stage of designing and preparing the project. Unfortunately, the idea of workers safety consideration in designing phase of construction projects often remains only at the level of legislation and its implementation in construction practice is rare. Most designers declare their responsibility only for the final product and no for means and methods affecting the workers safety. Few of them have recognized the process of incorporation the workers safety issues into construction project design phase, but they misunderstand how to provide it in practice. The cardinal barriers of PtD implementation in construction practice involve in particular: no/minimal site safety in designers education and training, lack of knowledge of how to design for safety, unclear authority and responsibility for PtD, fear of liability, difficult for designers to assess safety risks if lack of field experience and contractual separation of design and construction [2].

Development of design engineer experience and training from occupational safety point of view and creation and application of design/construction visualization tools are thought to be the most distinguished enablers to PtD implementation. Training and education programs play a significant role in enhancement of safety in construction and are important to increase safety awareness [3] and change behaviour of persons involved in construction projects. Sound safety training is a credit for strong safety performance and it is an essential element in developing excellence. A well-designed and administered training programme should emphasize safe work practices and be derived from a true assessment of need [8]. The effective safety training belongs to ten major factors that can give positive impetus towards improving safety compliance in the construction industry [7].

#### **4. EDUCATIONAL PROGRAM TO DEVELOP DESIGN ENGINEERS EXPERIENCE AND TRAINING FOR SAFETY RISK MANAGEMENT IN CONSTRUCTION PROJECTS**

Teaching techniques in safety education in the construction sector are traditionally based on memorizing

the standards and regulations concerning occupational safety in construction. There are still preferred lectures that are considered as a way to introduce new information to a group of learners. But the goals of safety education and improvement of awareness should be better achieved through some forms of practices and by creation and analysis of model situations. Lectures are often one-way, monotonous, directive and so encourage passivity. Furthermore it does not promote interaction in most cases; the view of the speaker dominates. Hence, teaching styles and techniques in safety education should be changed and noticeably moved from lecture-based activities towards more learner-centred activities. People can learn more effectively when are actively involved in the learning process.

In Slovakia, there is the absence of safety education and training of future architects or designers. The creation of suitable supporting tools focused on effective development of skills for early detection of construction safety risks in the design stage and consistent revision of the design solutions or protection equipment planning is inevitable. This need is in the Faculty of Civil Engineering in Košice satisfied by development of the multimedia educational program centered on implementation of PtD concept through increasing the designers' construction safety awareness. The materials of the educational program are convenient for construction safety skills and competences development through lifelong education of practicing designers. The objective of the program comes from the need of establishing the multidisciplinary approaches in construction project design education. It assuredly contributes to increasing the designers and future designers' competences for construction safety risks elimination in the early stage of construction project. The main objective of the program consists in integration of construction safety risks issues into education centred on buildings design.

As digital technologies become widely used in designing buildings, questions about their impacts on construction safety arise. The innovative approaches to construction safety management, as well as consideration of construction workers safety in the design phase, are deeply connected with application of digital design and in particular with the building modeling in virtual environment [9]. The potential of digital technologies widely used in designing buildings for creation of design/construction visualization tools focused on design for construction safety implementation is clear. The digital technologies involve mainly: the online databases, Geographic Information Systems (GIS), 4D Computer Aided Design (4D CAD), Building Information Modelling (BIM) and Virtual Reality (VR). In particular, BIM has the potential during early design phases and during construction to reveal situations that involve risk management attention and provides the possibility for designers to conceive hazard recognition during design and provide this information to constructors [6]. The BIM models created in the design process can be developed to serve site and safety planning by adding the planned temporary site and safety arrangements to the model created in the architectural design or structural engineering stages. The mentioned digital technologies suit to creation of tools for automated detection and elimination

of construction safety risks in designing stage. Such tools can present the base for designers training through unconventional teaching techniques in order to increase their awareness for implementation of PtD concept.

In order to realize the mission of designers safety awareness increase, the mentioned multimedia educational program involves several partial objectives, among those belong especially:

- drawing attention to imperativeness associated with establishment of approaches into construction safety risks reduction through building design,
- facilitating construction safety risks analysis and building designs assessment from health and safety point of view through building information modelling (BIM),
- creating the conception for implementation of occupational safety planning approaches in designing stage into integrated building designing within inventive seminars focusing on occupational injuries prevention,
- enforcing the utilization of digital technologies potential for purpose of creating the tools for automated detection and elimination of construction safety risks in designing stage,
- pressing for incorporation of innovative construction safety planning approaches into lifelong education of architects and building designers and ensuring the integration of construction safety risks minimization issues into education focused on building designing in design studio seminars,
- allowing learners the creation and communication in an interactive virtual educational environment and so developing their logical and critical thinking,
- motivating learners (by unconventional innovative education technique) to increased concern over creation of self logical verdicts and solutions in field of building designing from construction safety point of view,
- allowing training of variant solutions for complex construction conditions encompassment from construction safety point of view
- realizing the support for the knowledge base development by sharing the pieces of knowledge from foreign internet portals containing the newest information about approaches to safety improvement through building design.

The before mentioned objectives of the educational program are going to be reached by multimedia file of educational sources involved in the program. These sources support the performance of the developed program idea. The multimedia-based files of educational sources include:

- the interactive training tool “Virtual Prevention through Design Tool (VPtDT)”, supporting the effective skills development in field of automated construction safety risks detection and elimination during building designing in dynamic, virtual designing environment (the tool is developed on BIM platform and is aimed at selected fields from the key construction safety risks point of view, e.g. excavations, work at height, demolition works, etc.);
- the instructional module “Prevention through Design Manual (PtDM)”, containing the set of directions that

navigate the learners (users of VPtDT ) to its effective exploitation;

- the collection of virtual building models “Virtual Building Models (VBMs)”, destined for training and verification of active participating skills in construction safety arrangements’ planning by means of VPtDT;
- the set of educational virtual (multidimensional) presentations simulating the model situations of construction process “Construction Safety Case Study (CSCS)”, that are utilizable for attitudes to construction safety risks reduction training by so called “experiential learning”.

The most meaningful benefit of the program for the Faculty of Civil Engineering in Kosice consists in innovation of educational material (sources) and methods centred on designers training and education from occupational safety risks elimination point of view. Digitalization and accessing of these teaching aids is going to support the presentation as well as the distance form of learners’ education.

## 5. EFFECTIVENESS OF OCCUPATIONAL SAFETY EDUCATION IN CIVIL ENGINEERING STUDENTS

In order to compare the effectiveness of conventional vs. unconventional teaching method in safety and health education in Civil Engineering students, a small experiment was conducted. Students attended the lessons aimed at occupational safety risks reducing in excavation works, concreting works and works at height. Forty students divided into two groups (twenty students in each group) passed their lesson within two different courses. Teacher was the same and time duration of education was the same in both cases. In the first group, the teacher applied the conventional lecture based educational method. During two-hour lecture, the teacher explained the main safety rules of excavation, concreting and at height works and the principle of identification, assessment and controlling of occupational safety risks relating to before mentioned construction works. Education of students in the second group was different. The teacher applied the virtual building models (VBMs) and video sequences, visualising the various situations from the site during excavation, concreting works and works at height. The role of the teacher consisted in commenting these situations and in supporting the educational value of the models by providing the beneficial information about safety risks perception, identification, assessment and controlling during construction works. After lessons the level of the all students knowledge was checked, in particular their ability to perceive the safety risks in real situations from construction site was estimated. The teacher showed all of them six video sequences (not before presented) representing the situations/cases from a real construction site. On the basis of introduced shots, the students from both groups were asked: a) to identify all occupational safety risks covered in the situations from construction works execution, and b) to propose the most suitable measures to avoid the identified risks.

The results of the students’ occupational safety awareness, estimated based on the mentioned methodology, is presented in Table 1. There are the percentages of students those solutions of two presented tasks was right.

**Table 1** The percentages of students with right answers

Cases/Shots	Topic	Identification of occupational safety risks		Proposal of suitable measures	
		First group (Lecture based)	Second group (VBMs)	First group (Lecture based)	Second group (VBMs)
Case no. 1	Sheeting	55 %	80 %	40 %	75 %
Case no. 2	Foundation pit	30 %	85 %	15 %	75 %
Case no. 3	Excavators	70 %	75 %	30 %	60 %
Case no. 4	Formwork	60 %	85 %	40 %	55 %
Case no. 5	Roofing	35 %	60 %	20 %	60 %
Case no. 6	Multi-story building	55 %	75 %	45 %	70 %

From the results in Table 1 is evident that the right answers/solutions of tasks answered on the basis of presented video shots were more frequent in students from the second group. These are the students which were educated by using of video sequences and VBMs as the tools supporting effective unconventional teaching methods.

## 6. CONCLUSION

The ideal situation for the safety of the construction workers is to make this an important parameter for the planners and designers of the conceptual and preliminary design phase. But, no or minimal construction site safety in designer education and training and lack of knowledge of how to design for safety belong to the most meaningful barriers to implementation of PtD concept. Teaching practices in workers safety education often tend to be

limited to the transmission of knowledge rather than to promote a critical examination of safety problems. The result is that people know legislation concerning their work. But application in construction site is worse. In the paper is discussed the educational program centred on development of construction safety awareness through unconventional teaching techniques. The skills development through the program is based especially on the supporting tool, developed on building information modelling platform, aimed at effective education for detection of construction safety risks through virtual building modelling.

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