


Skills development for construction safety risks prevention through BIM based tools

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Rozvoj zručností pre prevenciu bezpečnostných rizík výstavby prostredníctvom nástrojov na báze BIM

Zuzana Struková, Mária Kozlovská

Technical University of Košice, Faculty of Civil Engineering, Institute of Construction Technology and Management, zuzana.strukova@tuke.sk, maria.kozlovska@tuke.sk

prevence rizik

design

vzdělávání

stavebnictví

výstavba

bezpečnostní rizika

Abstract

Although there is a clear improvement on the safety performance in construction sector, it is still a high risk occupational area and suffers from very high accident rates. One of the most effective ways to improve health and safety conditions in construction sites rests in sound education of people incorporated in construction planning, managing or executing. In our region, the creative approaches are essential to encourage new methods to teach health and safety in a stimulating way. 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 discussed in the paper. There is also presented the educational program centred on development of construction safety awareness through unconventional teaching techniques. It is addressed particularly to designers or future designers and is focused on implementation of Prevention through Design concept and so is aimed at designers' safety education especially through the supporting tool developed on building information modelling (BIM) platform.

Keywords: construction, safety awareness, safety education, prevention through design, occupational safety

Abstrakt

Aj napriek neustále sa zlepšujúcej úrovni bezpečnosti práce na staveniskách, stavebníctvo stále patrí k vysoko rizikovým odvetviam z pohľadu pracovných podmienok a má jednu z najhorších bilancí z hľadiska pracovnej úrazovosti. Jedna z najefektívnejších metód zlepšovania stavu bezpečnosti a ochrany zdravia pri práci na staveniskách spočíva v dôkladnom vzdelávaní osôb, ktoré sa podieľajú na príprave, riadení a realizácii stavebných projektov. U nás je nevyhnutné presadzovať tvorivé prístupy, podporujúce nové stimulujúce metódy výučby v oblasti bezpečnosti práce. Príspevok poukazuje na potenciál digitálnych technológií, dnes využívaných pri navrhovaní stavieb, pre ich využitie pri tvorbe tzv. vizualizačných nástrojov prispievajúcim k implementácii konceptu prevencie prostredníctvom návrhu v

stavebnej praxi. Zároveň je v príspevku prezentovaný vzdelávací program vytvorený s cieľom zvyšovania povedomia v oblasti bezpečnosti práce pri výstavbe prostredníctvom nekonvenčných výučbových metód. Zameriava sa najmä na projektantov a budúcich projektantov. Vzdelávanie prebieha najmä za podpory nástroja vybudovaného na platforme BIM, umožňujúceho prevenciu bezpečnostných rizík výstavby vo virtuálnom prostredí modelovania stavby, čo má významne prispieť k implementácii konceptu prevencie prostredníctvom návrhu v stavebnej praxi.

Kľúčové slová: výstavba, povedomie o bezpečnosti, vzdelávanie v oblasti bezpečnosti, prevencia prostredníctvom návrhu, bezpečnosť pri práci

Introduction

According to the International Labour Organization, the construction industry almost in the world over accounts for a disproportionate number of occupational related injuries and still remains one of the most physically demanding and risky occupational areas. Although there is some improvement on the health and safety performance in construction sites in recent years. In European Union, the construction sector is one of the largest industrial employers, encompassing more than 2,4 million enterprises and approximately 14 million employees (Goulding and Arif, 2013). Unfortunately, it also has almost the most problematic occupational safety and health records. For an example, from the year 1992 till 2010, there have been recorded more than three hundreds fatal injuries occurred at construction sites in Slovak Republic (Labour Office database on labour statistics, 2013).

The construction as a project based industry exists in a dynamic and changing environment. 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.

Many different approaches to safety should be implemented to achieve the goal of fewer injuries. Work-related injuries are often associated with insufficient knowledge and unsafe behaviours of construction workers as well as all other participants of construction projects. One of the most effective ways to improve health and safety conditions in construction sites rests in responsible development of construction safety risks awareness and sound education and training of people incorporated in construction projects planning, managing and executing. Training and education programs play a significant role in enhancement of safety in construction and are important to increase safety awareness (Ghani et al., 2010) and change behaviour of persons involved in construction projects.

Designing for safety in construction industry

Almost all injuries in the sites are predictable and preventable. According to Toole and Gambatese (Toole and Gambatese, 2008), 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.

The fundamental principles of safe buildability are among others described in the following manner (Baxendale and Jones, 2000):

- Safety has to be considered systematically step by step from the very beginning of a project
- Everyone who influences safety are to participate
- Good planning and coordination must be implemented from the beginning of the project
- Health and safety should be handled by competent personnel
- Communication and the sharing of information between all parties should be included
- A formal record of safety information for future use should be made

Addressing construction worker safety and health in the design of a project, also referred to as **Prevention through Design (PtD)** and designing for construction safety and health, has been slowly recognized and applied in the USA over the past ten years (History of PtD, 2013). Several research studies have identified the design aspect of projects as being a significant contributing factor to construction site injuries.

Prevention through design in construction implies:

- explicitly considering construction safety in the design of a project,
- making design decisions based in part on a project`s inherent safety risk to construction workers,
- addressing worker safety in the constructability review process.

The European Union have appreciated the beneficial impacts of PtD in construction and is leading the way through European Union (EU) directive - **Council Directive 92/57/EEC** of 24 June 1992 - concerning minimum demands for health and safety at temporary 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. The Slovak Republic adopted the mentioned directive; now it is represented by the Regulation of *the Slovak Republic Government no. 396/2006 Coll. on minimum safety and health requirements of construction sites*.

Indeed, not all of the prevention principles are relevant to what a designer can do, but it would appear correct that *a designer should as far as reasonably practicable*:

- enquire, for each design option, in a systematic way to identify the associated key construction safety risks, considering generally the methods that might be used by a contractor in the execution of each option,
- seek, on the same basis, to design out those risks that can be avoided,
- assess, as best as the designer can, those safety risks that remain and then mitigate them by “combating” at source, rather than relying on protective measures to be taken on site,
- in due course, facilitate, as far as reasonably practicable, other protective measures being taken on site by contractors.

Unfortunately, the idea of workers safety consideration in designing phase of construction projects often remains only at the level of legislation article and its implementation in construction practice is rare. Most designers use to make rarely decisions pertaining to construction worker safety. They declare their responsibility only for the final product and no for means and methods affecting the workers safety.

The cardinal barriers to PtD implementation in construction practice, identified by the worldwide propagators of the concept, involve in particular (Gambatese, 2012):

- no or minimal site safety in designer education and training
- lack of knowledge of how to design for safety
- difficult for designers to assess safety risks if lack of field experience
- contractual separation of design and construction.

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.

Construction safety and digital design practices: Tools to support design for construction safety

As digital technologies become widely used in designing buildings, questions about their impacts on construction safety arise. Architects and contractors use many computer tools for tasks related to 3D visualization, constructability reviews and digital fabrication which have potential to be used for purposes of occupational safety improvement by design. Several researchers have developed a variety of new tools for use in construction design and execution phase to help contractors achieve safety in their projects (Zhou et al., 2012). Digital technologies are noticeably applied in these tools for construction site risk prevention and safe project delivery. The digital technologies involve in particular:

- ❖ *Building Information Modelling (BIM),*
- ❖ *4D Computer Aided Design (4D CAD),*
- ❖ *the online databases,*
- ❖ *Geographic Information Systems (GIS),*
- ❖ *Virtual Reality (VR) etc.*

A key objective of **Building Information Modelling (BIM)** is to make construction processes more predictable and efficient via increased visual communication and removal of uncertainties at start of the construction process, thereby improving safety and predictability of construction. BIM is seen as a tool to achieve the goals of Virtual Design and Construction. Early involvement of key project stakeholders by BIM ensures that problems are resolved early in the project life-cycle when costs of any changes are minimal. 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. The visualization offers a totally new tool for risk assessment, planning, introduction and safety management. 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.

There are case examples of BIM that show applications for planning, scheduling, improved conflict control, and hazard recognition in buildings. The most known are *the BIM based safety management and communication system*, developed by VTT Technical Research Centre of Finland (Sulankivi et al., 2010) and *the automated rule-based safety checking system on BIM platform*, developed by researchers from USA and Republic of Korea (Zhang et al., 2013). The first mentioned research aimed to develop and test solutions for the planning and management of construction site safety using dynamic 4D site models and so revealed possibilities for improving construction safety using commercially available BIM tools as Tekla Structures, ArchiCAD and Revit. In the Fig. 1 is presented an example of custom components created for site layout planning, as it was developed during the system testing by some real case studies.

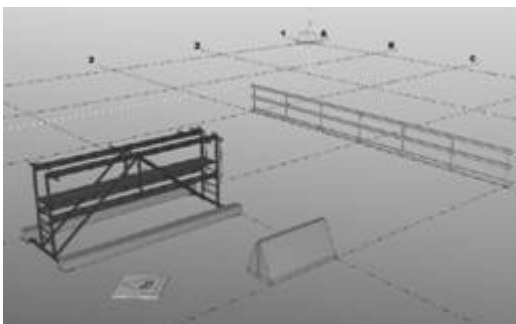


Figure 1: Example of BIM Safety custom components for site planning (Sulankivi et al., 2010)

As a result of the testing, a BIM based 4D safety railing demonstration has been created (Fig. 2).

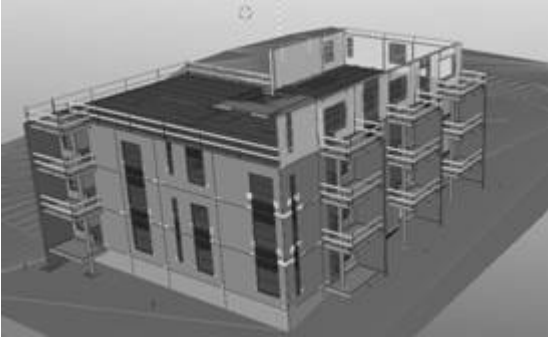


Figure 2: The 4D safety railing visualization as part of precast element erection visualization (Sulankivi et al., 2010)

Tasks corresponding erection of precast elements and related safety railings were created into a task list in the task manager - tool. Then the tasks were scheduled and linked with the corresponding parts in the model. After creating suitable visualization rules, it became possible to visualize project status on any selected review-date on the planned time scale.

BIM based multimedia educational program for safety awareness raising among designers

In our country, only students of construction technology and management field of study attend the course intent on construction health and safety knowledge. 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. In our faculty, this need is going to be satisfied by development of **the multimedia educational program** centred on implementation of PtD concept through increasing the designers' construction safety awareness. The materials of the mentioned educational program will be convenient for construction safety skills and competences development through lifelong education of practicing designers, as PtD education efforts should cover not only university education but also continuing education. The main objective of the program consists in integration of construction safety risks issues into education centred on buildings design. The educational program is developed as the multimedia-based interactive source for e-learning.

In our virtual laboratory, equipped by high-efficiency computers including right software available for various approaches to construction projects design, operative planning and management, are created good conditions for application of digital design technologies to enhance designers' skills for PtD implementation. For example, Tekla Structures, Autodesk Navisworks, Revit, 4D Google SketchUp, Solibri Model Checker, etc. (enabling 3D coordination, 4D planning, photorealistic visualization, dynamic simulation and accurate analysis) 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 program involves several partial objectives, among those belong:

- ▣ drawing attention to imperativeness associated with establishment of approaches into construction safety risks reduction through building design,
- ▣ modifying form and contents of educational and didactic materials and tools in compliance with development of

- progressive attitudes to solutions of construction safety risks issues during building lifecycle emphasizing the sustainable construction safety and health,
- 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,
- ensuring the integration of construction safety risks minimization issues into education focused on building designing in design studio seminars,
- promoting innovations of teaching process by creation of interactive distance educational resource for e-learning,
- 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 construction safety improvement through building design.

The 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 BIM based 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 building information modelling 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 (VBM)”, destined for training and verification of active participating skills in construction safety arrangements’ planning by means of VPtDT;
- the set of educational virtual (multimedia) 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 our faculty consists in creation 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.

Conclusion

Conventional safety practices have held designers responsible for safety of the end-users, and considered constructors responsible for the safety of construction workers. With Prevention through Design concept, designers and constructors can work together to enhance construction workers' safety early in the 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. In the paper is discussed the educational program centred on development of construction safety awareness through unconventional teaching techniques. It is addressed particularly to designers or future designers and is focused on implementation of well known concept of PtD. 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 and for relevant building design revise or protective equipments planning.

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References

BAXENDALE, T.; JONES, O. Construction design and management safety regulations in practice : progress on implementation. *International Journal of Project Management*, 2000, Vol. 18, pp. 33-40.

GAMBATESE, J. The Global Growth of Prevention through Design (PtD) : Overview of the PtD Concept. In *ASCE 142nd Annual Civil Engineering conference, Montreal, Quebec, Canada, Oct. 18 - 20, 2012*.

GHANI, M. K. ...[et al.]. *Safety in Malaysian Construction : the Challenges and Initiatives*. Construction Research Institute Malaysia (CREAM), CIDB Malaysia, 2010.

GOULDING, J.; ARIF, M. *Offsite Production and Manufacturing : Research Roadmap Report*. CIB General Secretariat, 2013. (CIB Publication, 372).

History of PtD : Origins and Growth [online]. 2013 [cit. 2013-01-12]. Dostupný na WWW: <<http://www.designforconstructionsafety.org/>>.

Labour Office database on labour statistics : occupational injuries : main statistics [online]. 2013 [cit. 2013-06-20]. Dostupný na WWW: <<http://laborsta.ilo.org/STP/guest>>.

SULANKIVI, K. ...[et al.]. 4D-BIM for Construction Safety Planning. In *Papers from the Special Track held at the CIB World Building Congress, 2010, 10 - 13 May 2010*. The Lowry, Salford Quays, United Kingdom.

TOOLE, T. M.; GAMBATESE, J. The Trajectories of Prevention through Design in Construction. *Journal of Safety Research*, 2008, Vol. 39, pp. 225-230.

ZHANG, S. ...[et al.]. Building Information Modeling (BIM) and Safety : Automatic Safety Checking of Construction Models and Schedules. *Automation in Construction*, 2013, Vol. 29, pp. 183-195.

ZHOU, W.; WHYZE, J.; SACKS, R. Construction safety and digital design : a review. *Automation in Construction*, 2012, Vol. 22, pp. 102-111.

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Autor článku:

[Ing. Zuzana Struková, PhD.](#)

[prof. Ing. Mária Kozlovská, PhD.](#)