EDUCATION ON CONSTRUCTION PROJECT MANAGEMENT THROUGH DIGITAL TRANSFORMATION

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ABSTRACT
The rapid development of advanced technologies and methods of Industry 4.0 represents in recent decades the basis for radical changes in traditional project management in all industrial sectors. It is a digital transformation, with a trend in digitalization and automation processes, and which in turn has a significant impact on the construction industry. Thus, the traditional construction project management has outgrown its basic elements and is focused on the challenges of comprehensive handling of mass data about the planned or built building. Therefore, managing construction projects today focuses on the use of Building Information Modeling (BIM), which is a digital platform where all information is collected in one place and accessible to all stakeholders throughout the construction project cycle. In this context, the basic education and continuous development of professionals through lifelong learning is so important. Through this learning, professionals acquire knowledge and competencies for working in this area, which is especially important for successful management of construction projects. Therefore, this chapter provides a more detailed overview of formal and informal learning at a higher education institution that focuses on advanced construction project management.

KEYWORDS
Construction project, Industry 4.0, BIM, Education.
1. INTRODUCTION

Project management which is included as a scientific and professional discipline in all industrial sectors has radically changed in the last decade. It is a period of so-called Industry 4.0 in which advanced technologies are rapidly evolving, which focus on digitalization and automation. Development continues at an accelerated pace, and thus today the first seeds of Industry 5.0 already exist. Unfortunately, the construction industry is lagging far behind in this area (Manyika, 2015).

Nowadays are globally important healthy lifestyle, concern for the environment and society’s development orientations, which are also the main goals for sustainable development of the European Union (European Union, 2022). In the construction industry, sustainability trends are expressed in the concepts of green building (Li et al., 2021), sustainable building (Boyle, 2005; Sourani and Sohail, 2008), circular economy (Norouzi et al., 2021), smart cities and buildings (Ghaffarianhoseini et al., 2018) and others. In Slovenia, the implementation of the priorities of the European Union is reflected in The Slovenian Smart Specialization Strategy S4 (Služba Vlade Republike Slovenije za razvoj in evropsko kohezijsko politiko, 2017). The strategy has the following five main objectives: 1. an inclusive, healthy, safe and responsible society; 2. high levels of collaboration, competence and managerial efficiency; 3. a preserved healthy natural environment; 4. a highly productive economy; and 5. lifelong learning.

All these strategic orientations and concepts of sustainable development have a direct impact on the construction project management. Priority must be given to responsible management and integration of advanced technologies and methodologies, which should be reflected in the construction project throughout all its life stages, i.e. in project planning, execution of construction projects and also during the use of facilities. (Wyman, 2018). This is especially important in the current times when digital transformation is accelerating at the global level.

Construction must therefore strive to follow trends and many innovations related to the use of advanced technologies and methods in Industry 4.0. The trends here are, for example, construction robotics, Building Information Modeling (BIM), advanced construction materials, construction monitoring, construction worker safety, offsite construction, green building, 3D printing, and connected construction sites (StartUs, 2021). However, trends in novelties are recognized in both academic and professional circles (Hasan and Sacks, 2021).

Integration of advanced technologies and methods of Industry 4.0 for a higher education institution in the field of civil engineering means the need to place modern content in the study process. Institutions usually achieve this by constantly updating content as well as learning methods. One of the most important updates to the learning context is, for example, active learning, which includes teaching techniques such as activating student through interactive lectures, collaborative learning, project-based learning, and experiential learning (Lassen, Hjelseth and Tollnes, 2018).

The paper aims to provide an overview of both formal and informal student learning at the Faculty of Civil Engineering, Transportation Engineering and Architecture (FCETEA), of the University of Maribor, Slovenia where the focus is on implementing methods and
techniques for digitalization and automation. To convey our teaching experience, the paper first outline how digitalization topics are formally incorporated into the learning process, namely in subjects where the content is supported by the BIM approach and the methods and technologies of Industry 4.0. It then shows a summary of the final thesis at FCETEA in the last 5 years in the field of digitalization in construction. Our contribution is intended to convey our pedagogical experience in the introduction of modern content due to digital transformation from the perspective of a higher education institution to the wider international professional public for discussion and suggestions for improvement.

2. IMPLEMENTATION OF DIGITALIZATION AND AUTOMATION IN THE STUDY PROCESS

The importance and implementation of methods and technologies for digitalization and automation are taught at FCETEA in 1st and 2nd level studies. In principle, the importance of digitalization is introduced into most professional teaching subjects. At the 3rd doctoral level, the importance of digitalization is essentially included in all elective courses, as the lecturers are competent researchers each in their own field, following the latest trends and research. We emphasize that we have already at the FCETEA since the academic year 2015/16 in the 2nd level compulsory subject BIM - Building information modeling, which includes the introduction of the general concept of BIM approach, the role and technology for BIM. Currently, Computer modeling of construction objects at the 1st level and BIM project for construction and infrastructure at the 2nd level are offered as elective courses on the topic of digitalization.

At the Chair of Construction Management, Technology and Economics, the digitalization and automation topics are included in the subjects like Construction Management, Project Management in Construction, Operative Planning, Safety at construction work, Spatial arrangement and advanced planning, and Maintenance and rehabilitation of structures. Colleagues at the department also provide mentoring on final theses to students who research and implement the tools and technologies of Industry 4.0 on practical examples.

The following is a more detailed description of working with students, namely a) learning process supported by the BIM approach; b) learning process involving Industry 4.0 methods and technologies; and c) final thesis on various topics related to digitalization and smart specialization in construction.

2.1 Learning process supported by BIM approach

The introduction of the BIM approach to the learning process has been carried out at FCETEA for many years. The first examples of work on the topic of BIM approach were introduced in the academic year 2015/16, when in the subject Project Management in Construction at the 2nd level, i.e. Civil Engineering and Industrial Engineering, students for the first time made a 4D and 5D BIM models for a garage house in Skopje. All subsequent years, students produce 4D and 5D BIM models, for various building construction project
for real-life examples of buildings. Since the 2019/20 academic year, such work has also been carried out in the professional study program Civil Engineering at the 1st level.

Work with students in the subject Project Management in Construction is focused on teaching the use of the basic 3D BIM model and upgrading it to 4D and 5D BIM models. 3D BIM extended with a construction schedule gives a 4D BIM, and extended with estimated construction costs a 5D BIM model. Students first gain theoretical knowledge about modeling higher BIM dimensional levels, i.e. for creating 4D, 5D and 6D BIM models. They then use the acquired knowledge in a tutorial and computer work, where they create 4D and 5D BIMs. For creation of 4D and 5D BIMs, Trimble Vico Office™ software (Trimble, 2022) modules (Cost Planner, Task Manager, Quantity Takeoff, and 4D Simulation) are used. Some other tools are also used as support tools, such as 4BUILD for cost estimation (Hermes, 2022) and MS Project (Microsoft, 2022) for scheduling. The paper (Pučko et al., 2019) provides a more detailed description and scheme of the creation of BIMs in the study process.

In the 2021/2022 academic year, students created 4D and 5D BIMs for the construction of a single-family house located in the cadastral municipality of Tepanje, Slovenia. Input data were given as part of a previously conceptual design created by ArchiCAD BIM software. The original 3D BIM model was created by a faculty student who also has given permission to use the 3D BIM model for study purposes. The 3D BIM model for the considered building and for the building plot are shown in Figure 1.

![3D BIM model and building plot](image)

**Figure 1.** 3D BIM model for the considered building (left) and the building plot (right)

The 4D and 5D BIM model creation was carried out in groups of 3-4 students, there were 5 groups in total. Each group was assigned a group of building elements as shown in Table 1. The groups first analyzed the assigned elements (technology, materials, dimensions, quantity, etc.) in more detail and obtained the input data (market prices for materials, equipment and machinery, average wages, norms of work items) required for unit cost estimation and scheduling. Then, first, a 5D BIM is created in the Cost Planner module, as part of the software Trimble Vico Office™. One of the major benefits of using this software is the ability to have cost information linked directly and bidirectionally to 3D BIM model elements. That means, when changing the geometry of the 3D BIM model the costs are
automatically updated. This is followed by defining the activities and their order of implementation, which is the basis for time planning of the construction of the building. With Vico Office software, time analysis is performed by creating a 4D BIM model in the Task Manager module. Another advantage of time analysis is that all elements, as defined in the 3D BIM model, are directly linked to activities in the schedule. The time analysis considers connections between activities and the allocated resources.

Table 1. Students group number, assigned project tasks and visualization of building elements

<table>
<thead>
<tr>
<th>Group number</th>
<th>The topic of the project task</th>
<th>Visualization (set in Vico Office)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>013_foundation slab</td>
<td><img src="image1.png" alt="Visualization" /></td>
</tr>
<tr>
<td></td>
<td>011_strip foundations</td>
<td></td>
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<td></td>
<td>012_pad foundation</td>
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<tr>
<td></td>
<td>001_façades</td>
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<tr>
<td></td>
<td>015_façades - borders</td>
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<tr>
<td></td>
<td>016_gutters</td>
<td></td>
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<tr>
<td></td>
<td>017_steel construction</td>
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<tr>
<td></td>
<td>018_roofing of the garage and terrace</td>
<td><img src="image2.png" alt="Visualization" /></td>
</tr>
<tr>
<td>2</td>
<td>002a_external walls of the ground floor</td>
<td><img src="image3.png" alt="Visualization" /></td>
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<td></td>
<td>002b_external walls of the 1st floor</td>
<td></td>
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<tr>
<td></td>
<td>003a_inner walls of the ground floor</td>
<td><img src="image4.png" alt="Visualization" /></td>
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<tr>
<td></td>
<td>003b_inner walls of the 1st floor</td>
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<tr>
<td></td>
<td>006_RC ties</td>
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<td></td>
<td>007_RC stairs</td>
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<tr>
<td></td>
<td>008_RC slab above the ground floor</td>
<td><img src="image5.png" alt="Visualization" /></td>
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<tr>
<td>3</td>
<td>009Terrain</td>
<td><img src="image6.png" alt="Visualization" /></td>
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<td></td>
<td>010_filling</td>
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<tr>
<td></td>
<td>026_curbs</td>
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<tr>
<td>4</td>
<td>014_finishing floors - wood</td>
<td><img src="image7.png" alt="Visualization" /></td>
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<tr>
<td></td>
<td>022_housing equipment</td>
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<td>024_doors</td>
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<td>025_windows</td>
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</tbody>
</table>
As a conclusion of the course, a final presentation was held in January 2022, where each group presented its created 4D and 5D BIMs (Figure 2). This presentation also included a presentation of the combined results of all groups as a comprehensive 3D, 4D and 5D BIM models (Figure 3) to give the student an insight into the overall cost estimate and schedule for the considered building. A simulation of the construction process is also created and presented to students. Details of the presentation can be found on the faculty website (https://www.fgpa.um.si/2022/01/vodenje-gradbenih-projektov/).
2.2 Learning process involving Industry 4.0

In recent years, students at FCE TEA have also acquired knowledge and skills about the use of advanced Industry 4.0 methods and technologies. One of the technologies is data capture of the environment with 3D Laser Scanner, which is included in the learning content of several subjects, such as Safety at construction work, Spatial arrangement and advanced planning, and Maintenance and rehabilitation of structures. A 3D Laser Scanner can be used for various purposes, such as to acquire the actual condition of the environment, to help ensure safety at the construction site, to find out the progress of work and to create a 4D As-built BIM model, etc. Students use the Leica RTC360 3D Laser Scanner (Leica RTC360 3D Laser Scanner | Leica Geosystems, 2022) to acquire point cloud data. Figure 4 shows the acquired point cloud data for the selected location, which the students acquired during the exercises in the subject Spatial arrangement and advanced planning.
Furthermore, students also gain knowledge and skills about advanced augmented reality technologies. It is a combination of a real environment with digital elements, and which allows visualization of the built environment in 1:1 scale. Technology is quite new in the construction industry and in practice only a few applications can be traced at present. However, we believe that this technology has a very high potential and it is expected that more innovations in construction project management will be developed in the coming years. Figure 5 represents the way of using advanced mixed reality during exercises in subject Safety in construction work.
3. FINAL THESIS

At FCETEA the topics of using advanced technologies and trends of digitalization and automation become an ongoing topic for the final thesis, both at the 1st and 2nd level study program. Theses focus on different areas of digitalization, mostly on BIM approach, quite a few topics are on data capture, and other topics from the use of advanced technologies, such as object scanning, virtual reality, 3D printing etc. Most of the thesis, in addition to theory, also include the use of advanced technologies on real-life examples of buildings.

Brief descriptions of some graduate and master's thesis in the implementation of BIM approach are given in paper (Pučko et al., 2017) and publication “Slovenian BIM talents” (Pučko, 2017). Examples of creating 4D and/or 5D models on various practical examples are presented, such as multi-storey underground parking garage in Maribor, prefabricated hall in Novo Mesto, multi-residential building in Ljutomer, for detached residential building in Braslovče, business-storage building in Hoče.

An analysis of the final works at FCETEA showed that 38 final theses on the topics of digitalization and smart specialization have been completed in the last 4 years. Of these, 18 were thesis in the bachelor's program and 20 theses in the master's program in civil engineering or industrial engineering. Table 2 summarizes the analysis of the final works by topics, in the years 2018 to 2021. The analysis shows that in the last two years, the number of final theses from the topics of data capture has increased. All thesis are available in the DKUM repository (DKUM - First Page, 2022).

Table 2. Final theses at FCETEA on topics of digitalization in years 2018 to 2021

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<tbody>
<tr>
<td>BIM - general</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
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<tr>
<td>BIM for building design</td>
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<tr>
<td>BIM for structures and infrastructure</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
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<tr>
<td>BIM for project management (4D and 5D)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Data capture</td>
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<tr>
<td>Other (3D printing, virtual reality, drones)</td>
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<tr>
<td>SUM</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>4</td>
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</table>

4. OTHER FORMS OF FORMAL AND INFORMAL LEARNING

In the last period, many activities of other forms of formal learning and many forms of informal learning have been carried out at FCETEA on the topic of digitalization and automation in construction. These activities can be combined into the following sets:

- participation in conferences and trade fairs,
- active participation in various professional events,
- excursions and site visits and
- involvement in various projects
We highlight some formal and informal learning activities that were carried out under the auspices of the faculty and in cooperation with construction companies in the recent period (detailed information are available in the reports published on the faculty website):

- **2-day professional excursion for students in 2018**, which included a visit of two construction sites the Archive of Recent History in Obersalzberg and Großlappen central wastewater treatment plant in Munich and participation in the BIM WORLD Munich Congress (*Poročilo: Strokovna ekskurzija v Obersalzberg in München | Fakulteta za gradbeništvo, prometno inženirstvo in arhitekturno Univerza v Mariboru, 2018*).

- **1-day excursion for students in 2021**, which included a visit of three construction sites on the route of the Second track of the Divača-Koper railway line (*Za razvoj Slovenije | Drugi tir, 2021*). This is currently the largest construction project in Slovenia using modern technology. (*Strokovna ekskurzija | Fakulteta za gradbeništvo, prometno inženirstvo in arhitekturno Univerza v Mariboru, 2022*).

- **Short visits to construction sites**, known as fieldwork and are a regular part of the formal learning process. In 2021 fieldwork were carried out on the construction site of the energy and structural renovation of the building of the Secondary School of Hospitality and Tourism in Maribor, where modern technologies such as BIM approach and communication tools Dalux (*Dalux | Digitalizing Construction Industry, 2021*), etc. are used.

- **Participation in "BIMathlon" competition** in 2016, which was conducted as part of international conferences under the auspices of the siBIM association. (*Dogodki - siBIM 2016 - BIMathlon (poročilo) - SIBIM, 2016*).

- **Involvement in projects under the title "Creative Path to Knowledge"** (*Creative path to knowledge | Public Scholarship, Development, Disability and Maintenance Fund of the Republic of Slovenia, 2020*). In 2020, 9 students participated in a project entitled "Integration of Industry 4.0 Technologies for Automation of Construction Process Monitoring" and the acronym "APP4ACCPM" for 6 months (*Pučko et al., 2020*).

The main purpose of all these activities is to help students to broaden their horizons and provide a more accurate insight into construction practice.

**5. CONCLUSION**

The purpose of this paper was a brief presentation of our BIM experience in teaching and introducing advanced technologies and methods of Industry 4.0, which today serve as tools for the advanced management of construction project. Thus, we put the current educational activities in the field of digitalization and automation in the foreground, and which are
currently carried out at FCETEA. The paper emphasized the BIM approach as well as Industry 4.0 methods and technologies covered in teaching subjects as part of the study process, and analysis of completed theses at FCETEA on topics of digitalization. Thereupon, the paper revealed how students participate in other form of formal and informal learning activities.

Education about BIM approach and methods and technologies of Industry 4.0 is carried out at FCETEA during study process through subjects on 1st and 2nd level studies. After completing the professional study program at the 1st level or at the 2nd level of the study graduates have enough knowledge to independently implement construction projects using the BIM approach. They are also independent in using advanced Industry 4.0 methods and technologies e.g. data capture, 3D Laser Scanning. Due to the increasing interest in modern trends that are currently relevant in the construction industry, in the last period, more students also decided that digitalization and smart specialization will be the topic of their final thesis, where they mostly deal with real projects from practice. Other forms of formal and informal learning such as students’ participation in conferences, trade fairs, professional events, excursions, site visits and involvement in projects also makes an important contribution to student education. Education on digitalization and automation through the implementation of the study process, as well as other formal and informal forms of learning is especially important in the current times when digital transformation is being accelerated at the global level.

REFERENCES


