Impact of BIM Technology on Development of Digital and Managerial Competencies of Project Managers in Construction Industry

Peter Mesaros, Tomas Mandicak, Annamaria Behunova, Jana Smetankova, and Katarina Krajnikova

1 Introduction

The construction project presents a series of relative processes. The success of the project is primarily influenced by the order of these processes. The primary aim is to execute individual processes in the right order and in the right way. The project has temporary character and results of these processes are a specific product. The construction project is a one-time organized process of construction, renovation, etc. An important factor in the project implementation process is the project team from which the success of the project depends [1]. Construction projects are strictly defined by result requirements, the cost and time constraints and are bounded by the environment in which they are implemented [2].

Project management is a basic element of any construction project. The construction project manager must acquire several skills and competences through which he manages the whole team. Construction projects are characterized by many unpredictable changes that need to be addressed promptly, which is the key to the stability of process [1]. Construction project management is the direction, regulation and supervision of the project from development to its completion. The aim of

P. Mesaros · T. Mandicak (✉) · J. Smetankova · K. Krajnikova
Technical University of Košice, Faculty of Civil Engineering, Košice, Slovakia
e-mail: peter.mesaros@tuke.sk; tomas.mandicak@tuke.sk; jana.smetankova@tuke.sk; katarina.krajnikova@tuke.sk

A. Behunova
Technical University of Košice, Department of Industrial Engineering and Informatics, Prešov, Slovakia
e-mail: annmaria.behunova@tuke.sk

L. Knapcikova et al. (eds.), *4th EAI International Conference on Management of Manufacturing Systems*, EAI/Springer Innovations in Communication and Computing, https://doi.org/10.1007/978-3-030-34272-2_16

the project is to fully satisfy the client's requirements for functionality and budget [1]. Decision-making in construction project is influenced by many factors and its difficult process [3, 4].

A construction project manager is a responsible person for planning, coordinating, budgeting and overseeing the project. A construction project manager is responsible for the following activities [1]:

- Putting together the budget and negotiate cost estimates
- Choosing the most efficient construction method and strategies
- Staying in touch with the clients for works- or budget-related issues
- Arranging the work timetables
- Discussing about technical and contract details with workers and other professional parties
- Cooperating with building and construction specialist
- Keeping an eye on the personnel in the construction site

Construction project management refers to project management tasks and managers based on their past experience. It is more useful than following a theoretical approach in new case [5]. The primary objective of construction project management is to manage construction through the specification of project objectives and plans, including developing the scope, schedule, budget, decision-making and selection of project participants, increasing resource efficiency (worker, equipment), supporting coordination and contracting, planning, estimating, design and construction and effective communication development [6].

Learning process is a first step and presumption for better results of every construction manager. The achievement of higher level of competencies increases the precondition for its successful results in the management of construction projects [7]. Increasing of information and communication technology impacts productivity levels and developing of managerial competencies of managers [8].

El-Baz and El-Sayegh described four groups of managerial competencies for construction industry: concretely technical competencies, management competencies, leadership management and financial competencies. Technical competencies include statistical analysis, decision analysis, resource optimization, information technology control, SCM and so on. Management competencies include typical planning and managerial competencies as strategic and operation planning, human resource planning, change management and so on. Leadership competencies are ability of managers to have effective communication, vision, responsibility and motivation. The last one represents financial competencies. It includes cost management ability, financial analysis, accounting and so on [9].

Kerzner in his study mentioned leadership abilities, creativity, ability to make decisions, ability to identify problems, ability to organize work to subordinates, effectiveness, ability to persuade and having ambition, vision and leadership abilities [10]. Project Manager Competency Development (PMCD) by Project Management Institute (PMI) standard defines three project managers' competence

areas. They are knowledge competencies, performance competencies and personal competencies. International Project Management Association defined 20 technical competency elements and 15 behavioural competency elements. It includes 11 contextual competency elements too [11].

Building information modelling (BIM) is a digital representation of the physical and functional characteristics of a device that connects project information databases [12]. BIM is defined as the use of ICT technology to make building more efficient across a project life cycle to provide safer and more productive environment, eliminate environmental impact and promote efficient operational management and use of the building across its life cycle [13].

BIM is an intelligent 3D model-based process that gives architecture, engineering and construction professionals the insight and tools to more efficiently plan, design, construct and manage buildings and infrastructure. Application of BIM is steadily gaining popularity in construction industry, and as such, BIM knowledge represents an important learning outcome in higher students' education. The main problem in this area, which is related to BIM training in building management, is to define the learning outcomes, course curricula and specific knowledge needed for future building and project managers [14].

In the context of BIM and learning competencies of projects was set the most used and mentioned project competencies and their main groups. These were set on literature review and mentioned sources (Table 1).

Based on these facts, BIM is a tool that helps eliminate costs and time load across the building's life cycle, and probably, it has a positive effect on development of digital and managerial competencies. Of course, on productivity and economic parameters impact, there are other factors like materials and other aspects with them (e.g. waste management and so on.) [15, 16]. In spite of this fact, BIM technology includes many points of view. Currently, the industry is undergoing rapid changes that will also affect the population and one of the reasons why BIM technology is here [17].

Table 1 Groups of competencies and competencies of project managers

Technical competencies	Behavioural and personal competencies	Financial and economic competencies
Ability to organize work to subordinates Ability to make decisions Ability to formulate goals Ability to use project management software Ability to design project	Ability to communicate Ability to motivate team members Help in solving problems Ability to resolve conflicts Ability to humans resource planning Ability to motivate Ability to take a responsibility	Ability to manage the scope, time and cost of the project Ability to cost management Budgeting and accounting

Source: own processing based on literature review

2 Methodology

The data collection was done by a questionnaire survey form. The questionnaire is one of the most common methods of research use. It is used for mass and faster detection of facts, attitudes, values, opinions, etc. The questionnaire contained simple and comprehensible questions about the learning competencies of project manager's development by use of BIM technology. The structure of the questionnaire was basic information about the project managers and construction projects. Another part of the questionnaire had direct questions about the research problem. Project managers used the Likert scale for the quantification of impact in the main research questions (1, low impact on development of digital and managerial competencies; 5, high impact on development of digital and managerial competencies).

The research sample consisted of project managers who participated in construction projects in Slovakia and Czech Republic. Project managers and construction projects were selected randomly. The return rate was 4.89%, which means 147 project managers. The research sample therefore incudes 2% of project managers of large companies, 19% of project managers who work in medium-sized companies and 79% of project managers who work in small and microenterprises.

A similar research sample was in Czech Republic. Totally, participants (project managers) in Czech Republic were 142.

For determining the weights and the resulting model, the Analytic Hierarchy Process (AHP) method was used. The AHP method to support multi-criteria decision-making was originally developed by Prof. Thomas L. Saaty. The basis for decision-making is empirical decision-making criteria and using AHP is to outline the whole decision problem as a hierarchical structure [18]. AHP is based on the value of the information obtained, derives ratio scales from paired comparisons of criteria to discover and correct logical contradictions. Questionnaire surveys in general contain subjective opinions of respondents. These opinions were taken as inputs and divided according to alternatives $A_1,...,A_m$ (competencies) and specific criteria $K_1,...,K_n$ (abilities of project managers). This process allows to translate these opinions into measurable numeric relations.

Internationally, AHP is used in a wide range of applications, for example, for the evaluation of suppliers, in project management, or for our selection of the best alternative in the decision tree. As a result, the main model represents the intensity of each competency acquired through the use of BIM technology, where priorities (weightings) and a consistency ratio could be calculated. AHP helped us to make decisions in a more rational way and to make them more transparent and better understandable [19]. Using AHP as a supporting tool for decision-making helps to gain a better insight in complex decision problems. It means the selection of the best alternative in the decision tree. As you need to structure the problem as a hierarchy, it forces you to think through the problem, consider possible alternatives (decision criteria) and select the most significant criteria with respect to the decision objective.

The criterial matrix for the evaluation of alternatives according to criteria is represented by $Y = (y_{ij})$, where rows are alternatives and columns are criteria. For every criterion, it was necessary to calculate its weight (number from 0 to 1). The more important the criterion, the higher the number of its weight (denoted v_j for criterion $K_j, j = 1,...,n$). Some of the methods of criteria weights:

Method of entropy: no preferences, weights of criteria are equal ($w_j = 1/n$)

Method of order and Fuller's method: ordinal information about criteria are known

The Scoring Method and the AHP Method (Saaty's method): ordinal information and distances between criteria are known. Scale of points for criteria are 1, 3, 5, 7, 9, where 1 = criteria are equal, 3 = the first criterion is more significant than the second one, 9 = the first criterion is absolutely more significant than the second one [20].

Mathematically, the AHP method is based on the solution of an Eigenvalue problem. The results of the pair-wise comparisons are arranged in a matrix. Saaty's matrix is squared, consists of estimated elements $s_{ij} \approx \frac{w_i}{w_j}$ which are ratios of weights i-th and j-th criterion. Elements on the main diagonal are equal to 1. In ideal case, for every $i, j, k = 1, \ldots, n$ should apply

$$s_{ij} = \frac{w_i}{w_j} = \frac{w_i}{w_k}.\frac{w_k}{w_j} = s_{ik}.s_{kj} \tag{1}$$

and then, this matrix is called consistent and reciprocal. So, it could be multiplied from right side by normalized right Eigenvector $(w_1, w_2, \ldots, w_n)^T$ (n is Eigenvalue) gives the ratio scale (weighting), the Eigenvalue determines the consistency ratio:

$$\begin{pmatrix} 1 & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & 1 & \cdots & \frac{w_2}{w_n} \\ \cdots & \cdots & \cdots & \cdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & 1 \end{pmatrix} \cdot \begin{pmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{pmatrix} = \begin{pmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{pmatrix} \cdot n$$

In practice, it is very rare to obtain fully consistent matrix. Then, the maximal Eigenvalue of matrix is taken and the index of consistency $CI = \frac{\lambda_{max} - n}{n-1}$. As an appropriate value for approximation of weights, Saaty suggested a normalized geometrical mean of row's numbers in Saaty's matrix:

$$w_i = \frac{\sqrt[n]{\prod_{j=1}^{n} s_{ij}}}{\sum_{k=1}^{n} \sqrt[n]{\prod_{j=1}^{n} s_{kj}}}. \tag{2}$$

From these normalized weights for alternatives, the Saaty's normalized matrix was generated where in i-th row and j-th was normalized weight for i-th alternative was derived in Saaty's analysis of alternatives for j-th criterion. For this matrix, the

weighted row's sums were determined (according to normalized weights of each criterion). The best alternative was then the one with the largest weighted row's sum. The results were arranged to tree.

3 Results and Discussion

Results of research are divided to the tree hierarchy and show impact rate or level on development of digital and managerial competencies. The main element has a weight value of one. This is then divided into elements at level 2. The formulation of the main objective emerged from the research questions determined on the basis of the theoretical analysis of the issue and the following basic research questions for the area.

First level: Main objective of the AHP model – Analyse the impact of development of digital and managerial competencies by BIM technology.
Second level: Partial objectives of the AHP model – Quantify the impact of the use of BIM technology on selected groups of project manager's competencies.
Third level: Quantify the impact of the use of BIM technology on digital and managerial competencies of project managers.

For more details, BIM technology impacts especially technical competencies. This group of manager's competencies achieved value 0.54, what represents the biggest value on the learning competencies of project managers. The next group was set as financial and economic competencies. The last one was the so-called group of behavioural and personal competencies with a value of 0.17. Separately, BIM is the most positive in the development of ability to design project. It achieved a value 0.19 and it is the biggest value. Interestingly, more than 50% of respondents find this answer more important. The ability to manage the scope and time of the project is the second in this case (Fig. 1).

Project managers achieved this competency when using BIM technology. Ability to use project management software was set as the third important and more positive learning competency by BIM technology. Similar situation is in Czech Republic (Fig. 2).

BIM has the highest impact on development of ability to organize work to subordinates, use project manager software and design project. The most important group to development of competencies were technical competencies. They achieved 0.48 impact rate according to the AHP method. Generally, there are small differences, but globally the results are very similar. It can be from more reasons. First of all, BIM technology is used in similar rate and level as in Slovak construction industry. Next, it has very nearest culture and market conditions of these countries. And the last one, a lot of projects and construction companies are in the same markets in

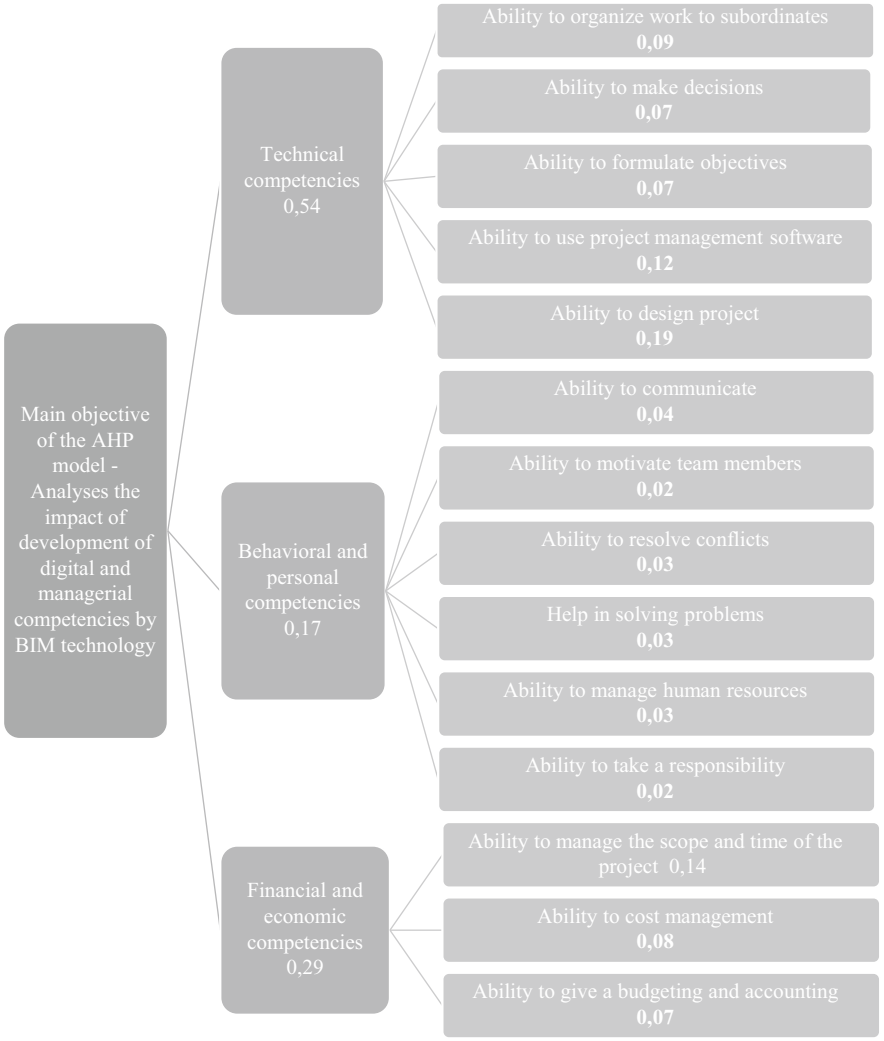

Fig. 1 Development of digital and managerial competencies by BIM technology in Slovak construction industry

Slovakia and Czech Republic. Actually, this model was applied and tested in a large construction company in Slovakia. It is currently exploring whether the theoretical model discovered in this research is applicable in practice and whether it brings real benefits. This is another phase of research that cannot be accelerated.

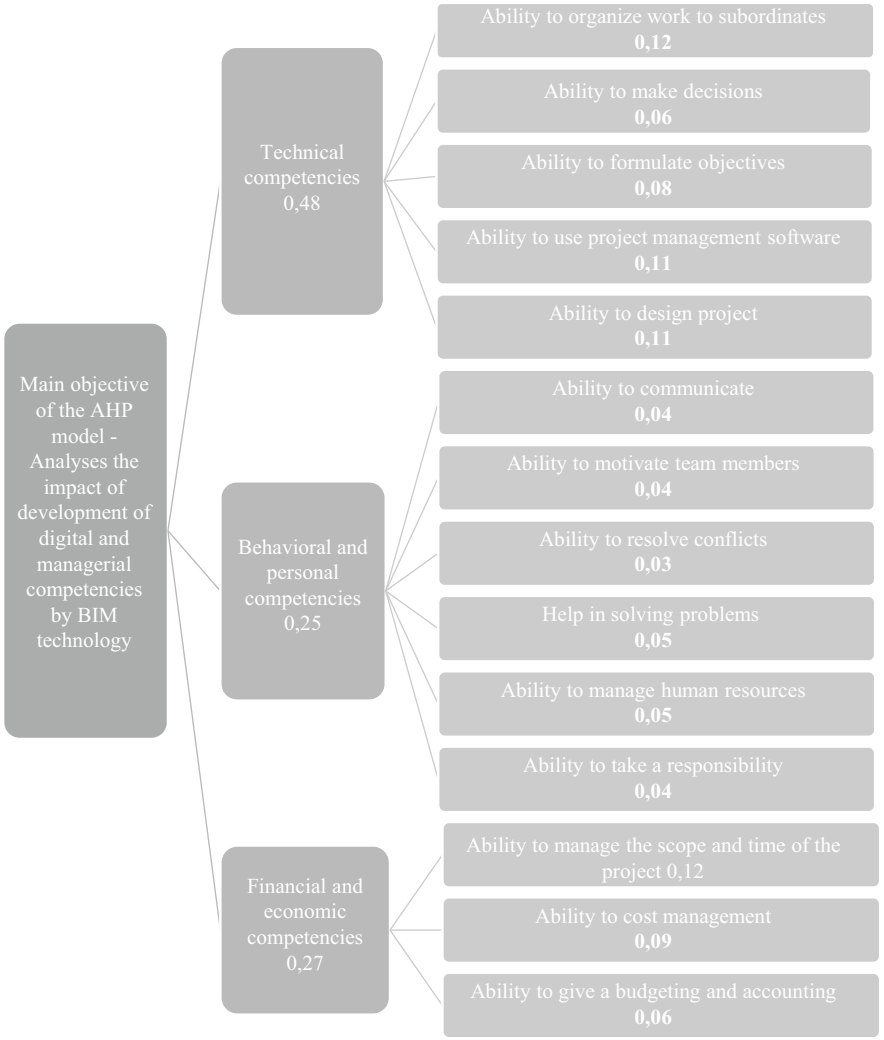

Fig. 2 Development of digital and managerial competencies by BIM technology in construction industry in Czech Republic

4 Conclusion

Management of construction projects is difficult and involves competencies-requirement processes. Project managers present an important issue of construction project management. Currently, digital age is a thankful space for the implementation of technology that helps in the management processes. BIM technology presents one of them. BIM technology can be considered as one

of the most effective and powerful tools in construction project management. Research problem and objectives were identified based on theoretical background and market demand. The impact of BIM technology on the development of digital and managerial competencies was analysed and based on AHP method quantified. There were described main impact groups and digital and managerial competencies. Results compare two very similar construction markets in two countries. Results in both countries are very similar. It takes into account a little difference between culture and industry conditions, and it is not a surprise. But some differences were recorded, e.g., in the perception of soft managerial or behavioural competencies. BIM impacts more in Czech Republic than Slovakia on this issue. The survey sample and the similarity of countries showed a strong link between the construction markets and market constraints. Next research questions are oriented to extend research countries. It is worth considering moving research in this direction as well. That means comparison of different countries, e.g., country from West Europe or different continent. This reasoning is supported by the claim that these countries are generally pioneers in the use and implementation of BIM technology. It is important for extending it to the whole world context.

Another area for research is one that is already described in the results. This means that research has progressed to a stage where the model is tested under real conditions. One of the construction companies in Slovakia is in the stage of testing the research conclusions, and therefore in the near future, it will be possible to verify the theoretical model in real conditions. Generalized research results in individual points are as follows main points of results.

Technical competencies are the most important work of the development of competencies of project managers. Ability to design is other individual with the highest impact on the development of manager's competencies.

Acknowledgements This work was supported by the Slovak Research and Development Agency under contract no. APVV-17-0549.

References

1. Designing Building Wiki. (2019). *Construction project.* [Online] Available at: https://www.designingbuildings.co.uk/wiki/Construction_project. Accessed 12 May 2019.
2. Mandičák, T. & Mesároš, P. (2017). Impact of ERP systems on cost reducing in construction project management in Slovakia. *OTMC 2017.* – Zagreb: Croatian Association for Construction Management. (pp. 345–355). – ISBN 978-953-8168-21-5.
3. Radziszewska-Zielina, E., & Szewczyk, B. (2016). Supporting partnering relations management in construction projects' implementation using AHP and fuzzy AHP, WMCAUS 2016. *Procedia Engineering – Journal – Elsevier, 161*, 1096–1100.
4. Radziszewska-Zielina, E., Śladowski, G., & Sibielak, M. (2017). Planning the reconstruction of a historic building by using a fuzzy stochastic network. *Automation in Construction, 84*, 242–257.
5. Maqsood, A. (2006). Applying project histories and project learning through knowledge management in an Australian construction company. *The Learning Organization, 13*(1), 80–95.

6. Geniebelt, P. *Construction project management processes: Everything you need to know*. [Online] Available at: https://geniebelt.com/blog/construction-project-management-processes. Accessed 12 May 2019.
7. Mesároš, P., et al. (2017). Impact of education and experiences of managers on performance of Slovak construction enterprises. *ICETA 2017*. – Danvers: IEEE, (201, pp. 263–268). – ISBN 978-1-5386-3294-9.
8. Bolek, V., et al. (2016). Factors affecting information security focused on SME and agricultural enterprises. *Agris On-line Papers in Economics and Informatics, 8*(4), 37–50.
9. El-Baz, H. & El-Sayegh, S.M. (2007). *Developing engineering management core competencies*. In Fifth LACCEI International Latin American and Caribbean Conference for Engineering and Technology "Developing entrepreneurial engineers for the sustainable growth of Latin America and the Caribbean: Education, innovation, technology and practice.
10. Kerzner, H. (2005). *Project management* (9th ed.). Hoboken: John Wiley & Sons.
11. Caupin, G., et al. (2009). *IPMA, ICB IPMA competence baseline version 3.0.* Nijkerk: International Project Management Association, June 2006
12. Ahmad Latiffi, A., Brahim, J., Mohd, S., & Fathi, M.S. (2014). The Malaysian government's initiatives in using Building Information Modeling (BIM) in construction projects. *Sustain Solut Struct Eng Constr*. no. Cream, 767–772.
13. Ariyaci, Y., Egbu, C., & Coates, P. (2012). Building information modelling (BIM) implementation and remote construction projects: Issues, challenges, and critiques. *Journal of Information Technology in Construction, 17*(May), 75–92.
14. Kolarić, S., et al. (2018). *BIM training in construction management educational practices in Croatia and Slovakia*. In Proceedings of the Creative Construction Conference. https://doi.org/10.3311/CCC2018-130. Creative Construction Conference 2018, CCC 2018, 30 June – 3 July 2018, Ljubljana, Slovenia Sonja.
15. Knapčíková, L., et al. (2018). Advanced materials based on the recycled Polyvinyl Butyral (PVB). *MMS Conference 2017*. – Ghent: EAI (pp. 1–9).
16. Knapčíková, L., et al. (2016). Material recycling of some automobile plastics waste. *Przemysl Chemiczny, 95*(9), 1716–1720.
17. Behún, M., Gavurova, B., Tkacova, A., & Kotaskova, A. (2018). The impact of the manufacturing industry on the economic cycle of European union countries. *Journal of Competitiveness, 10*(1), 23–39. – ISSN 1804-171X.
18. Saaty, R. (2009). *Participant names and papers.* In Proceedings of the 10th International Symposium on the Analytic Hierarchy/Network Process. Pittsburgh, Pennsylvania: ISAHP.
19. Goepel, K. D. (2018). Implementation of an online software tool for the analytic hierarchy process (AHP-OS). *International Journal of the Analytic Hierarchy Process, 10*(3), 469–487.
20. Saaty, H., et al. (2008). *Group decision making: Drawing out and reconciling differences*. Pittsburgh: RWS Publications. ISBN 978-1-888603-08-8.