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Use of BIM technology and impact on productivity in construction project management

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Abstract

Building information modelling is a illustration of the physical and functional characteristics of a technology which connects project information databases in every fields. Use of building information modelling technology represents one of the most progressive approach in construction project management. Construction project management is a difficult process depends on many factors. Human resources are one of them. Project results depends on productivity of human resources. There are some questions about productivity of employees and managers. Productivity of employees depends on many processes and factors. Progressive technology can be one of them. BIM technology presents probably affective tool for productivity. This research discussed issue of use of BIM technology and analyses BIM effect on productivity in construction project management. Main aim of research was set like analyze of use BIM technology in construction industry and effect of this on productivity.

Keywords BIM technology · Productivity · Construction project management

1 Introduction

Today construction project management is a difficult process. Effective management processes bring a many request on managers, employees and technical resources. Material request is important in this field too [1, 2]. The construction project presents a series of relative processes. The success of the project is primarily influenced by the order of these processes [3]. Based on some experts, Building Information Modeling (BIM) is not a software, but it's process that bring information model as a result. This contains graphical and non-graphical information. Some parts represent information and dimension [4]. Also, Building Information Modelling based approach to address sustainability issues regarding material selection and supply decisions [5, 6]. Future studies on Civil Engineering and Construction and research themes may focus on the application or integration of innovative technologies such as BIM, augmented reality, radio-frequency identification (RFID) and other for increasing productivity [7]. BIM has emerged into the mainstream bringing a different process of collaboration and a new way of working transforming current AECOO industry structures and practices, with the aim of improving efficiency and environmental objectives [8]. BIM presents the art of data management and collection by CPIC (Construction Project Information Committee). This a process that runs through the entire asset lifecycle [9, 10]. Implementation of the BIM concept to suit the specific requirements of infrastructure projects will be a key aspect in effective BIM deployment and UK contractors' ability to meet the 2016 requirement.

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In view of the potential benefits of BIM for the infrastructure construction industry, this study aims to provide a review of existing re- search and industry development on the use of the BIM concept within the infrastructure sector and its application by the contractor role [11]. Building Information Modelling is currently receiving worldwide recognition in the architecture, Engineering and Construction (AEC) industry due to its ability to store and also ease the use and reuse of project data across the project development phase [12].

The main idea driving the concepts of a sustainability in the construction industry is primarily the development of standards and the implementation of Building Information Modelling and sustainability practices. Several research studies have discussed the possibilities of BIM to advance the implementation of sustainability practices in construction projects. Alsayyar and Jrade [13] developed an innovative model which integrates BIM tools with sustainable design requirements to evaluate the cost and benefits of a proposed building in the planning and design stages. The model was developed with a data base module and tested on a real-life project [14].

Moreover, Gilkinson et al. [15] regarded BIM as a revolutionary de-sign-based technology and process which provides considerable value to construction projects throughout the lifecycle stages. BIM implementation can be considered from two aspects—(1) the use of 3D technology (software) to model and analyses building model using software such as Revit, ArchiCAD etc.; and (2) the process/conceptualization which enable other knowledge domains such as cost, schedule, project management, safety, sustainability parameters to be embedded in BIM software to provide one-source, central hub of information for project stakeholders. Olatunji et al. [16, 17] affirmed BIM capability to offer both functions (application and process) which enables it to be useful for construction stakeholders and organizations in managing project data.

On other hand, BIM technology is not only about technology. Generally, productivity in construction industry depends on many factors. One of the can be technology. Generally, productivity is defined as the ratio of outputs to inputs. Construction projects are mostly labor based field with basic hand tools and equipment. According some analyses and expert statements, labor costs comprise 30–50% of overall project cost. Productivity in economics refers to measures of output from production processes, per unit of input. Productivity may be conceived of as a measure of the technical or engineering efficiency of production. Productivity in construction is often broadly defined as output per labor hour. Since labor constitutes a large part of the construction cost and the quantity of labor hours in performing a task in construction is more susceptible to the influence of management than are materials or capital, this productivity measure is often referred to as labor productivity [18].

Productivity is one of the key performance indicators (KPIs). Generally, business performance measurement includes a process of efficiency and effectiveness quantifying [19]. It means especially cost and revenues. Generally, performance measurement has some rules that have to be accepted by expert society. KPIs are focused on cost, safety, customer satisfaction, profitability and productivity. Group of authors describe measurement construction key performance indicators in Australia [20]. They present more approach in performance measurement. They claim, that it depends from resource of measurement. It's different to say key performance indicators for project and other for construction business. Based on this, they set 10 KPIs. Productivity is number seven between them. According this study, productivity is economic KPIs. In addition, there are two more powerful groups of KPIs. There are social KPIs and environmental KPIs. Another authors claim, that KPIs present one the factors that constitute construction project success criteria which is the reason while performance measurement on construction projects are usually carried out [21]. According this study, it's not possible measuring only one performance indicators. But, it's very important to set trend. Productivity is one of the most powerful indicators for performance measuring in construction project management. They set and confirmed these KPIs in construction industry:

- Construction time
- Profitability
- Project management
- Material ordering, handling and management
- Risk management
- Quality assurance
- Client satisfaction (product)
- Safety
- Time predictability (project, design, construction)
- *Productivity*
- Client satisfaction (service)
- Cost predictability (project, design, construction)
- Procurement Construction cost
- Defects
- Human resource management

There are many researches, that was analyzed KPIs in construction industry. Some authors tried defining these performance indicators. More information about these researches and KPIs are detailed described in Table 1.

There are sample, that productivity is very important factor for project performance measuring. The issue of sue BIM technology and its impact on productivity is necessary to discusses and find new way, how to achieve increasing of this parameter.

Table 1 Key performance indicators in construction project management [22–25]

Research		KPIs—key performance indicators
Title	Autor	
12 Business metrics that every company should know	Karola Karslon	Sales revenue
		Net profit margin
		Productivity
		Sales growth year-to-date
		Cost of customer acquisition
		Customer loyalty and retention
		Net promoter score
		Qualified leads per month
		Lead-to-client conversion rate
		Monthly website traffic
		Met and overdue milestones
		Employee happiness
12 Key financial performance indicators you should be tracking	Bill Gerber	Operating cash flow
		Working capital
		Current ratio
		Debt to equity ratio
		LOB revenue versus target
		LOB expences versus budget
		Accounts payable turnover
		Accounts receivable turnover
		Inventory turnover
		Productivity
		Quick ratio
		Customer satisfaction
11 Key business performance metrics for better operations	Alicia Wiliams	**Financial business performance metrics**
		Gross profit margin
		Net profit
		Net profit margin
		Debt asset ratio
		Marketing business performance metrics
		Return on advertising spend
		Customer acquisiton cost
		Time to payback
		Marketing oroginated customer percentage
		Employee business performance metrics
		Employee efficiency and productivity
		Quality of work
		Adherence to values

2 Methodology

The issue of use BIM technology and measuring its impact on productivity in construction project management is difficult process. Construction project management has more specifics. First of all, there are more participants with different interests. The measurement way it must be different. It's not about one manager, or employee, but it's must by based on more interest's people. Use of BIM technology was examined in random selected construction projects. It's rate of use BIM technology in some project phase. That means 3D software and another supporting BIM concept. The main aim of research was analyzing the use of BIM technology in construction project management and analyze its impact on productivity on construction project management.

Data collection was done by questionnaire about productivity and use of BIM technology in construction project management. Research sample includes 65 participants of construction projects and project managers, and they set value of use BIM technology and its impact on productivity like one of the most powerful key performance indicators in construction field. More information about research sample and participants of construction projects are recorded in Fig. 1. Respondents evaluated the productivity in the construction project. It was answer not only one expert, for each project group of experts (project manager, employees, and so on.). Based on these more values for each project were set mean and standard deviation. It was set a Likert scale from 1 to 5. Perception of project participants and in this case, respondents too were important value for data processing in this research.

Research sample includes participants of construction projects. There is different business in construction industry, that participated on construction projects. Every project includes more experts, not only one in this project. It's important for objectivity of research results.

Data processing was based on statistical methods. In data processing was used Chi square test. The range of all possible values of the random variable is divided into k non-overlapping parts. For each part, the probability of p_i that the random variable takes values from some part. The expected frequencies in each section are compared Np_i with real frequencies X_i using the formula:

$$\chi^2 = \sum_{i=1}^{k} \frac{(X_i - Np_i)^2}{Np_i} \tag{1}$$

Another case of this it was used the Cronbach's alpha. Cronbach's alpha is a statistic commonly quoted by authors to demonstrate that tests and scales that have been constructed or adopted for research projects are fit for purpose [26].

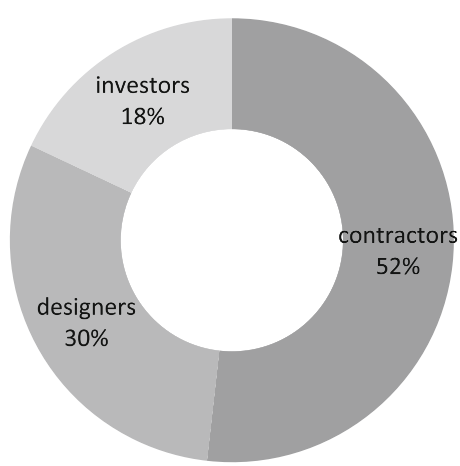

Fig. 1 Research sample in construction project management by construction project participants

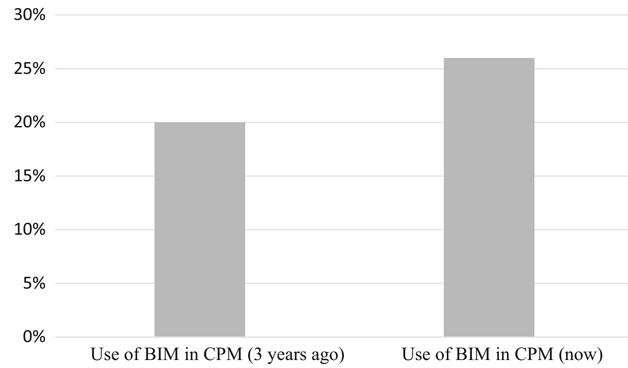

Fig. 2 Use of BIM technology in construction project management (in Slovak construction industry)

3 Results

Construction project management is difficult process and it depends on many activities and parameters. Progressive technology like BIM technology can be helpful with them.

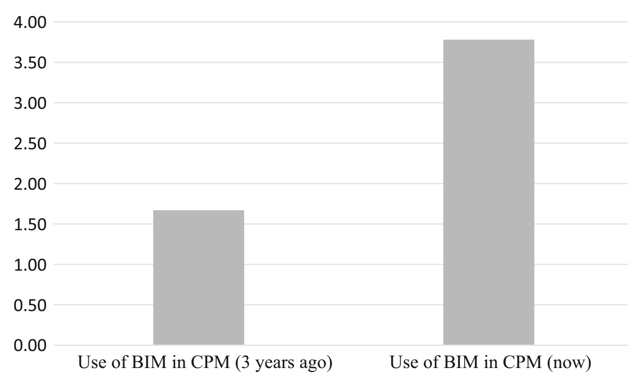

Fig. 3 Use level of BIM technology in construction project management

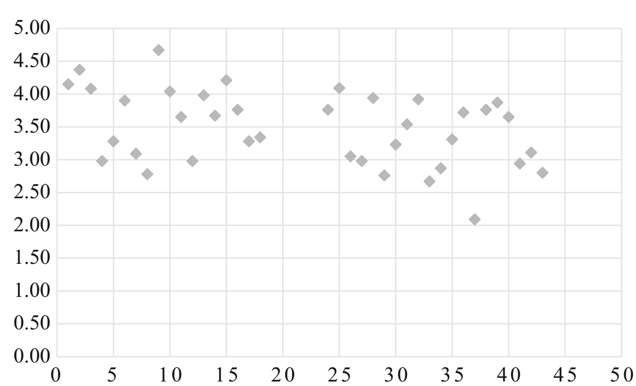

Fig. 4 Floating the resulting productivity impact values

Table 2 Final results of BIM impact

	All participants			Contractors			Designers			Investors		
	Mn	SD	Rk	Mn	SD	Rk	Mn	SD	Rk	Mn	SD	Rk
A1	4.15	0.345	1	4.15	0.345	1						
A2	4.37	0.789	3	4.37	0.789	5						
A3	4.08	0.624	9				4.08	0.624	3			
A4	2.98	1.456	12							2.98	1.456	11
A5	3.28	0.876	20				3.28	0.876	7			
A6	3.90	1.239	23	3.90	1.239	9						
A7	3.09	0.652	4	3.09	0.652							
A8	2.78	0.879	2				2.78	0.879	2			
A9	4.67	1.082	10	4.67	1.082	2						
A10	4.04	0.916	19	4.04	0.916	15						
A11	3.65	0.652	13	3.65	0.652	16						
A12	2.98	0.921	63							2.98	0.921	12
A13	3.98	0.654	39	3.98	0.654	4						
A14	3.67	0.765	43				3.67	0.765	9			
A15	4.21	0.543	27							4.21	0.543	54
A16	3.76	0.917	45				3.76	0.917	45			
A17	3.28	1.097	41	3.28	1.097	3						
A18	3.34	0.263	37	3.34	0.263	6						
…	…	…	…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…	…	…	…
A46	3.76	0.602	28	3.76	0.602	8						
A47	4.09	1.725	11				4.09	1.725	34			
A48	3.05	0.234	36				3.05	0.234	12			
A49	2.98	0.435	61							2.98	0.435	4
A50	3.94	0.234	5	3.94	0.234	15						
A51	2.76	0.846	7	2.76	0.846	18						
A52	3.23	1.345	18	3.23	1.345	20						
A53	3.54	1.002	22				3.54	1.002	39			
A54	3.92	0.528	49	3.92	0.528	22						
A55	2.67	0.211	15	2.67	0.211	19						
A56	2.87	0.513	44							2.87	0.513	11
A57	3.31	0.522	16	3.31	0.522	14						
A58	3.72	0.112	8	3.72	0.112	17						
A59	2.09	0.121	60							2.09	0.121	7
A60	3.76	0.111	29	3.76	0.111	4						
A61	3.87	0.227	45	3.87	0.227	14						
A62	3.65	0.332	48				3.65	0.332	43			
A63	2.94	0.409	20				2.94	0.409	57			
A64	3.11	0.922	38				3.11	0.922	18			
A65	2.80	0.287	59	2.80	0.287	12						
Cronbach's α	0.901			0.838			0.942			0.832		
Number of Respondents (n)	65			22			11			6		
$\chi2$	147.756			145.361			96.015			138.844		
df	65			65			65			65		

Table 2 (continued)

	All participants			Contractors			Designers			Investors		
	Mn	SD	Rk	Mn	SD	Rk	Mn	SD	Rk	Mn	SD	Rk
Significance level (p)	0.004			0.003			0.003			0.002		

Generally, implementation of information and communication technology should be bringing some miserable improving. That's reason why is important checking key performance indicators in construction project management. There is assumption, that BIM technology can increasing productivity in construction project management.

Use of BIM technology in constriction project management is increasing in the last decades. In similar research before 3 years ago, it was a rate of use of BIM technology less than 20%. But actually, this situation is better. Actually, from this research, The BIM technology use in more than 26% of construction projects from addressed and researched projects (see Fig. 2).

Use of BIM technology increasing for last years. It shown research and it was confirmed in other countries too. That's very important information for systematic software works and increasing automatization in construction project management.

Next figure (see Fig. 3) shown level of Use of BIM technology in construction project management. It confirmed utilization of this.

Based on a literature review and assumption, that BIM technology can be helpful in increasing of productivity, it was done research about impact of use of BIM technology on productivity in CPM. Figure 4 shown level and value of participants answer. Impact value floating about 3.5 value, what presents significant impact. There is only selected sample for illustration. Generally, research shown trend in this field.

Significant value can be considered each value more than 3.5 and it's mean probably high level of impact on productivity in construction project management. But, it's not only about value. This research must be confirmed statistical methods and other tests. Table 2 described detailed value and results of statistical tests for confirmation assumption, that use of BIM technology impacts on productivity in constriction project management.

Cronbach's alpha and Chi square were used in data processing and for confirmation of statistical results. It achieved value 0.901 for all participants. Generally, these tests confirmed dependence. These results shown, that progressive technology and information and communication technology can be helpful in construction project management and BIM technology impact on productivity. All respondents tried eliminated other factors which can influence on results. That's very important information for confirmation of research results.

4 Conclusion

Management of construction projects is difficult and technology-requirement processes. BIM technology brings a lot of advantages. It's helpful tool for construction project management. Generally, it can be possible to say that progressive technology and information and communication technology increasing project results and they have positive impact on many processes. BIM technology represents one of the most progressive tools in construction project management and many project managers sign it for the most important tool in their everyday work. But, the aim of this research it was analyze the use of BIM technology and its impact on productivity in construction project management. Implementation of BIM technology can mean first rejected change by employees and it must by done the teaching process in new system. In spite of this, research confirm increasing productivity on next time. It's was confirmed by examine tests. Productivity presents one of the so-called key performance indicators in construction project management. It's first step to achieve better project results in construction industry. Statistical test confirmed assumption, that BIM technology has a real impact on productivity as a one of KPIs in construction project management.

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References

1. Knapčíková, L., et al. (2018). Advanced materials based on the Recycled Polyvinyl Butyral (PVB). In *MMS Conference 2017. EAI, Ghent* (pp. 1–9).
2. Knapčíková, L., et al. (2016). Material recycling of some automobile plastics waste. *Przemysl Chemiczny, 95*(9), 1716–1720.
3. Mesároš, P., Behúnová, A., Mandičák, T., & Behún, M. (2019). Impact of enterprise information systems on selected key performance indicators in construction project management—an empirical study. *Wireless Networks*. https://doi.org/10.1007/s11276-019-02048-w.

4. Krajníková, K., Smetanková, J., & Behúnová, A. (2019). Green buildings and building information modelling. *Strojárstvo Extra, 23*(9), 1–6.
5. Kol'veková, G., et al. (2019). Regional tourism clustering based on the three Ps of the sustainability services marketing matrix: An example of central and eastern European countries. *Sustainability, 11*(2), 1–18.
6. Behún, M., et al. (2018). The impact of the manufacturing industry on the economic cycle of European Union countries. *Journal of Competitiveness, 10*(1), 23–39.
7. Ahmadian, F. F. A., Rashidi, T. H., Akbarnezhad, A., & Waller, A. S. T. (2017). BIM-enabled sustainability assessment of material supply decisions. *Engineering Constructustion Architect Management, 24,* 668–695. https://doi.org/10.1108/ECAM-12-2015-0193.
8. Jung, Y., & Joo, M. (2011). Building information modelling (BIM) framework for practical implementation. *Automatization in Construction, 20*(2), 126–133. https://doi.org/10.1016/j.autcon.2010.09.010.
9. Howard, R., & Björk, B. C. (2008). Building information modelling—experts' views on standardization and industry deployment. *Advanced Engineering Informatics, 22*(2), 271–280. https://doi.org/10.1016/j.aei.2007.03.001.
10. Karshenas, S., & Niknam, M. (2013). Ontology-based building information modeling. In *2013 ASCE international workshop on computing in civil engineering, IWCCE 2013*, Los Angeles, CA (pp. 476–483).
11. Bradley, A., Haijiang Li, H., Lark, R., & Dunn, S. (2016). BIM for infrastructure: An overall review and constructor perspective. *Automatization in Constriction, 71,* 139–152.
12. Olawumi, T. O., Chan, D. W. M., & Wong, J. K. W. (2017). Evolution in the intellectual structure of BIM research: A bibliometric analysis. *Journal of Civil Engineering and Management, 23*(8), 1060–1081. https://doi.org/10.3846/13923730.2017.1374301.
13. Alsayyar, B., & Jrade, A. (2015). Integrating building information modeling (BIM) with sustainable universal design strategies to evaluate the costs and benefits of building projects. In *Proceedings of the 5th international/11th construction specialty conference* (pp. 1–10).
14. Olawumia, T. O., Chana, D. W. M., Wongb, J. K. W., & Chana, A. P. C. (2018). Barriers to the integration of BIM and sustainability practices in construction projects: A Delphi survey of international experts. *Journal of Building Engineering, 20,* 60–71.
15. Gilkinson, N., Raju, P., Kiviniemi, A., Chapman, C., Raju, P., & Chapman, C. (2015). Building information modelling: the tide is turning. *Proceedings of the Institution of Civil Engineers-Structures and Buildings, 168,* 81–93. https://doi.org/10.1680/stbu.12.00045.
16. Olatunji, S. O., Olawumi, T. O., & Awodele, O. A. (2017). Achieving value for money (VFM) in construction projects. *Journal of Civil and Environmental Research-International Institute for Science, Technology and Education (IISTE), 9,* 54–64.
17. Olawumi, T. O., & Chan, D. W. M. (2018). Identifying and prioritizing the benefits of integrating BIM and sustainability practices in construction projects: A Delphi survey of international experts. *Sustainable Cities and Society, 40,* 16–27. https://doi.org/10.1016/j.scs.2018.03.033.
18. Shashank, K., Hazra, Sutapa, & Nath Pal, K. (2014). Analysis of key factors affecting the variation of labour productivity in construction projects. *International Journal of Emerging Technology and Advanced Engineering, 4*(5), 152–160.
19. Neely, A., Adams, C., & Kenerley, M. (2002). *The performance prism: The scorecard for measuring and management business success*. London: Prentice-Hall.
20. Furneaux, C., et al. (2000). Australian Construction Industry KPIs. ResearchGate.
21. Sibiya, M., Aigbavboa, C., & Thwala, W. (2014). Construction projects' key performance indicators: A case of the South Africa construction industry.
22. Karslon, K. (2019). 12 Business metric that every company should know. Retrieved November 3, 2019, from https://www.scoro.com/blog/12-business-metrics.
23. Gerber, B. (2018). 12 Key financial performance indicators you should be tracking. Retrieved November 3, 2019, from https://www.accountingdepartment.com/blog/12-key-performance-indicators-you-should-be-tracking.
24. Wiliams, A. (2017). 11 Key business performance metrics for metrics better operations. Retrieved November 3, 2019, from https://alistemarketing.com/blog/business-performance-metrics.
25. Jackson, T. (2018). 18 Key performance indicator (KPI) examples defined. Retrieved November 3, 2019, from https://www.clearpointstrategy.com/18-key-performance-indicators/.
26. Taber, K. (2017). The use of Cronbach's alpha when developing and reporting research instruments in science. *Education*. https://doi.org/10.1007/s11165-016-9602-2.

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