The Impact of Information and Communication Technology on Cost Reducing in the Execution Phase of Construction Projects

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Abstract **–This research discusses the issue of ICTs impact on cost reducing in the execution phase of a construction project. The main objective of the research is to analyse and quantify the impact of selected ICTs on cost reducing in the execution phase of a construction project and design the list of ICTs with impact on cost reducing in the phase of a construction project. The research sample includes all construction project participants in Slovak construction industry. It includes mainly contractors and sub-contractors. Designers and investors were implemented into the research too. Several exact methods are used for the research. The results of the research are verified by the Kruskal-Wallis test.**

Keywords **– Information and communication technology, cost saving and reducing, execution phases, construction projects**

1. Introduction

Construction industry is an area where competition is relatively large [1].

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Construction companies need to look for solutions to overcome competition and be better [2]. One option for achieving competitive advantage is cost saving and reducing in the construction industry [3]. One option for achieving a competitive advantage is cost-saving and reducing in the construction industry [3]. On the one side, it is a total cost reduction in construction projects [4] and on the other hand, it is the cost of the management process in the construction industry and projectsthe management process in the construction industry and projects.

Based on several studies, management processes were also presented as a significant cost item in the management of construction projects. The need to reduce the cost of these processes is necessary for the prosperity of the enterprise [5]. Another view of the costs in the field is the cost in the execution phase of a construction project. Several experts in the sector claim that the execution phase represents the biggest cost [6], [7]. Based on these facts, it can be said that the construction industry requires investment in technologies to achieve cost reducing. Cost reducing in projects can be achieved by different ways. One of them is to invest in new equipment and facilities. This is the way how to achieve total cost savings in the long time period. This doesn´t way how to reduce the cost of the management process, this is equally important. For these reasons, project managers are trying to invest into the information and communication technologies (ICTs). This can be one of the ways to reduce the cost of construction project management. Here, however, the question arises: What impact do the ICTs have on the cost of the construction project management? It´s necessary to quantify that, what represents the first step for cost minimizing and reducing.

2. Information and Communication Technology in the Construction Industry

The information is very important in construction industry [8]. Several experts in the field confirm this.

Effective communication and information exchange is very important. Many of the participants in the construction project represent this reason [9]. It confirmed another fact about the need to have timely information for managers due to: time saving of project duration, making better exploitation of resources, increasing productivity and the last one, decreasing costs [10]. Other authors [11], [12] have also confirmed cost reduction flowing from sufficient early information [13], [14]. Better communication and timely information can be provided by the ICTs [15], [16], [17].

According to Doherty, information technology is possible defined like technology using handle data, information and knowledge. It includes use of devices, software for purpose of storage, transfer, processing and presentation of information and results [18]. The ICT is a complex of technical and program resources. It includes communication technologies that enable the processing and manipulation of data [19].

As can be seen from the above, ICT is on the one hand technical equipment (hardware), which now includes a wide range of equipment that can be used directly on site. The most common are all types of computers (corporate, portable, tablets), communication devices (Smartphone), and so on. On the other hand, software solutions and applications that support the exchange of data and information (communication) between individual participants are also necessary. Integration of hardware, software and application solutions is a system. Effective construction project management is a demanding process due to the high number of participants and interest groups. This also entails great demands on the interconnection of systems that are often beyond the individual businesses. Information and communication technologies make up a huge complex of various technical and program resources, tools and systems that ensure the high performance of current ISs [20]. The ICTs are providing construction enterprises with new opportunities for enhancing information management processes, communication and collaboration [21]. According to Peansupap, ICT implementation in the construction industry can present an important driver for improving the efficiency and effectiveness of production [22]. Based on past facts, it can be said that ICT is essential in the field of construction for the management of construction projects [28]. Also, on this basis, it can be assumed that ICT will have a significant impact on the reduction of construction project management costs.[31], [32]. This is an important knowledge or assumption that represents the main research question in this area. This stems from the analysis of several sources (Table 1.) and previous definitions and information on this topic.

Table 1. Literature review about ICT in construction industry

Title of publication	Year of publi-cation	Authors
Use of ICT for e-procurement in the UK construction industry: a survey of SMEs readiness	2004	*Wong and Sloan [11]*
Implementation of enterprise resource planning ERP systems in the construction industry	2003	*Ahmed et al. [24]*
An investigation into the use of ICT in the Nigerian construction industry	2007	*Adebayo and Oladapo [23]*
Exploitation of semantic web technology in ERP systems	2007	*Anjomshoaa et al. [25]*
The Impacts of Enterprise Resource Planning Systems on Firm Performance: An Empirical Analysis of Chinese Chemical Firms	2010	*Liu, Miao and Li [26]*
Promoting the use of ICT in the construction industry: Assessing the factors hindering usage by building constractors in Ghana	2012	*Sekou [16]*
The Impact of Enterprise Resource Planning (ERP) System on the Cost and Price of Auditing–Auditor's Perspective	2013	*Azaltun et al. [27]*
Application of ICT in the construction industry in Kampala.	2014	*Mutesi and Kyakula [14]*
Factors for the acceptance of enterprise resources planning (ERP) systems and financial performance	2015	*Bazhair and Sandhu [26]*

Based on the theoretical analysis, the groups of information and communication technologies that are related are defined and specified. Each research area

therefore included the following technology groups and it is very important for the purposes of this research in this area:

i. Communication technology (or systems) - (CTs, CSs). It includes PCs, notebooks, smartphones, mobile devices, SMS technology, fax, and application-supported communication as Skype, Hangouts, Viber and so on.
ii. DMS systems and support systems for document and data exchange (DMS). It includes DMS, cloud-computing technology, server, free applications for sharing documents (for example Google docs, drive, Dropbox, MS Sharepoint, iCloud and so on) and administration systems.
iii. Information system (IS). It includes ERP systems, controlling systems, Business Intelligence, BIM technology, CAD software, GIS and GPS, auction systems, cost management software, schedule software, project management software.

3. Research Methodology

3.1. Problem Statement, Research Questions and Aims

The issue of information and communication technology in construction industry is very current topic in context of cost reducing. It claims a lot of researches and studies are based on a theoretical background. The general assumption that ICT has an impact on cost reducing at each stage is based on several assertions. In terms of costs and investments, the construction phase of the construction project is the most financially difficult.

This is the reason why we need to address this issue a lot more in this phase. This has raised several research questions:

- Which ICTs have an impact on cost reducing in the implementation phase of a construction project?
- What is the impact of these ICTs on cost reducing of construction projects?
- Based on these questions and theoretical background the main research aims were established:
- Analyse and quantify the impact of selected ICTs on cost saving in the execution phase of a construction project,
- Design the list of ICTs with impact on cost reducing in a phase of a construction project.

3.2. How to Measure and Quantify the Impact of the ICTs?

The selection and method of measuring and quantifying the impact is an important process. This selection is based on the nature and substance of the research and obtaining data. The possibility of quantifying the impact is possible on the basis of the so-called impact level. Likert scale ranging from 1 to 5 was used for quantification (where 1- is minimal impact and 5 - is maximal impact). According to group of authors, the value 3.5 is reference value. Values greater than 3.5 may be considered as significant. This method is most commonly used in the assessment of the ICT.

Very important is the interpretation of research results and statistical significance (reliability and verification of all results). Verification is based on statistical testing of results for each research group. Statistical significance was tested by Kruskal–Wallis H test. Statistical significance was $\alpha = 0.05$ [29], [30].

First step (1) is average range, or average value. The test statistic is given by [29], [30].

$$H = (N-1) + \frac{\sum_{i=1}^{g} \boldsymbol{n_i} \, (\boldsymbol{r_i} - \acute{r})}{\sum_{i=1}^{g} \sum_{j=1}^{ni} \boldsymbol{n_i} \, (\boldsymbol{r_{ij}} - r)} \quad (1)$$

where:

ni is the number of observations in group i
rij is the rank (among all observations) of observation j from group i
N is the total number of observations across all groups (participants)

Final formula (2) is follow:

$$H = \frac{12}{N\,(N+1)} \sum_{i=1}^{g} \boldsymbol{n_i} \, \acute{r}_i - 3(N+1) \quad (2)$$

3.3. Data Collection and Research Sample

A questionnaire was used for data collection. The questionnaire was sent to construction enterprises in Slovakia. It includes contractors, sub-contractors, designers and investors and relevant persons were asked and responsible for collecting data for the business. The questionnaire was anonymous, but the on-line system only secured the fill-in of the peer-to-peer based on the recognition of the uniqueness of the IP addresses.

The structure of the questionnaire contended three parts. The first part was focused on general information of the respondents (construction enterprises). Those were basic general information about research parameters. They include information about the size and the owners of enterprises, definition of the status - participants of a construction of project and other features important for research

purposes. The next part includes information about the ICTs, especially exploitation of the ICTs. The last part of the questionnaire includes data about the impact of ICTs on cost reducing in the execution phase of construction projects.

Research sample was divided based on research parameters. Table 2. includes attributes of research groups. The first point of view is the enterprise size as a parameter for differences between results.

Table 2. Research sample and parameters

Enterprise size	Large enterprises Medium-sized enterprises Small enterprises Microenterprises	12.73 % 21.82 % 30.91 % 34.55 %
Owner (private Equity)	Foreign private equity Slovak private equity	20.36 % 79.64 %
Participant of construction project	Contractor Sub-contractor Designer Investor	50.91 % 23.64 % 18.18 % 7.27 %

Source: Own processing based on research data (Processing in STATICTICA software and MS Excl)

Large enterprises represent 12.73% of the respondents. Medium-sized enterprises represent 21.82% of the respondents. Research sample includes 30.91% of small enterprises and 34.55% of microenterprises. Research sample was selected by random choosing from database of construction enterprises. Divided according to owner or exploitation of private equity is another important parameter. 80.64% of enterprises use Slovak private equity. In other words, it's Slovak owner. 20.36% of respondents use foreign private equity. There are enterprises with a foreign owner, or enterprises, that are managed by other foreign company. Last point of view is divided of research sample by participant of construction project. Contractors are represented by 50.91% of the respondents, and sub-contractors are represented by 23.64% of the respondents. 18.18% of the respondents are designers. Investors are represented by 7.27% of the respondent.

4. Results and Discussion

Communication Technology

The execution phase represents the most extensive part of the construction project, both in terms of time and cost. The results should be placed on the selection and use of ICTs, which are a prerequisite and instrument for achieving decreasing of the costs in CPM and thus on the total cost savings. Communication technology (CT) is principally used for communication and coordination of activities in the execution of construction projects. Mobile phones, as well as PCs and laptops are also widely implemented, as well as communication-supporting applications. The Figure 1. shows the impact of communication technology on cost reducing in the execution phase. This level achieved the value 3.75 and in the total cost section it achieved 3.63. These results confirmed the theory of positive impact on cost reducing in this field. As we can see, large construction companies used more technology, and generally it brought highly impact than in small enterprises (Figure 1.).

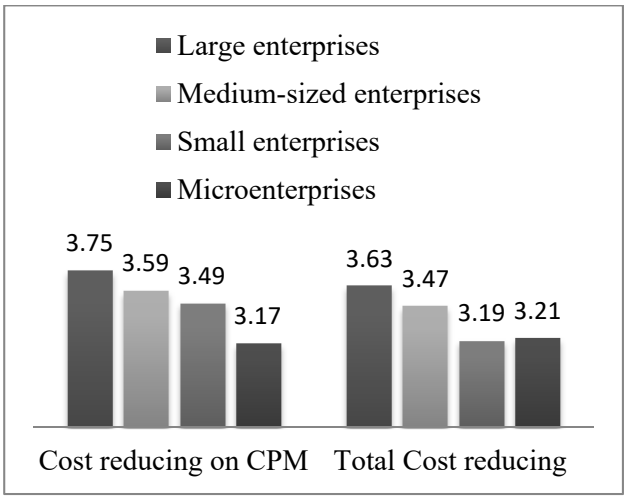

Figure 1. The impact of communication technology on cost reducing in the execution phase

Figure 2. presents the results in terms of the division of construction enterprises by majority owner. CTs require a considerable amount of investment to implement them. Generally, it´s confirmed that foreign companies give more investments to the technology. Their impact is higher in both monitored areas.

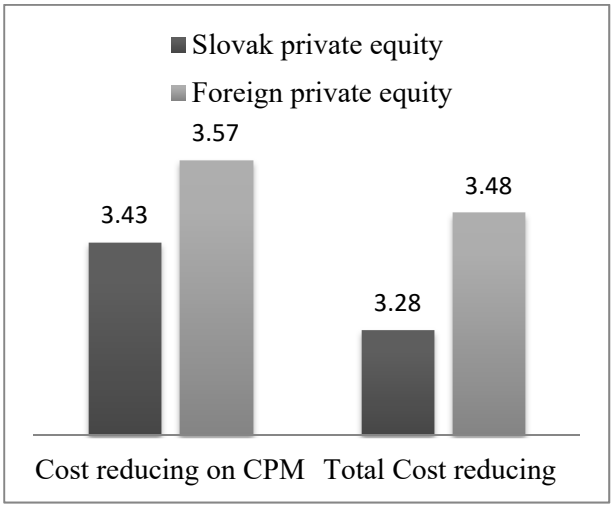

Figure 2. The impact of communication technology on cost reducing in the execution phase

Major contractors have seen a more significant impact of CTs utilization on reduction of CPM cost

up to 4.44. Sub-contractors recorded a very high rate of 3.95. The largest impact was recorded for contractors and the lowest impact was for designers. The same results were confirmed for total cost reducing.

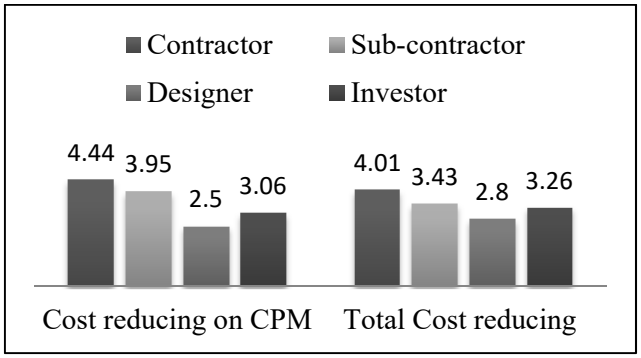

Figure 3. The impact of communication technology on cost reducing in the execution phase

DMS Systems and Support Systems for Document and Data Exchange

DMS systems and support systems for document and data exchange are widely used in the project phase. Their use is relatively extensive in the execution phase of the construction project. The situation is similar to the one in the IS. Large companies recorded high impact in both fields. Microenterprises achieved the lowest results.

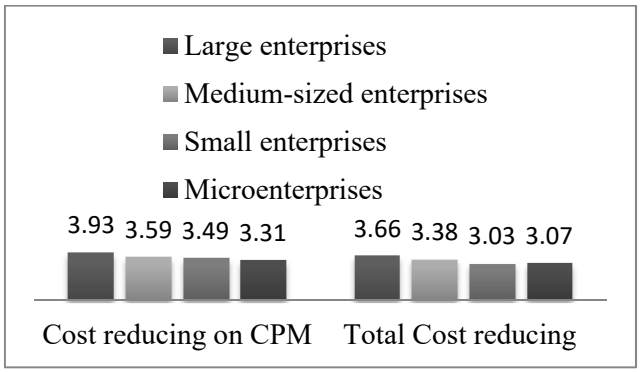

Figure 4. The impact of DMS systems on cost reducing in the execution phase

Construction enterprises using foreign private capital once again have a greater impact on cost reducing due to the use of DMS.

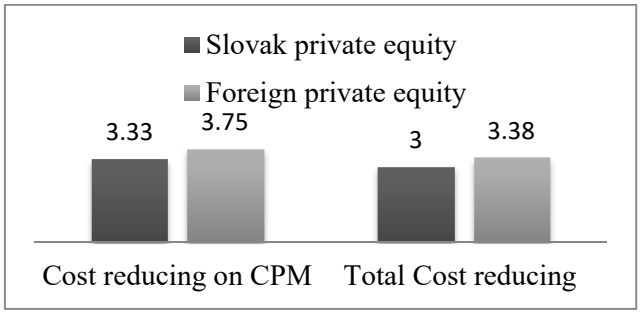

Figure 5. The impact of DMS systems on cost reducing in the execution phase

Construction enterprises using Slovak private capital have reached 3.33 and 3. In terms of specific technologies, it is necessary to draw attention to cloud-computing technology that has a significant impact on cost reducing.

In the case of individual project participants on the basis of exploitation research and the consequent impact on cost reducing, some differences were recorded.

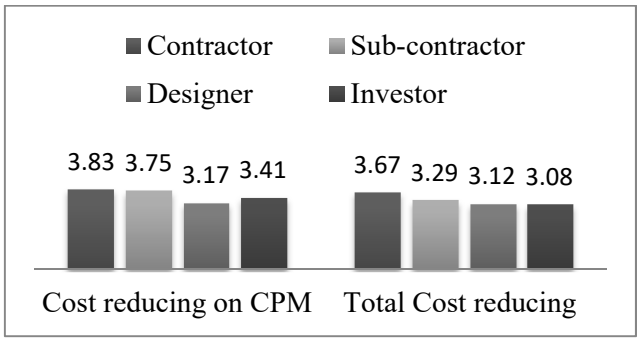

Figure 6. The impact of DMS systems on cost reducing in the execution phase

Information Systems

ISs also greatly contribute to reduce the cost of the CPM in large enterprises, including the execution phase. In terms of enterprise size breakdown, complex ERP systems played a significant role. The BIM technology also contributed to this.

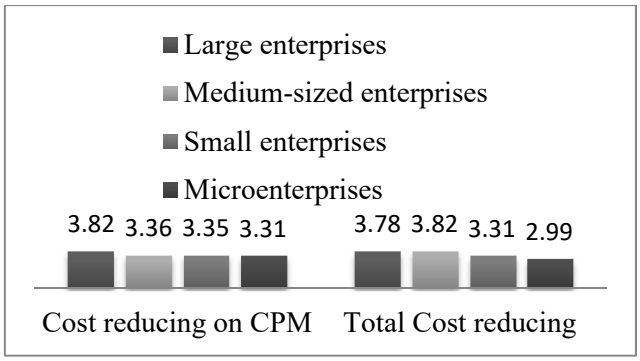

Figure 7. The impact of information systems on cost reducing in the execution phase

Figure 8. describes the results of the impact of ISs on cost reducing by prime equity. Again was confided the advantage of foreign private equity to investments in this technology.

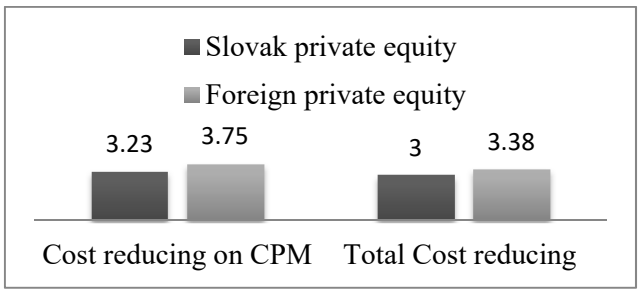

Figure 8. The impact of information systems on cost reducing in the execution phase

Similar sub-suppliers were approached, even though their level was lower. The similarity of the results depends to a certain extent on the subject of performing the same or similar activities as the main contractors. Due to the fact that the sub-contractors are predominantly smaller construction companies, this also reflected on the results, namely in a comparison with the main suppliers which reached higher impact values. The designers who were at the execution phase of the construction project had the least impact on the cost reduction.

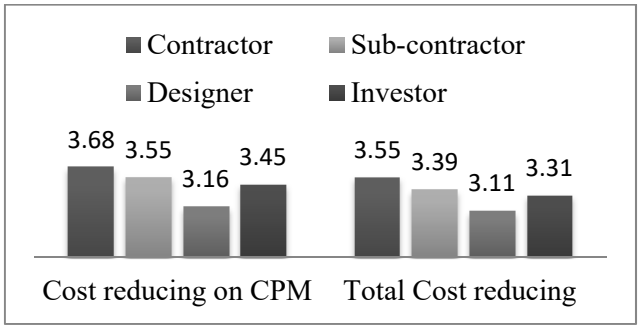

Figure 9. The impact of information systems on cost reducing in the execution phase

The impact on cost savings for the management of construction projects was 3.16 and the total cost was only 3.11.

Developers and investors recorded higher values at 3.45 on the impact on cost savings on the management of construction projects and 3.31 on the impact on the reduction of the total cost of the construction project.

Table 3. describes the values of the Kruskal-Wallis test and the impact of selected ICTs on cost reducing. The Kruskal-Wallis test demonstrated the impact of selected technologies, which are marked in gray. There are DMS based on cloud computing (factor of size and owner), ERP systems (factor of size and owner), controlling systems (factor of owner) and BIM technology (factor of size and owner). These technologies have confirmed both a significant impact on cost reducing, as well as the factors influencing the results of each area. The results show that important ICTs on the one hand are important, on the other hand, it also depends on the size of the enterprise or the owner too, as the tests have demonstrated.

The assumption that the ICTs have impact on cost reducing was in some technologies confirmed. It must be done by 2 conditions. Value more than 3.5 must be confirmed by Kruskal-Wallis test. Main results are signed by grey field. Some results were confirmed only in special divided (e.g. the size of construction companies and so on.).

Table 3. The impact of information and communication technology on cost reducing in the execution phase of construction projects

Technology	Factor	K-W ANOVA (p)	Group	Impact level on cost reducing (total cost point of view)
Communication systems				
(CS) PC a notebook	Size	0,8852	Large enterprises	**4,00**
			Medium sized enterprises	**3,80**
			Small enterprises	**3,56**
			Microenterprises	**3,72**
	Owner (equity)	0,9165	Slovak private equity	**3,71**
			Foreign private equity	**3,78**
	Participant of CP	0,6458	Main contractor	**3,88**
			Sub-contractor	**3,82**
			Designer	3,20
			Investor/developer	3,50
(CS) Smartphones and tablets	Size	0,9806	Large enterprises	**3,60**
			Medium sized enterprises	3,45
			Small enterprises	3,19
			Microenterprises	**3,56**
	Owner (equity)	0,9895	Slovak private equity	3,39

			Foreign private equity	**3,55**
	Participant of CP	0,8239	Main contractor	3,50
			Sub-contractor	3,18
			Designer	3,44
			Investor/developer	3,00
DMS systems and support systems for document and data exchange				
DMS systems	Size	0,3942	Large enterprises	**3,90**
			Medium sized enterprises	**3,85**
			Small enterprises	**3,73**
			Microenterprises	3,46
	Owner (equity)	0,2906	Slovak private equity	3,46
			Foreign private equity	**4,15**
	Participant of CP	0,4226	Main contractor	**3,98**
			Sub-contractor	**3,78**
			Designer	3,56
			Investor/developer	3,43
(DMS) Cloud	Size	**0,016**	Large enterprises	**4,13**
			Medium sized enterprises	**3,78**
			Small enterprises	3,47
			Microenterprises	3,44
	Owner (equity)	**0,0442**	Slovak private equity	3,48
			Foreign private equity	**3,98**
	Participant of CP	0,1042	Main contractor	**3,78**
			Sub-contractor	**3,81**
			Designer	3,23
			Investor/developer	**3,70**
(DMS) E-mail	Size	0,5128	Large enterprises	3,46
			Medium sized enterprises	3,43
			Small enterprises	3,39
			Microenterprises	3,41
	Owner (equity)	0,8416	Slovak private equity	3,49
			Foreign private equity	3,41
	Participant of CP	0,7149	Main contractor	**3,51**
			Sub-contractor	3,50
			Designer	3,40
			Investor/developer	3,42
Information systems				
(IS) ERP systems	Size	**0,0482**	Large enterprises	**3,89**
			Medium sized enterprises	**3,76**
			Small enterprises	3,43
			Microenterprises	3,12
	Owner (equity)	**0,0433**	Slovak private equity	3,43
			Foreign private equity	**3,78**
	Participant of CP	0,8335	Main contractor	**3,67**
			Sub-contractor	**3,66**
			Designer	3,43
			Investor/developer	3,40
(IS) Controlling systems	Size	0,0852	Large enterprises	**3,63**
			Medium sized enterprises	**3,64**
			Small enterprises	3,44
			Microenterprises	3,47
	Owner (equity)	**0,0472**	Slovak private equity	**3,75**
			Foreign private equity	**4,16**
	Participant of CP	**0,0338**	Main contractor	**4,31**
			Sub-contractor	**4,09**
			Designer	1,83
			Investor/developer	3,47

(IS) Business Intelligence	Size	0,5017	Large enterprises	**3,78**
			Medium sized enterprises	3,54
			Small enterprises	3,45
			Microenterprises	3,46
	Owner (equity)	0,222	Slovak private equity	3,38
			Foreign private equity	**3,69**
	Participant of CP	0,2712	Main contractor	**3,67**
			Sub-contractor	**3,64**
			Designer	3,46
			Investor/developer	**3,56**
(IS) BIM	Size	**0,0436**	Large enterprises	**3,67**
			Medium sized enterprises	**3,63**
			Small enterprises	3,43
			Microenterprises	3,18
	Owner (equity)	**0,0409**	Slovak private equity	3,29
			Foreign private equity	**3,65**
	Participant of CP	0,0542	Main contractor	3,43
			Sub-contractor	3,38
			Designer	**3,79**
			Investor/developer	**3,68**
(IS) CAD	Size	0,6503	Large enterprises	2,67
			Medium sized enterprises	2,78
			Small enterprises	2,76
			Microenterprises	2,56
	Owner (equity)	0,8011	Slovak private equity	2,59
			Foreign private equity	2,67
	Participant of CP	0,8394	Main contractor	2,14
			Sub-contractor	2,25
			Designer	3,13
			Investor/developer	2,39
(IS) Cost management software	Size	0,3613	Large enterprises	**3,75**
			Medium sized enterprises	**3,56**
			Small enterprises	**3,51**
			Microenterprises	3,43
	Owner (equity)	0,9865	Slovak private equity	3,48
			Foreign private equity	**3,72**
	Participant of CP	0,6317	Main contractor	3,13
			Sub-contractor	3,23
			Designer	**3,65**
			Investor/developer	**3,59**
(IS) Project management software, schedule programs	Size	0,6317	Large enterprises	3,15
			Medium sized enterprises	3,18
			Small enterprises	3,48
			Microenterprises	**3,52**
	Owner (equity)	0,5235	Slovak private equity	3,43
			Foreign private equity	3,42
	Participant of CP	0,8676	Main contractor	3,26
			Sub-contractor	3,26
			Designer	**3,57**
			Investor/developer	**3,58**
(IS) GIS and GPS	Size	0,4314	Large enterprises	3,45
			Medium sized enterprises	3,47
			Small enterprises	3,43
			Microenterprises	3,26
	Owner (equity)	0,3623	Slovak private equity	3,36
			Foreign private equity	3,47
	Participant of CP	0,2932	Main contractor	3,72
			Sub-contractor	3,73
			Designer	2,26
			Investor/developer	2,78

5. Conclusion

The issue of cost reducing in construction projects is a very important topic from a number of perspectives. On the one hand, it is the effort of all participants to minimize these costs. On the other hand, it strives for maximum utility and efficiency and maximum added value for the final user of the building. The current digital age brings many possibilities in the form of progressive technologies not only in building equipment, but also in the management process. Information and communication technologies are one of the options. However, their impact on cost savings was unclear. Research seeks to quantify and measure the impact of the use of the ICT in the implementation phase of construction projects. Based on the exact methods that were used for the research and treatment of the results, we can conclude that the ICT are important for cost reduction. Several technologies have confirmed the relevance of our research and its impact has been quantified. These technologies include ERP systems; DMS based on cloud computing approach, controlling systems and BIM technology. These results are based on data from the Slovak construction industry. Every market has its own specifics. Therefore, these results can be taken as a supportive tool to illustrate the impact of the ICT in reducing costs in construction projects. Therefore, other markets need to be examined for the final conclusions. What are these results in other countries? Currently, data collection is also taking place in other areas, currently in the construction industry in Croatia. For further scientific progress in this area, it will be an interesting sight to compare the results in these countries. It will be interesting to see if these technologies will have a similar impact on cost reducing of construction projects in other countries. Actually, the research is moving forward. Data will be evaluated and compared with data form Slovak construction industry.

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