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Information Technology Impact Factor Model in Life Cycle Cost Management of Construction Project

Peter Mésároš [1], Tomáš Mandičák [2]* and Marcela Spišáková [3]

[1] Faculty of Civil Engineering, Technical University of Košice; peter.mesaros@tuke.sk
[2] Faculty of Civil Engineering, Technical University of Košice; tomas.mandicakl@tuke.sk
[3] Faculty of Civil Engineering, Technical University of Košice; marcela.spisakoval@tuke.sk

* Correspondence: tomas.mandicak@tuke.sk; Tel.: +421-055-602-4378

Abstract: Construction project management and cost management is a difficult process that affects the overall success of construction projects. The success of a construction project can be assessed according to key performance indicators (KPIs). Cost savings and cost optimization over the life of a construction project is one of these KPIs. Cost management is largely performed through intelligent information technology in the construction industry. Information systems and information technologies have seen an increase in use in the management of construction projects. The same goes for cost management. Several studies mentioned in the paper point to this increase in use in recent years also in the management of costs at various stages. Many studies point to the use of information technology and software applications in the field of cost management. Still, to a large extent, there are no surveys focused on the analysis of the impact and impact factor of information technology on cost savings or cost optimization in various phases of construction projects. The research discusses the issue of the impact of information technology on cost management in various phases of a construction project. The main goal of the research is to analyze the influence of information technology factors on cost savings and optimization in individual phases of a construction project. Several statistical methods were used in the research. The resulting model of information technology impact factor was created based on data processing and the use of the AHP method.

Keywords: information technology; construction project management; cost management; impact factor model; progressive technology; construction industry, life cycle cost management.

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1. Introduction

The issue of successful management of construction projects and key performance indicators (KPIs) in construction is discussed by more studies, which agree on the importance of this issue [1], [2], [3]. A study of authors from Slovakia addressed the issue of lost profits in construction [4]. Other researchers discussed the issue of constriction workers productivity from KPIs [5]. In many cases, KPIs are addressed by the issue of costs in construction [6]. Costs associated with the management of construction projects and the total cost of the construction project are discussed many studies [7], [8], [9].

The life cycle cost (LCC) estimate system in construction projects was solved by the authors with a focus on train transport infrastructure projects [10]. The LCC Estimation Model was the subject of a study by Biolek and Hanák [11]. Researchers [12] addressed the issue of prices and costs, as well as the development of material costs throughout the construction project. Energy upgrading of residential building in context of LCC Analysis was discussed in case study in Italy [13]. LCC assessment approaches are detailed described in some sources [13]. Nevertheless, the issue of cost management still represents a large space for research.

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Information technologies have recently been intensively implemented in the field of construction project management [14]. Building information modelling (BIM) technology in particular is a frequently discussed topic in architecture, engineering and construction [15], [16]. This topic is also discussed in terms of training and work experience in the field of BIM [17]. The use of information technology in the field of construction also has several advantages, which are based on studies and surveys. On the one hand, it is about increasing the quality of construction projects also due to the use of new technologies [18]. Progress in the use of progressive materials in the industrial area has also occurred with the use of information technology [19]. Many studies point to the positive economic impact of information technology utilization [20]. The use of information and communication technologies also has other benefits. Economic benefits include improved competitiveness and productivity. It has an equally positive influence of safety in construction. According to Love and Matthews [21], these factors have been improved through the use of mainly BIM technology and the Internet of Things (IoT). Researchers at New York University Abu Dhabi (NYUAD) [22] have pointed to the positive impact on digitization productivity in construction. Another study [23] pointed to the positive impact of digital technologies in construction on improvement of construction industry performance. The implementation of information (especially BIM based technology) technology in AEC also brings positive improvements in performance in construction project management (CPM) [24]. A study by Khayyat [25] pointed to the positive impact of technology on construction costs.

Based on the above literature and a summary of this information, it can be assumed that the use of information technology in the field of cost management of construction companies has a positive impact. In other words, the use of information technology leads to cost savings in the management of construction projects. This raises another scientific question of how these technologies affect costs throughout the life cycle of a construction project. Another research question focuses on how to measure this impact and what methods to use. The research area of cost management and the use of information technology is relatively often researched. A detailed analysis of the issue of the impact of information technology on cost management in various phases of a construction project is still not described. This research seeks to answer these questions and create an Information Technology Impact Factor Model for life cycle cost management.

2. Materials and Methods

The issue of the impact of information technology on the costs of construction projects is a topic that requires the constant attention of participants in the construction project at all times. Overall, the study of the impact of information technology on KPIs is a comprehensive topic addressed in many studies published in the most valuable databases. However, the need to address this issue is not just about a scientific problem, but above all about the practice and use of this knowledge in the sector. The costs of construction projects or their savings and optimization, belong to one of the basic KPIs, which is monitored mainly in practice. Trying to analyze this information and find the optimal solution for setting up technologies is a challenge in every construction project.

The research focused on the analysis and compilation of an information technology impact model in the field of cost management and optimization throughout the project has several steps. It uses several methods to set, analyze and implement a research goal. The individual research steps are described in the relevant chapters.

2.1. Research Steps and Goal

The research goal to analyze the impact of information technologies on cost optimization in individual phases of a construction project and to design an information technology impact model for cost management during the life cycle of a construction project.

This goal was created after a thorough analysis of theoretical background and research in the field. Based on interviews with practitioners, a stimulus arose to solve this problem scientifically. The output of this research is a model that can be applied and verified in practice, but there are some pitfalls where these scientific results cannot be taken as the only decision-making tool.

The first step in establishing this scientific problem was an in-depth analysis of resources in the use of information technology while managing the cost of construction projects. This was also supported by interviews with experts in practice, including all participants in construction projects.

After determining the research problem and identifying the needs of the practice, a research goal was subsequently formulated. After formulating the research goal, the available scientific and statistical methods that can be used to achieve the set goal were evaluated (more detailed research steps are described in Figure. 1).

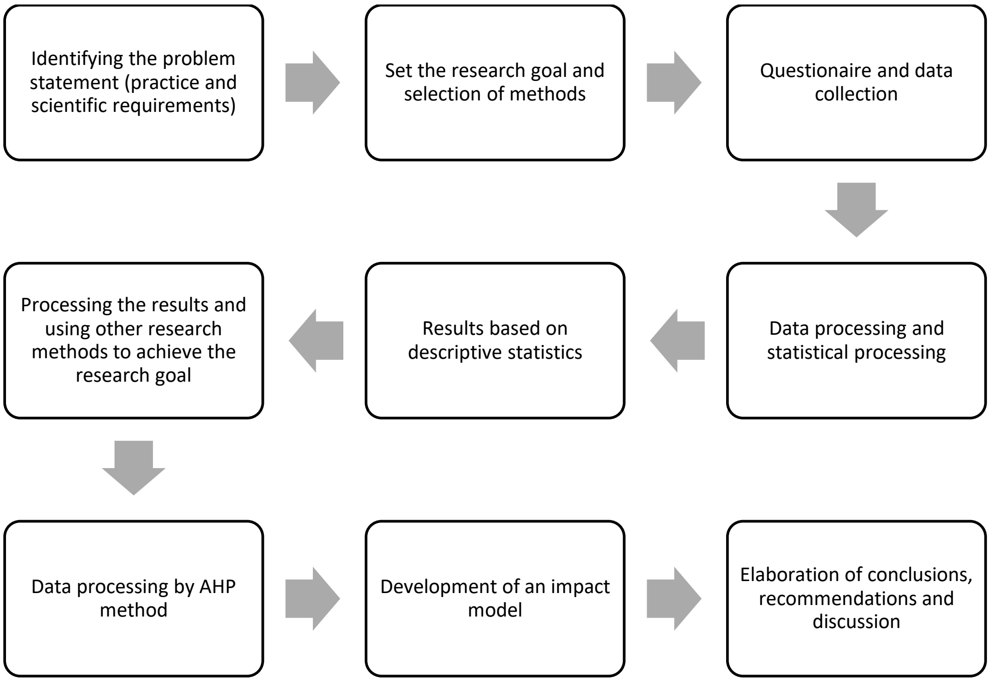

Figure 1. Research steps and activity to achieve the research goal

Due to the research problem, data collection was provided by a questionnaire from practice. The questionnaire was divided into several specific sections. The questionnaire was disseminated online and included questions focused on research issues. Data processing was followed by data collection. However, this was preceded by the selection of appropriate statistical methods. The choice of specific statistical methods was influenced primarily by the research sample and the identified research problem. It was mainly the distribution of the research sample concerning the number of respondents and the nature of the data. Also, the scientific goal (to find an impact model) narrowed the use of appropriate methods.

The final model was compiled on the basis of the use of the AHP method, which is based on the expert assessment of research questions by experts from practice. This final output of this research was determined as a reference model, which, however, applies under certain specific conditions. More information on the pitfalls of research is described in a separate chapter.

2.2. Data Collection and Research Sample

Data collection was provided by an online questionnaire. This form appeared to be the most efficient way to collect data due to its speed and simplicity. The questionnaire contained several thematic sections. The first part concerned general information about the research sample, based on which it was possible to make dependencies between the investigated phenomena. Although this information characterized the research sample, anonymity was ensured. The next part dealt with the issues of using information technology in various phases of the construction project. The next part was based on determining the impact of individual technologies on cost optimization in construction projects. This part was the most important for this research. The selection of the research sample was random. It was based on a database of construction companies and companies operating on the Slovak construction market. Construction companies of various sizes were involved in the survey. Likewise, the selection of participants in the construction project reflected all the interest groups in the construction project. Their relative distribution copied the distribution on the market so that there was no disparity between the real distribution of construction companies and the respondents.

A total of 1276 respondents (participants in construction projects in Slovakia) were asked to answer basic research questions. 125 respondents participated in the questionnaire survey, but only 55 companies filled in a complete questionnaire, usable in our research, which represents a return of 4.31%. Given the scope of the examined areas in the questionnaire survey, the return at the level of 4.31% can be considered as a good.

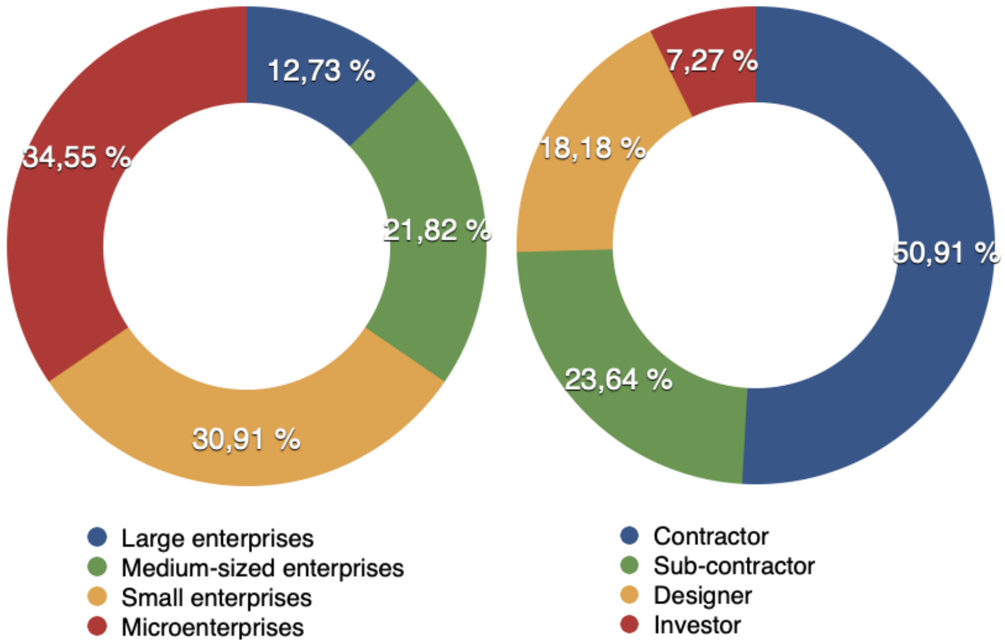

Figure 2. Research sample by company's size and participants of construction project

12.72% of respondents were large enterprises. This is not a breakdown by the total number of construction companies, but it is an interesting sample for the survey. SMEs respondents accounted for 52.73%. The breakdown of respondents according to the status of a participant in a construction project can be characterized as follows 50.91% of contractors, 23.64% sub-contractors, 18.18% of designers and 7.27% of investors.

2.3. Structure of Questioniare

This research understood the issue of the impact of information technology on life cycle cost management. Therefore, research questions aimed at identifying and collecting data for the analysis of the impact of information technology on costs had to be asked for each monitored phase of the construction project. These phases: pre-design, design and construction phase were monitored based on information from already completed construction projects, which are already used by users at this time. The use phase could not yet be processed in the research, as data collection is ongoing, and the processing of this longest phase takes a long time. Described in more detail in the section Obstacles of Research.

The first part of the data presents the basic characteristics of the research sample, based on which it was possible to make dependencies and categorize research groups and results. These were information on the size of the construction company, the participant in the construction project, the use of foreign capital and know-how, the region of operation, the experience of project managers, information on the construction project, etc.

The second part deals with issues related to the use of information technology for each phase separately. Information technologies aimed at reducing costs were mainly monitored. The third part was the most important from the point of view of the research topic. Project managers and other respondents were tasked with identifying on a liqueur scale from 1 to 5 (where 1 - the minimum impact of IT on cost-reducing; 5 - maximum impact) to determine the level of impact of selected IT on cost-reducing for the relevant construction cycle. This level should also be determined as a percentage (verification of construction project costs and possible savings) to verify the objectivity of the results and a correct understanding of the perception of quantification.

2.4. Data Processing

The data were evaluated based on several statistical methods using MS Excel and STATISTICA and MatLab software. Mostly descriptive and inductive statistics were used in processing the results of the research. When evaluating data from research areas of the use of information technologies and their influx to optimize the costs of construction projects, the so-called utilization rate, resp. the degree of impact they used in research to identify and quantify the benefits of using ICT in construction, including [26]. We got a measure of arithmetic averages from selected areas. A Likert scale in the range 1 - 5 was used to determine the response. Based on the determined values, an arithmetic average of the values for the selected research area was made. The result was the mentioned rate of utilization, or degree of impact. Subsequently, the results were interpreted in verbal and graphic form. The PAGES and NUMBERS tools and Excel were used for graphical processing and presentation of results.

The AHP method was used for the resulting model. The AHP (Analytic Hierarchy Process) method is a comprehensive methodology created for the purpose of decision-making when choosing from several options. The basis for using the AHP method is to outline the whole decision-making problem as a certain hierarchical structure. This is a classic tree representation and branching of the main problem into sub-areas that affect the main goal. The basis of the AHP method is the comparison of individual pairs of possibilities, where the pairs are compared by the system each with each value. The intensity or weight of the individual criteria is determined by a recognized team of experts [26]. In this case, they were participants in construction projects on behalf of individual construction companies. These experts were to determine the importance of the impact of information technology on reducing the overall cost of construction projects. This method is based on the value of the information obtained. The main purpose of this modification of the AHP method is to exclude subjective evaluation and to ensure independence in assessing individual criteria based on the amount of data [28]. Entropy measures the information content of a particular data set. It is a criterion for the amount of uncertainty represented by a discrete probability distribution. The selected method works by determining weights based on the "amount" of data it contains.

The AHP method is a tool for making a flexible model for decision-making, thus clarifying in more detail the problems that have several possible solutions [29]. AHP is performed by an expert and subsequently mathematical method, which divides the main problem into smaller and more detailed elements. According to Saaty, the AHP method can be divided into three different degrees [30]: hierarchy, priorities, consistency. The quantities R_{IJ}, the relative significances of the criteria, are arranged in a square matrix of relative significances R [31]:

$$R = \begin{pmatrix} r_{11} & r_{12} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2m} \\ \dots & & & \dots \\ r_{m1} & r_{m2} & \dots & r_{mm} \end{pmatrix} \quad (1)$$

The intensity coefficients of the relation of the i-th variant to the j-th variant are determined in the same way as Saaty states:

$$w_{ij} = \sqrt[m]{\prod_{k=1}^{m} s_m^j} \qquad i = 1, \dots, m\,; j = 1, \dots, n. \qquad (2)$$

in this relation m is the calculation of variants and *n* is the number of criteria. The final rating is determined as the weighted sum of the intensity coefficients [32]:

$$c_i = \sum_{j=1}^{n} w_{ij}\, v_j \qquad i = 1, \dots, m. \qquad (3)$$

2.5. Obstacles of Research

Research activities in this area have brought several limitations that could potentially reduce the value of the results or change the conclusions of the research. The research focused on the influence of information technologies on the optimization of construction project costs in individual phases of construction projects. These facts may lead to the question of the subjective evaluation of this respondent. However, this was prevented in the research by a detailed description with percentages for each area of research and question. Based on real accounting data, the respondent was able to clearly define the answer within the Likert scale.

Another issue from the point of view of the correct interpretation of the results and comparison was the size of the companies participating in the research and the establishment of a condition for the comparison of these results. For this purpose, the answers were determined in the form of a Likert scale with a description of the values (relative indicator in percent). Therefore, in the area of cost perception in projects of different sizes, the possibility of comparing absolute values was not possible and a relative indicator appears to be the most relevant type of research data acquisition.

The research also took into account the number of information systems and the technologies used, but only at intervals. The use of information systems and technologies was considered to be all construction projects that pointed to the use of 3 or more IS and IT. However, for comparison, the results may be skewed according to the number of information systems and technologies used.

the importance of the impact of information technology on reducing the overall cost of construction projects. This method is based on the value of the information obtained. The main purpose of this modification of the method is to exclude subjective evaluation and to ensure independence in the evaluation of individual criteria based on the amount of data [28]. Entropy measures the information content of a particular data set. It is a criterion for the degree of uncertainty represented by a discrete probability distribution. The selected method works by determining weights based on the "amount" of data it contains.

The research is also at the stage of evaluating the maintenance and use phase of the construction project. As only a short time has passed for some construction projects, it isn't easy to evaluate this phase. Therefore, the final model does not include these results from this phase, but the conclusions contain a clearing trend. The results for this phase will be possible to evaluate in the coming years, where it will be possible to determine the solution exactly based on appropriate methods.

3. Results and Discussion

Being efficient in constriction industry means optimizing costs and maximizing production. If various factors limit production, the only way to achieve a state of efficiency is to optimize costs. The same applies to the implementation of construction projects. One of the conditions for implementing a successful construction project is to optimize, i.e. minimize costs and maintain high quality. In addition to the efforts of participants in construction projects to achieve cost reduction through the use of new technologies that are used in construction processes, there is room to reduce the cost of the construction project management process itself. Information technologies are a tool for achieving a reduction not only in the costs of managing construction projects but also in the overall costs of construction projects.

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The impact of the use of ICTs in the pre-designed stage of a construction project on the costs of construction projects reaches the value of 3.19, which represents a relatively large impact. When assessing the impact of these selected technologies on the costs associated with the management of construction projects, it is an even higher value, namely 3.28. Fig. 3 described ICTs impact on cost reducing in pre-designed stage. However, compared to communication systems or DMS, they have reached a lower impact level.

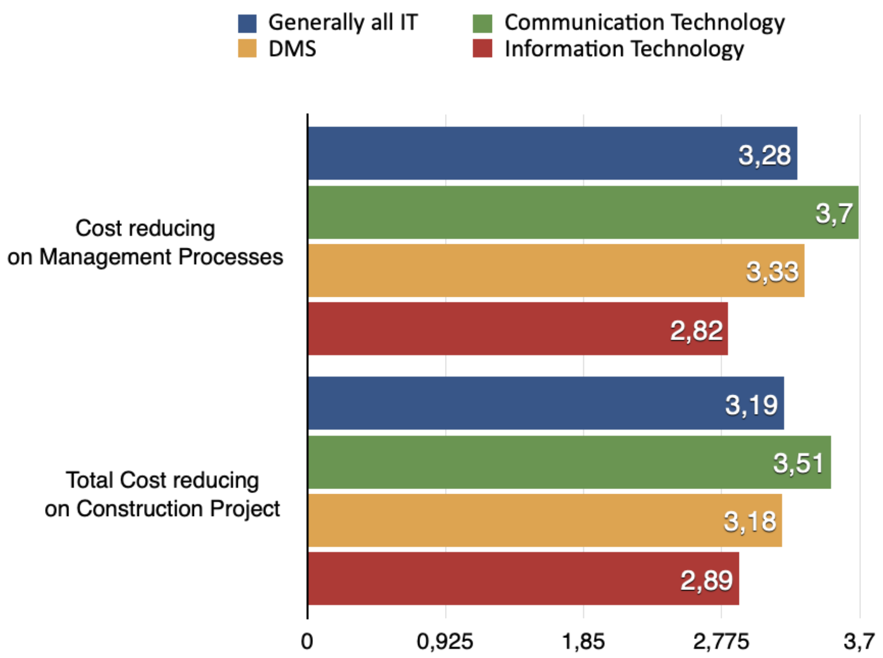

Figure 3. The impact level of the use of information technology on cost reducing in the pre-design phase

The designed phase confirmed the assumption of a large impact of technologies associated with the development of project documentation and other requirements associated with the preparation for the implementation of construction projects. Their frequent and necessary use also led to cost savings for selected processes within the construction project.

In construction projects where BIM technology was used, a reduction in costs was recorded due to this use. For contractors and sub-contractors, software for creating construction budgets and calculations and tools for creating time plans and schedules represented a relatively large impact on saving the total costs of the construction project. Large companies reported a relatively large impact on reducing the overall, but also the cost of managing construction projects complex ERP systems. Overall, therefore, IS have an impact on reducing the cost of construction projects in the design phase. More detailed information in Fig. 4.

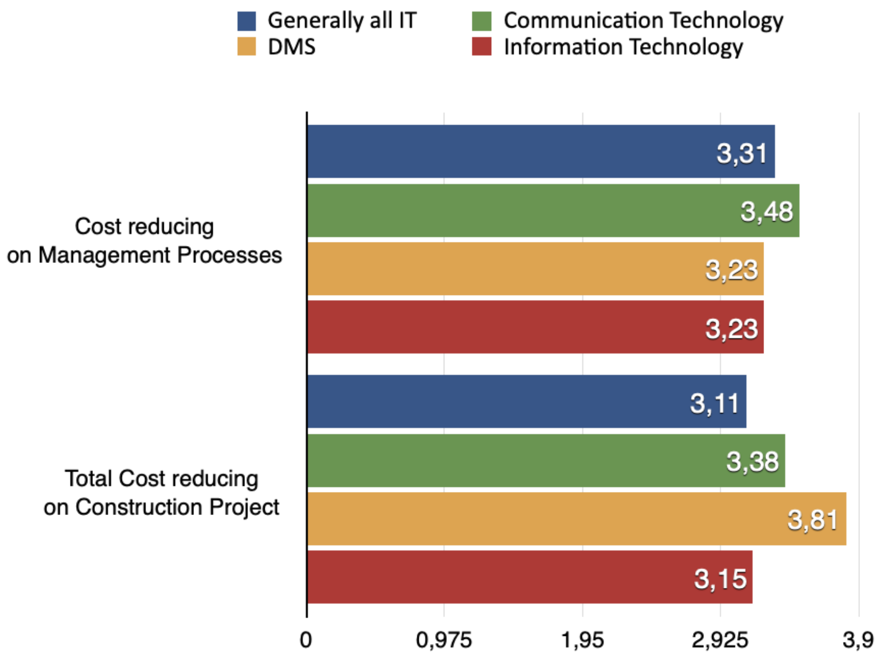

Figure 4. The impact level of the use of information technology on cost reducing in the designed phase

The impact level of the use of information technology on cost management is described in Fig. 5. These results point to the impact of information technology on cost reduction at level 3.45 and total costs to 3.19 impact level. These results show that the use of information technology has the effect of reducing costs in the management of construction projects. These are mainly controlling tools that are used to control costs for construction managers. BIM technology also proved its worth in this phase, as checking the real state with project documentation was simpler and more efficient. These technologies have directly indicated a high degree of efficiency, as long as their use is common and the processes are well set up.

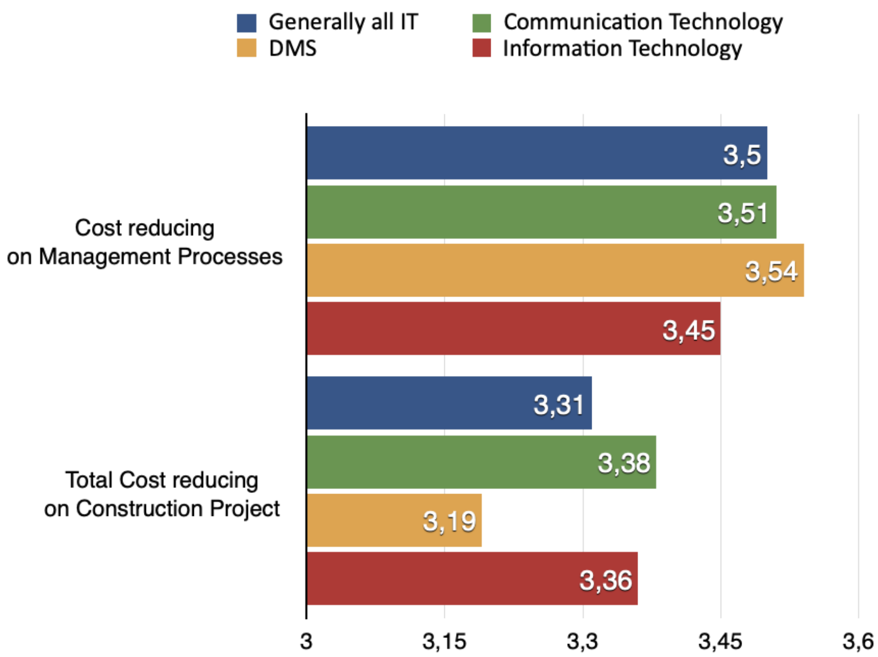

Figure 5. The impact level of the use of information technology on cost reducing in the construction phase

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These results were averaged for each technology group. However, Tables 1, 2 and 3 provide specific K-W ANOVA values for technologies in construction life cycles. The research also assumed that some companies use these information technologies to a greater extent. This also results in a greater impact. One criterion was the size of the company, which was expected to be differently used in different groups. Thus, it could also have a higher impact level. However, the reality is not so clear-cut. The research showed that even for small companies, where the rate of use of selected technologies is lower, they could achieve good results in the field of cost reducing in individual phases due to their use.

Another view was also the division of the research group according to the participants in the construction project. The assumption was that this should have a different effect. With some technologies, this has really been confirmed. It was also interesting to follow the comparison of the results in individual phases—especially when dividing the research sample based on the participants in the construction project. The results were especially different when comparing the design stage and the constriction stage. Since the Kruskal-Wallis test was performed at 95% significance levels, *p* values less than 0.05 can be considered highly relevant (these are indicated in the tables by bold).

Likewise, specific impact level values according to sources listed in the literature and methodologies can be considered significant if they reach an impact level value 3.50 and more. These technologies and their value are also bolded in the tables.

Table 1. K-W ANOVA for information technology in pre-design stage of construction project.

Information Technology	**Factor**	**K-W ANOVA (p)**	**Research Group**	**Impact level on Cost Reducing**
ERP Systems	Enterprise Size	**0.0383**	Large Enterprises	**3.57**
			Medium-sized Enterprises	2.70
			Small Enterprises	2.64
			Microenterprises	2.45
	Participant of Construction Project	**0.0451**	Contractor	2.35
			Sub-Contractor	2.38
			Designer	2.89
			Developer	**3.67**
Controlling Systems	Enterprise Size	0.0933	Large Enterprises	**3.51**
			Medium-sized Enterprises	3.35
			Small Enterprises	3.40
			Microenterprises	3.23
	Participant of Construction Project	**0.0341**	Contractor	**3.89**
			Sub-Contractor	3.53
			Designer	1.89
			Developer	2.23
Cost Management Software	Enterprise Size	**0.04202**	Large Enterprises	**3.91**
			Medium-sized Enterprises	**4.00**
			Small Enterprises	**3.80**
			Microenterprises	3.27
		0.0741		

	Participant of Construction Project		Contractor	3.41
			Sub-Contractor	**4.00**
			Designer	**3.89**
			Developer	**3.67**
BIM	Enterprise Size	0.0965	Large Enterprises	3.14
			Medium-sized Enterprises	3.00
			Small Enterprises	2.81
			Microenterprises	2.82
	Participant of Construction Project	0.2572	Contractor	2.35
			Sub-Contractor	3.25
			Designer	3.38
			Developer	2.67
CAD	Enterprise Size	0.1571	Large Enterprises	3.14
			Medium-sized Enterprises	**3.89**
			Small Enterprises	2.73
			Microenterprises	2.75
	Participant of Construction Project	**0.0478**	Contractor	3.12
			Sub-Contractor	2.75
			Designer	**3.78**
			Developer	**3.67**
Time Schedule Software	Enterprise Size	0.5299	Large Enterprises	3.14
			Medium-sized Enterprises	3.20
			Small Enterprises	2.91
			Microenterprises	2.75
	Participant of Construction Project	**0.0478**	Contractor	2.31
			Sub-Contractor	2.38
			Designer	3.63
			Developer	3.51
GIS a GPS	Enterprise Size	0.4983	Large Enterprises	2.86
			Medium-sized Enterprises	2.89
			Small Enterprises	2.10
			Microenterprises	2.25
	Participant of Construction Project	0.6799	Contractor	2.29
			Sub-Contractor	2.50
			Designer	2.25
			Developer	2.33

Table 2 contains these results processed for the pre-design phase of the construction project. The research pointed to a significant impact of cost management software among several participants in a construction project. These results are also supported by the BIM technologies used in this phase of the construction project.

Table 2. K-W ANOVA for information technology in design stage of construction project.

Information Technology	Factor	K-W ANOVA (p)	Research Group	Impact level on Cost Reducing
ERP Systems	Enterprise Size	**0.0369**	Large Enterprises	**3.90**
			Medium-sized Enterprises	**3.79**
			Small Enterprises	2.91
			Microenterprises	2.50
	Participant of Construction Project	0.7057	Contractor	2.59
			Sub-Contractor	2.75
			Designer	**3.67**
			Developer	3.33
Controlling Systems	Enterprise Size	0.2124	Large Enterprises	**3.63**
			Medium-sized Enterprises	3.17
			Small Enterprises	2.35
			Microenterprises	3.40
	Participant of Construction Project	**0.0119**	Contractor	**3.87**
			Sub-Contractor	**3.53**
			Designer	1.79
			Developer	3.43
Cost Management Software	Enterprise Size	0.1299	Large Enterprises	**3.53**
			Medium-sized Enterprises	3.23
			Small Enterprises	3.01
			Microenterprises	2.98
	Participant of Construction Project	**0.0419**	Contractor	**3.57**
			Sub-Contractor	3.13
			Designer	2.95
			Developer	3.13
BIM	Enterprise Size	0.1490	Large Enterprises	2.00
			Medium-sized Enterprises	2.91
			Small Enterprises	**3.60**
			Microenterprises	**3.98**
	Participant of Construction Project	0.4153	Contractor	3.05
			Sub-Contractor	2.75
			Designer	**3.86**
			Developer	2.01

CAD	Enterprise Size	0.2285	Large Enterprises	3.02
			Medium-sized Enterprises	3.40
			Small Enterprises	3.45
			Microenterprises	3.92
	Participant of Construction Project	**0.0264**	Contractor	3.38
			Sub-Contractor	2.25
			Designer	**3.78**
			Developer	2.33

Time Schedule Software	Enterprise Size	0.0988	Large Enterprises	**3.81**
			Medium-sized Enterprises	**3.80**
			Small Enterprises	**3.82**
			Microenterprises	3.36
	Participant of Construction Project	0.08687	Contractor	2.31
			Sub-Contractor	2.38
			Designer	**3.63**
			Developer	**3.51**

GIS a GPS	Enterprise Size	0.3200	Large Enterprises	1.80
			Medium-sized Enterprises	3.00
			Small Enterprises	2.90
			Microenterprises	**4.00**
	Participant of Construction Project	0.5815	Contractor	3.12
			Sub-Contractor	3.25
			Designer	2.50
			Developer	2.00

Table 3 contains the results processed for the construction phase of the construction project. Controlling systems were the biggest benefit here. These systems clearly bring benefits in the form of cost savings in this phase of the construction project. This was confirmed by almost all respondents.

Table 3. K-W ANOVA for information technology in construction stage of construction project.

Information Technology	**Factor**	**K-W ANOVA (p)**	**Research Group**	**Impact level on Cost Reducing**
ERP Systems	Enterprise Size	**0.0482**	Large Enterprises	**3.89**
			Medium-sized Enterprises	**3.76**
			Small Enterprises	3.43
			Microenterprises	3.12
	Participant of Construction Project	0.8335	Contractor	**3.67**
			Sub-Contractor	**3.66**
			Designer	3.43
			Developer	3.40

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Controlling Systems	Enterprise Size	0.0852	Large Enterprises	**3.63**
			Medium-sized Enterprises	**3.64**
			Small Enterprises	3.44
			Microenterprises	3.47
	Participant of Construction Project	**0.0338**	Contractor	**4.31**
			Sub-Contractor	**4.09**
			Designer	1.83
			Developer	3.47
Cost Management Software	Enterprise Size	**0.0361**	Large Enterprises	**3.78**
			Medium-sized Enterprises	**3.56**
			Small Enterprises	3.09
			Microenterprises	3.02
	Participant of Construction Project	0.0867	Contractor	**3.61**
			Sub-Contractor	3.03
			Designer	2.87
			Developer	**3.67**
BIM	Enterprise Size	**0.0436**	Large Enterprises	**3.67**
			Medium-sized Enterprises	**3.63**
			Small Enterprises	3.43
			Microenterprises	3.29
	Participant of Construction Project	0.542	Contractor	3.43
			Sub-Contractor	3.38
			Designer	**3.79**
			Developer	**3.68**
CAD	Enterprise Size	0.6503	Large Enterprises	2.67
			Medium-sized Enterprises	2.78
			Small Enterprises	2.76
			Microenterprises	2.56
	Participant of Construction Project	0.8394	Contractor	2.14
			Sub-Contractor	2.25
			Designer	3.13
			Developer	2.39
Time Schedule Software	Enterprise Size	0.6317	Large Enterprises	3.15
			Medium-sized Enterprises	3.18
			Small Enterprises	3.48
			Microenterprises	**3.52**
	Participant of Construction Project	0.6317	Contractor	3.26

			Sub-Contractor	3.26
			Designer	**3.57**
			Developer	**3.58**

GIS a GPS	Enterprise Size	0.4314	Large Enterprises	3.45
			Medium-sized Enterprises	3.47
			Small Enterprises	3.43
			Microenterprises	3.26
	Participant of Construction Project	0.2932	Contractor	**3.72**
			Sub-Contractor	**3.73**
			Designer	2.26
			Developer	2.78

This research was focused on creating an economic-mathematical model (information technology impact model which, based on theoretical analysis and research in construction companies operating in Slovakia, discusses the issue of identifying information technologies that have an impact on cost-reducing throughout the life cycle of construction projects. This model thus presents the selection and weights of selected information technologies for optimizing the costs of construction projects in individual phases. Within the proposed model, key information technologies were identified that have a significant impact on reducing the cost of construction projects. Based on the AHP method, individual weights were determined while achieving the greatest possible savings and reducing costs within all phases of the construction project. In practice, the proposed economic-mathematical model can be a tool for the selection of information technologies to help in the effort to optimize costs in the management of construction projects, thus reducing the total cost of construction projects.

The formulation of the main goal resulted from research questions determined based on a theoretical analysis of the issue and subsequently determined basic research questions for the area. Subsequently, the key monitored information technologies were specified in the questionnaire survey. The main goal of the model was thus formulated based on the results of a questionnaire survey, where the impact on reducing the cost of construction projects and thus auxiliary tools on life cycle cost management was monitored. The creation of the model proceeded in a hierarchical structure, which contained 3 levels, namely the main goal of the model, sub-goals in the form of quantifying the impact of selected groups of information technologies and quantifying their impact on the cost of construction projects in various stages of the life cycle.

The main goal of the information technology impact model is to reduce the cost of a construction project through the use of information technology. The partial goals of the model are to quantify the measures of the impact of information technologies on the costs of a construction project in individual phases. The resulting information technology impact model includes the results processed based on the Kruskal-Wallis test and average values for individual groups and works with the AHP method. The resulting model points to the importance of using information technology in each phase and their impact on cost-reducing in individual phases of the construction project life cycle: in the pre-design phase at 0.3053, in the design phase at 0.2760, in the construction phase at 0.2451 (Fig. 6).

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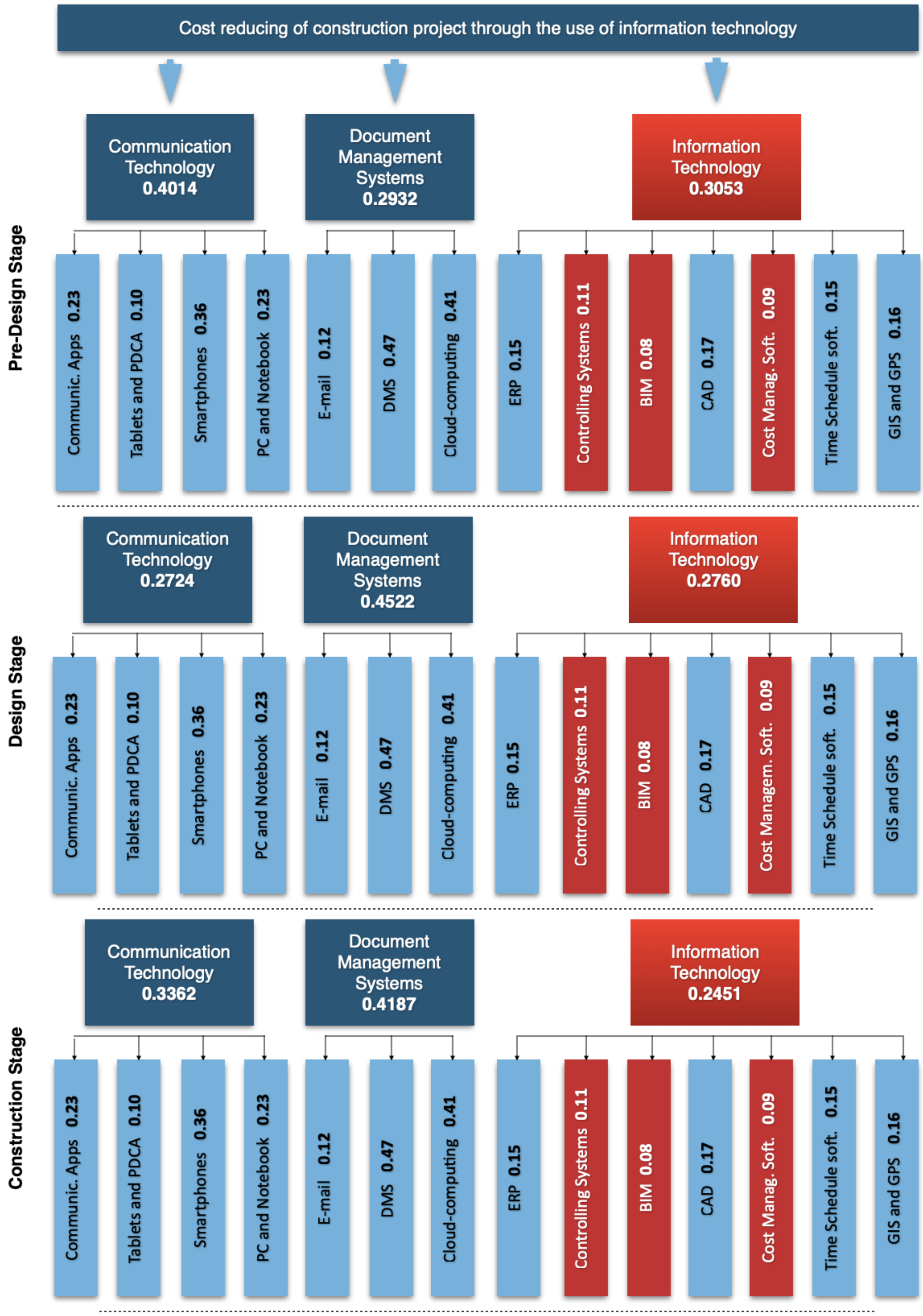

Figure 6. The information technology impact model in life cycle cost management of construction project

The effort to reduce the cost of a construction project by implementing information technology has several benefits. The research pointed out the impacts of information technologies on the area of cost management in individual stages of a construction project. The Information Technology Impact Model provides a description and types of information technologies as well as values that represent the values of the probability of cost savings in a standard construction project. These results from the detailed model represent a space for the selection and implementation of given information technologies in individual phases of a construction project, where the main goal is cost savings.

The model highlights technologies for cost management. This model points to different values of the impact of these technologies based on the project phase. It takes into account the fact that at different stages of a construction project, the same technologies have different effects on the project costs.

6. Conclusions

Management of construction projects is a demanding process, which, according to the latest studies requires the implementation of information technologies. Information technology, as this research has arrived at, is beneficial for the cost management of construction projects. The research worked with data obtained from the practice, based on the testimonies of experts, project managers and other participants in the construction project. Data collection was carried out by a questionnaire survey and took into account the current situation on the construction market. Based on the use of appropriate and statistical methods in the processing of survey data, several facts were identified and confirmed.

The implementation and use of information technology have a positive and, in many cases, a significant impact on cost-reducing in each phase of the life cycle of a construction project. This is one of the basic confirmations, and based on the results, it can be recommended to construction companies to implement and use information technology in this process. Their level for individual phases is specified in more detail by the final model. However, it can be stated unequivocally that it is appropriate to use these technologies from the initial phase of a construction project. The results in the individual phases vary. On the contrary, in each phase, these results of the positive impact were exactly confirmed, and this recommended nature applies to all examined phases of the life cycle of the project under construction.

The results also varied between technologies. If in the initial phase, the positive impact of planning software (cost management software, BIM, CAD, etc.) prevailed, i.e. applications that are primarily intended for planning, not control. In the construction phase, control systems predominated, and this phenomenon was significant. In the Construction phase, the control systems were significantly good for GPS and GIS systems. ERP systems have shown a constant impact of use and a positive impact on cost management. This only confirmed their suitability for use during the entire cycle of the construction project.

The information technology impact model brings a model situation where it points to the impact of individual technologies on cost reduction in individual phases of the life cycle of a construction project. Here it is important to state several facts arising from the research. This model works with a situation where other fundamental factors do not change. This means influences that the construction market and participants in construction projects cannot influence. This is, for example, the macroeconomic situation and the development of economies. The impact of the COVID-19 pandemic may also affect this area. Similar economic cycles and turbulence can affect cost management outcomes, and this model cannot take them into account. Another indicator is the difference based on the size of the project, which in many cases confirmed this research. It is also important to monitor the development of costs and the impact of information technologies during the last phase of the life cycle of a construction project. The currently processed results point to a similar trend, but these still need to be confirmed by statistical methods.

This research and the resulting model is the result of demanding research and is applicable in practice. It is currently being verified, and the results appear to be successful. However, it should be noted that this process is long-term, and the results can only be evaluated later. Here are important knowledge and space for the advancement of this research. The processing of results for individual research groups is currently underway, where other factors could be added (size of the company, size of the construction project, position of the participant in the construction project). This means that the resulting impact model would take into account other factors and would be more specific based on the specification of the construction project. It is also interesting to make dependencies between different types of construction projects. These are other options that are already being worked on intensively, and the results should be available over the next period.

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