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Factors of Success in Electronic Public Procurement as Part of E-government

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Abstract: Key factors in the functioning of the public administration system is increasing the efficiency of electronic public procurement as one of the components of e-government. Efficiency in public procurement is often assessed from only one point of view, and that is price, or of the difference between the expected and competitive price. However, this view is insufficient, as a number of other factors enter into the entire public procurement process, which have a significant impact on the price. It is also important to examine the price not only from the point of view of the contractor, but also of the applicant. This paper deals with the investigation of factors, that have influence on the price in public procurement in Slovakia from the point of view of the applicant. The research was carried out on the basis of the methodology of the planned experiment, which is referred as Design of Experiment and within this method we used a partial (one-eighth) factorial design of the experiment. Through the statistical processing of the obtained data, we identified three factors, that significantly influenced the success of the applicant for a public contract in the procurement process of a specific type of goods.

Keywords: public administration; public procurement; price; experiment; factors

JEL Classification: H41; H57; H83

1. Introduction

One of the areas of public finance, that attracts more and more public attention is the public procurement process. This is mainly, because the procurement of goods and services, or construction works by the public sector uses resources, that come largely from state budget or local budgets, the main contributors of which are mainly citizens. The field of public procurement in Slovakia was and is problematic from many points of view. This is mainly due to constantly changing legislation, a high level of bureaucracy and corruption, an insufficient level of control, a low level of efficiency, a conflict of interests, or a small circle of suppliers involved (Bednárová et al., 2020).

The public procurement process should generally meet the principles of transparency, openness and professionalism in every country. In many cases, this is not the case, and the redistribution of public finances becomes non-transparent and ineffective. Lack of transparency and inefficiency is not prevented, although developing countries of Central and Eastern Europe have significantly increased the volume of the public procurement market in recent years. It is estimated, that public procurement in these countries represents more than 10% of GDP (Nemec et al., 2020).

As already mentioned, despite the fact, that the size of the public procurement market has been growing in recent years, not enough attention is currently paid to measuring the economic efficiency of this processes. The above-mentioned facts are also confirmed by many studies. Grega (2018) pointed out in his study, that the most important factor, that determines the efficiency of public procurement in Slovakia is excessive bureaucracy. The second most frequent factor was the constant change of the relevant legislation, and the third factor was the lack of ethics and morals on the part of the contracting authorities. The fourth most important factor was corruption and the efficiency of public procurement in Slovakia was the fifth most important factor, from the point of view of the contracting authorities (Grega, 2018).

When solving the issue in question, it is appropriate to first analyze the concept of efficiency itself and then address it in the context of public procurement. Samuelson and Nordhaus (1992) define the term efficiency as a state, in which there is no waste. According to Afonso et al. (2006), efficiency is more difficult exactly and objectively to define, than to identify. When examining the concept of efficiency, it is also necessary to distinguish between allocative and technical efficiency. Stiglitz (2011) defined allocative efficiency as the optimal allocation of scarce resources in the economy, and according to him, achieving this efficiency belongs to one of the four basic economic functions of the state, which also has a microeconomic character. According to Kerstens (1999), allocative efficiency mainly requires setting the goals, that we want to achieve. Achieving allocative efficiency therefore means the use of resources in the economy, in which the maximum possible benefit occurs. Allocative efficiency is mainly concerned with whether the use of resources achieves a predetermined state. On the other hand, technical efficiency is defined by Kerstens (1999) as production at the limit of production possibilities, i.e. scarce resources are used to the maximum extent possible.

One of the other suitable tools for evaluating the economy and, to a certain extent, the efficiency of public procurement is benchmarking, which can be used for internal (prices of the same goods, services and construction works within the organization) or external comparison (with market prices or with the prices of other contractors) and ultimately it can increase the efficiency of public procurement (Chamberland, 2005; Triantafillou, 2007; Raymond, 2008). The resulting benefit of the systematic use of benchmarking in the evaluation of the public procurement is the prevention of collusion (Langr, 2020), the increase of ,,competitiveness" between public contracting authorities, a better reporting ability than in the traditional comparison with the expected value of the contract, and increased transparency of the evaluation of the effectiveness of public procurement. The disadvantage is, that benchmarking in public procurement can only be used for comparable and easily measurable goods, it also does not take into account the volume of purchased goods (economies of scale), quality, post-contractual behavior of the supplier, and last but not least, its reporting ability over time is limited by the level of inflation.

In the context of the efficiency of public procurement, we most often encounter the fact, that efficiency is perceived as the so-called saving, which is quantified by the difference between the expected value of the contract and the final price, while simultaneously monitoring the factors affecting the saving. We can state, that a number of already conducted studies focus on examining the price only from the point of view of the public

contracting authority and the determinants, that influence it, but only a few of them, examine the price from another point of view, i.e. from the applicants. We focused on this issue in this paper. For this reason, the main goal of the submitted paper is the identification of factors, that have a relevant influence on the price in public procurement in Slovakia from the applicant point of view.

2. Methodology

In order to achieve the main goal of the presented contribution, we used the method of planned experiment, which is referred to as Design of Experiments (DOE), for the statistical processing of the obtained data.

Experimentation has been the main way mankind has come to knowledge since time immemorial. A small child makes sure, that the stove is hot by making an attempt - grabbing it. He performs some activity, which we call an experiment, and upon the result of the experiment he becomes familiar with a new fact. Overall, experimentation is action and reaction. In practice, ,,trial-and-error" experimentation is often performed. These are experiments: ,,I'll try and see if it's good or bad". The problem with this experimentation is the unstable result, which usually does not provide true insight. Experiments are usually very expensive and knowledge is paid a lot. And that's why it's good, if we consider in advance what we're going to do, how we're going to do the experiment, i.e. we will develop a plan. Therefore, with the given approach, we speak of a planned experiment (Turisová & Pačaiová, 2017).

We perceive the term experiment itself in general as a system of attempts, which are ideally arranged in a planned experiment. A crucial goal of DOE is to find out the links and relationships between the variables of the process, that we are investigating. So here we have a method capable of perceiving even a complex and difficult-to-understand process as an element for which, although we cannot find a suitable mathematical model, we can empirically estimate how its inputs affect the outputs. The aim of the experiment is to determine, which explanatory variables - factors (input, influencing quantities) influence the explained variables - responses (monitored, output quantities). Another task is to find the levels of the factors, with the help of which we would work towards the optimum (the so-called maximum and minimum) of the monitored quantity (Veber et al., 2007).

DOE is a method of planning experiments, that is generally used to test and optimize processes, products or services. It can be used to obtain more information about the behavior of the process or product under different conditions. It allows to systematically plan and select factors, that can be further analyzed based on data obtained from the process running under changed conditions. Generally, experiments are done to find factors of possible influence or to optimize some effects. For optimization, data from the experiment is used to create an assumed model, which is an equation designed to describe the functional dependence of the output characteristic on the input factors. The method consists in carrying out several experiments of the process, in which it is determined, what the output is for different combinations of input factors. The obtained values are processed into a mathematical expression of dependence, which can be used in process control, i.e. for setting factors to achieve the required value of the output characteristic or to achieve its maximum or minimum (Kučerová, 2012).

To construct the model, it is necessary to have measured quantities obtained by tracking without targeted intervention, the so-called planned experiment. The planned experiment creates the conditions for the smallest possible range of attempts, but in such a way that the volume and form of data, but mainly the quality of information, is as large as possible (Woods & Lewis, 2015). For factors, we create ideal levels within permissible intervals. The requirement for efficiency is mainly applied in experiments with multiple factors.

The mathematical model of the experiment belongs to the basic concepts of the theory of the experiment. The model of the experiment is in accordance with physical ideas and includes a description of the given state of the object, that is being measured, as well as a description of directly or indirectly measurable quantities, that are measured and determined by experimentation, respectively the state of the object, that is the object of interest (Antony, 2014). Thanks to the DOE method, we can find out as much information as possible with the smallest possible scope of the experiment. Using input factors (denoted as x_1, x_2, ..., x_n) we understand their influence on outputs (denoted as y_1, y_2, ..., y_m) (Mason et al., 2003). In this way, correlations between the inputs of the process and its outputs are determined. A functional relationship is mathematically constructed (Montgomery, 2001):

$$y = f(x_1, x_2, \dots, x_n) + \varepsilon \quad (1)$$

where ε is the error of the experiment, i.e. deviation of a given experiment. The error of the experiment probably describes the non-existent exact functional relationship between y and x_1, x_2, ..., x_n. When designing experiments using DOE, we seek such inputs, that the method represents a robust tool. A tool, that serves to understand processes and research factors - their parameters, that significantly affect it. So it sorts the factors into important and less important, according to the surrounding conditions. This is how we get information that expresses the mutual influence of responses y_1, y_2, ..., y_m by factors x_1, x_2, ..., x_n (Montgomery, 2001).

Due to the fact, that the planned experiment method offers several alternatives for its application, we decided to use the factorial design of the experiment. The reason for choosing this type of experiment was mainly the fact, that it can identify statistically significant factors when examining several factors at once, with several levels. Since we considered several factors at two levels (lower and upper level), we applied a multifactorial two-level experiment. As a response, we chose the unit price in public procurement. Individual factors were chosen based on the analysis of already conducted studies, which described the factors probably influencing the price. By synthesizing the conducted studies and at our own discretion, we finally chose eight factors, with the aim of examining their influence on the chosen response. The factors investigated were:

1. Type of institution – type of contractor depending on its source of financing. The upper level was made up of procurers, who are financed from the state budget. The lower level consisted of procurers financed from local budgets, i.e. from the budgets of cities and municipalities.
2. Area – examination of whether the procurers comes from the same or a different territorial region. We considered the regions in the context of eastern Slovakia, western

Slovakia, central Slovakia and Bratislava. The upper level was represented by applicants and procurers coming from the same regions and the lower level from different regions.

3. Number of pieces – the total number of pieces of procured goods within one order. The upper border was made up of 2 or more pieces, while the lower border was made up of only one piece.
4. Number of applicants – the total number of applicants, who submitted price offers and participated in the contract. The upper limit was three or more applicants and the lower limit was 1 to 2 applicants.
5. Technical parameter no. 1 – the size of the hard disk (HDD). The upper limit was represented by a 1,000 GB HDD and the lower limit was 500 GB.
6. Technical parameter no. 2 – type of processor. The upper limit was the i5 type processor and the lower limit was the i3 type processor.
7. Number of days of fulfillment – the total number of days required for the delivery of the selected goods. Five or more days represented the upper limit and one to four days represented the lower limit of the given factor.
8. Savings – the difference between the estimated contract price and the competitive price. The upper limit was a saving, that was higher than five Euros, and the lower limit was a saving lower than five Euros.

Since the number of measurements in a full factorial two-level experiment would mean up to 256 measurements, based on the 2^k relationship, we decided to finally apply a partial – one-eighth factorial design of the experiment to simplify the conditions. The notation for this design of experiment is of the form 2^{k-p}, where ,,k" represents the number of factors and ½p represents part of the full 2^k factorial experiment. While it is true, that the number of attempts of a partial experiment must not be lower, than the number of factors, i.e. $n \geq k$ (Montgomery, 2001). Finally, a partial (one-eighth – 2^{8-3}) factorial design of the experiment was implemented with 32 measurements. As part of the experiment, we investigated the effects of individual factors on the change in response that the factor causes if its level changes from – 1 (lower level) to + 1 (upper level). The effect of the factors on the response is subsequently determined as the difference of the response averages for the factor at the upper level $\bar{y}_{A+}$ and for the factor at the lower level $\bar{y}_{A-}$. This can be written as (Montgomery, 2001):

$$effect\ of\ factor\ A = \bar{y}_{A+} - \bar{y}_{A-} = \frac{1}{2n}\,[ab + a - b - (1)] \tag{2}$$

Analogously, the effect of factor B is calculated as follows (Montgomery, 2001):

$$effect\ of\ factor\ B = \bar{y}_{B+} - \bar{y}_{B-} = \frac{1}{2n}\,[ab + b - a - (1)] \tag{3}$$

In addition to the main effects, we can determine the presence of their mutual interactions among the individual factors. We determine the effect of the interaction of factors AB as the average value of the difference between the effect A on the upper level B and the effect A on the lower level B, which has the form (Montgomery, 2001):

$$effect\ of\ interaction\ AB = \frac{1}{2n}\,[ab + (1) - a - b] \tag{4}$$

The result of the experiment is a regression model, that predicts the magnitude of the response at a different combination of individual factors at their best level. The regression model for a planned experiment with factors observed at two levels usually has the form (Montgomery, 2001):

$$y = \beta_0 + \beta_1 A + \beta_2 B + \cdots + \beta_{12} AB + \beta_{13} AC + \cdots + \varepsilon \quad (5)$$

where:

y – response value,

β_0 – average response value,

β_1, β_2 – values of regression coefficients,

β_{12}, β_{13} – regression coefficients for interactions between factors,

A, B, C – factors of the experiment,

ε – random error

Based on the above facts, the program generated an experiment plan, which consisted of random combinations of the values of the selected factors within 32 measurements. The created factor plan was used to identify such orders that met the combinations of values of the selected factors. In the next step, we used market research to find out the prices of the subject type of goods at a specific time at selected public contracting authorities on the basis of a factor plan. Through market research, we simulated the conditions of public procurement.

The source of data for the execution of the planned experiment was public procurement in Slovakia for the period 2019 to 2021, carried out through the Electronic Contracting System, one of the tools of which is the electronic marketplace. Since a large number of procurements are carried out within the electronic marketplace, we focused only on the procurement of selected types of goods, i.e. computing technology (ICT), specifically laptops. The reason for choosing this area of data was the fact, that electronic public procurement in Slovakia provides publicly available data and also, that computer technology is one of the most frequently procured goods in the electronic marketplace.

Subsequently, we focused only on public procurement of computing technology for the years 2019 to 2021, in which computing technology was procured in the form of portable computers, that met the technical parameter of HDD 500 GB and 1,000 GB and processor i3 and i5. After that, we collected available information about the contracts implemented in this way regarding the competitive price, expected price, contracting authority, bidders, time of fulfillment, auction options, and the like. The source data set consisted of a total of 420 procurements of the subject pre-specified goods.

3. Results

After creating the research sample, determining the response and defining the individual research factors, an experiment plan containing random combinations of the values of the selected factors within 32 measurements was created. We analyzed the results of individual measurements through the use of several statistical-mathematical methods, which we describe in the next part of the paper.

In the first step, after conducting the experiment, we proceeded to identify the factors, that significantly affect the response through Pareto analysis. In this case, the Pareto analysis does not show the classically well-known Pareto diagram, since the x-axis is replaced by the y-axis. This analysis separates significant factors from those, that are only the result of experimental noise based on the constructed factorial design. In addition, the analysis is performed for all factors and for all mutual interactions of these factors. Monitored p-values determine, which factor and interaction of factors is statistically significant in the model, respectively insignificant. With the help of regression analysis, the least significant interactions and factors are successively eliminated, starting with the highest value until all p-values of the model are ≤ 0.05 (Sabová, 2015).

The alpha significance level was chosen at the level of 0.05, while the absolute values of the effects are on Figure 1 shown on the x-axis and individual factors including their combinations on the y-axis. Resulting from graph no. 1 we can state, that we consider factors exceeding the alpha significance level on the right to be statistically significant factors. Conversely, all other factors located to the left of the vertical line showing the alpha significance level are below the chosen significance threshold, i.e. we consider them to be statistically insignificant. The conclusion of this investigation is the knowledge, that a total of four factors have a statistically significant effect on the competitive price in the public procurement process, based on the conducted experiment.

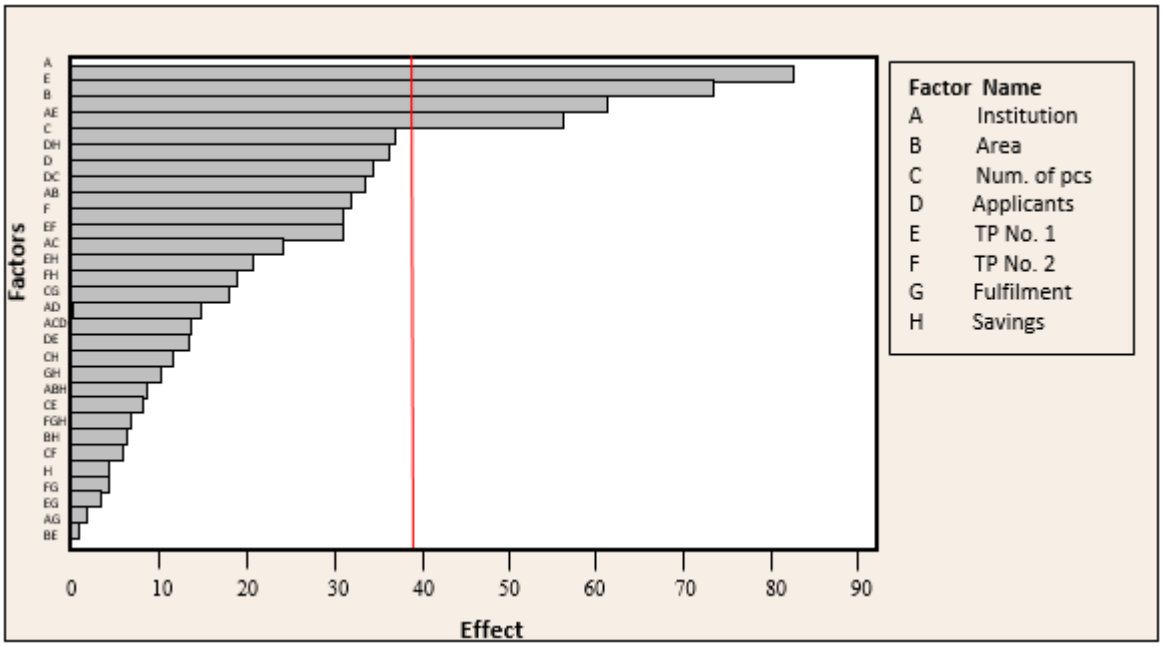

Figure 1. The results of Pareto diagram of effects

The first statistically significant factor is the type of institution, i.e. whether it is a procuring entity financed directly from the state budget or from the budgets of cities and municipalities. The second factor is technical parameter no. 1, i.e. hard disk size of either 1,000 GB or 500 GB. The third statistically significant factor is the same or different area of the contracting authority and the applicant, within the individual regions. The last statistically significant factor is the combination of two factors at once, i.e. type of institution and technical parameter no. 1.

For confirmation, or refuting the results of the Pareto analysis, we decided to use several methods in the next part. The first method used was the probability plot of the normal distribution. In this type of investigation, the points located on the straight line (close to it), which we call the linearized distribution function of the normal distribution, are considered statistically insignificant. On the contrary, all factors located outside the distribution function of the normal distribution are considered statistically significant and therefore have an impact on the response, i.e. for the price. In this case too, a total of four factors affect the response was confirmed, i.e. type of institution, technical parameter no. 1, area and combination of factors, type of institution and parameter no. 1. In this case, we can state, that the results of the Pareto analysis and the probability graph of the normal distribution match.

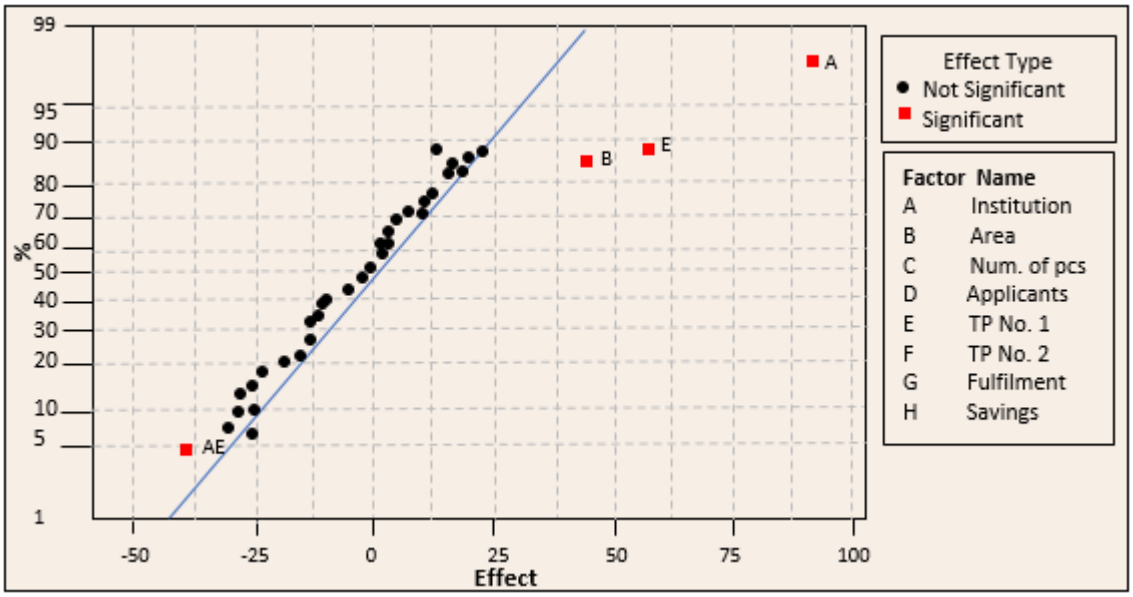

Figure 2. The results of the Normal Probability chart

The main effects of the selected factors were the subject of further investigation, while the main effect is defined as the difference in average responses between the upper and lower levels of individual factors. The results of the examination of main effects are shown in the form of a graph using short lines, with the starting and ending points representing the means for the upper and lower levels of the selected factor. It is true, that if the segment rises from left to right, i.e. upward, so it is a positive effect. With a positive effect, the average response at the upper level is higher, than at the lower level. On the contrary, if the segment descends from left to right, i.e. descending, so the effect is negative. In the case of a negative effect, on the contrary, the average response at the lower level of the factor is higher, than at the upper level. By evaluating the line segments in the graph of the main effects, we come to the conclusion, that the type of institution, area factor, technical parameter no. 1 and technical parameter no. 2 are factors with positive effect. The change compared to previous investigations occurred with the last named variable, but despite the fact, that technical parameter no. 2 has a positive effect on the response, it cannot be considered statistically significant.

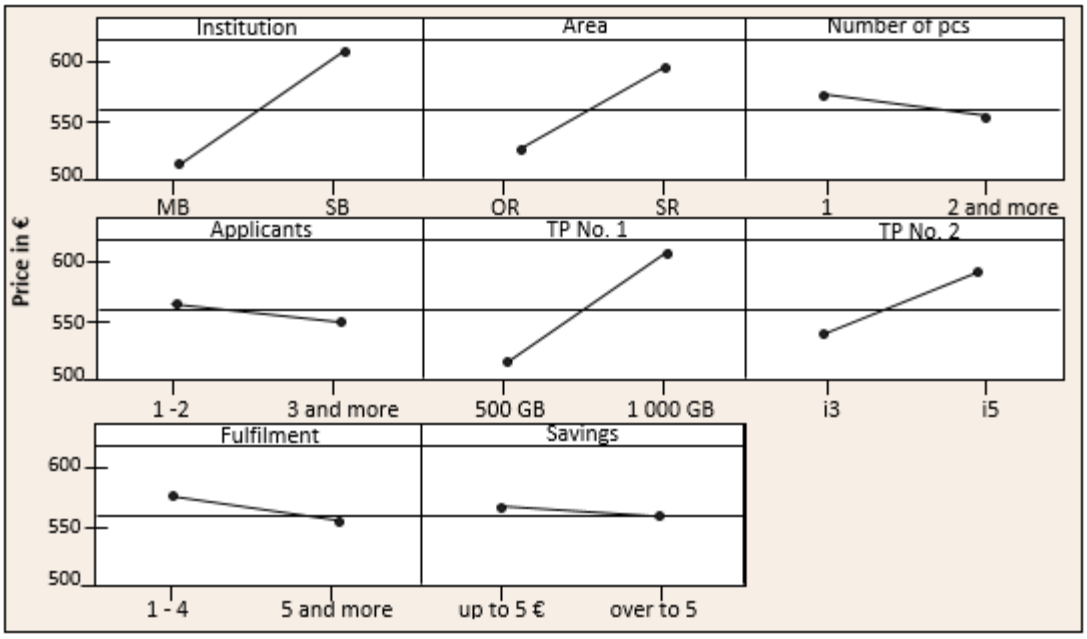

Figure 3. The results of Main effects chart

The last subject of the investigation was the investigation of mutual interactions of individual factors. The results of the Pareto analysis determined the combination of the factors type of institution and technical parameter no. 1 as a statistically significant interaction. In this case too, we tried to confirm or refute these results, for which the interaction graph was used. In general, an interaction plot describes whether the effect of one factor depends on the level of another factor. We can state, that this investigation confirmed several strong and moderate interactions within the selected factors, but only one interaction was statistically significant, i.e. combination of factors, type of institution and technical parameter no. 1. In many cases, research has proven, that some selected factors have no influence on the selected response. Even in this partial investigation, the results of the Pareto analysis regarding mutual interactions of individual factors were confirmed.

4. Discussion

International institutions, including the OECD, have been criticizing the way how public resources are managed through the public procurement system in Slovakia for several years. Among the critical factors of this process are mainly non-coordination between institutions, incorrectly set procedures, low enforceability and, last but not least, low efficiency. For the reasons mentioned above, it would be appropriate to pay more attention to the public procurement process, not only in the form of frequent changes in its legislation. Public procurement itself gives companies a great potential to participate in the competition. If the basic rules set by law were followed within the framework of a transparent competition, it would be possible to reduce not only the state's expenses, but also to satisfy the needs of the public to a greater extent and involve a larger number of applicants from the ranks of business entities. The analysis of public procurements already carried out proves in many ways, that only a small and recurring circle of business entities wins a large part of public

contracts. In the context of public procurement, it is also necessary to monitor this area, i.e. applicants and point out, what affects their success, or failure in this process.

The aim of the presented paper was to identify factors, that have a relevant influence on the price in public procurement in Slovakia from the applicant's point of view. It is the price, that is key in the public procurement process, because it decides, which entity will be successful and which, on the contrary, will not. As a research sample, we mapped public procurement in Slovakia through the electronic marketplace for the period 2019 to 2021 for a selected type of goods, i.e. computing technology, specifically laptops. The results of the planned experiment prove, that a total of three factors and one mutual combination of these factors influence public procurement, which we consider to be statistically significant. Specifically, it was the type of institution, area, technical parameter and mutual combination of the factors of type of institution and technical parameter. In this context, it seems, that every combination of significant factors should also be equally named statistically significant, be it a combination of institution type and area, or area and a technical parameter. However, the results of the Pareto analysis and also the graph of the main effects confirmed, that only one of them can be considered as a statistically significant combination - the type of institution and the technical parameter. In this context, it is important, that the contracts are announced by institutions, that are financed from the state budget, are located in the same region as the applicant, and require laptops with a hard disk parameter of 1,000 GB. On the contrary, the factors, that do not have a decisive influence on the price and which should not be given so much attention include the number of procured pieces, the number of applicants involved, or the number of days of fulfillment.

By comparing the achieved results with similar foreign studies, we can conclude, that the price is the basic measure of the efficiency of the public procurement process. Gregor and Nemec (2015) pointed out in their research, that savings in public procurement are influenced by a total of three factors, i.e. the number of applicants involved, drawing financial resources from European Union structural funds and the lowest price. Studies by Soudek and Skuhrovec (2013), Šipoš and Klatik (2013), Onur et al. (2012), Gómez-Lob and Szymanský (2001), Pavel (2010), Bajari (2002), Nemec et al. (2005) also evaluated the efficiency of public procurement based on the price and the factors, that determine it. The core conclusion of Saudek and Skuhrovec (2013) was, that the key factor determining price was the selection method. On average open tenders delivered a 7% price decrease compared to other methods. Sičáková-Beblavá et al. (2013) analysed 725 procurement actions in 32 Slovak organisations during 2008–2010. They confirm the positive effects of e-auctions and of competition. Finally, some studies have examined how contracting and outsourcing impact on competition. Most of them confirm, that final prices decreased as the number of bids grew and if open tenders were used.

Due to lack of capacity, time, or absence of data, the study has several limitations. It may be mentioned, that we focused only on a selected pre-selected type of product with specific features. Furthermore, the study only concerns public procurement in Slovakia and only for the selected period. Another limitation was the number of measurements and the resulting only partial factor plan. However, all these limitations are removable and could be taken into

account in further research. Enterprises, or researchers, who are not limited by such restrictions can improve and refine the proposed procedure, for example, by replicating the experiment, by repeating it in time intervals, or by applying a full factorial plan.

5. Conclusions

In conclusion, it can be assessed, that the current era provides companies with wide opportunities to apply for public resources, private contracts, or structural funds. The effort to obtain them requires considerable time, financial resources and human capacities on the part of the company in connection with the preparation of project documentation or complex preparation of price offers. Our intention in the submitted paper was to identify relevant factors in the public procurement process, which made it easier for applicants, i.e. companies to choose a contract or project, with the aim of possibly ensuring their success in this process.

Conflict of interest: none.

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