DE GRUYTER OPEN

ECONOMIC THEMES (2016) 54(1): 103-128

DOI 10.1515/ethemes-2016-0006

APPLICATION OF MULTI-CRITERIA ANALYSIS IN THE PUBLIC PROCUREMENT PROCESS OPTIMIZATION

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UDC 658.7: 005.311.121
Review paper

Abstract: One of the key steps in the implementation of a public procurement process is the criteria selection that are associated with the bidders, which are intended to ensure that bidders will be able to meet the requirements from the contract. Implicitly, the criteria selection includes their evaluation in situations when the criterion of the lowest price is not applied, but instead the criterion of the most economically advantageous tender. The aim of the paper is to show that decision-makers in the public sector can use multi-criteria analysis for the efficient and fair public procurement process implementation and the establishment of objective conditions for the contract awarding in accordance with the general social interests. In this sense, the paper presents a comparative approach to the Analytic Hierarchy Process and Analytic Network Process as the methods of support in decision making, measurement and evaluation criteria for the selection of the best bids in the procurement process. Hierarchical model with five criteria and nine sub-criteria and the network model, which takes into account the mutual influences of criteria, were developed in a hypothetical public procurement selection procedure for the best performers for the construction of the infrastructure facility. Selection of the best bidder, i.e. bids for the realization of the work, is distinctive, multi-criteria problem which includes both qualitative and quantitative factors.

Received: 22.12.2015
Accepted: 23.03.2016

Key words: procurement, criteria, evaluation, weighting coefficient, choice, multi-criteria analysis

JEL classification: C44, C82

The paper is the result of internal research project at the Faculty of Economics, University of Kragujevac, entitled "Economic and social aspects of Serbia joining the EU"

1. Introduction

As the purchase of goods or services by the public sector, the scope of public procurement has increased significantly over the last few decades. State administration are the biggest consumers around the world, so that the government's spending generally varies between 15% to 45% of gross domestic product (GDP), of which internal costs (salaries, etc.) make up a large part of this consumption, and 20- 25% are external costs (purchase of goods and services), mainly through public procurement, which increasingly constitute a key economic activity of each state administration (Dobi et al. 2010, 448). The share of public procurement in the gross domestic product of the EU countries has increased in recent years and reached 16% (in 2008, even 17%; Strand et al. 2011). At the same time, as a result of improving regulation and its efficient implementation, savings of 30% total were achieved. When it comes to Serbia, the existing Law on Public Procurement was adopted at a meeting of the National Assembly of the Republic of Serbia on December 29th, 2012 and began to be implemented from April 1th, 2012. The given law represents an improvement over the former regulations (from 2002, with significant 'changing from 2004, followed by a 2008 law) and it is in significant measure tailored by European Union directives that govern public procurement - EU Directive 2004/18 /EZ "Traditional directive" and the EU Directive 2004/17/EC "Utilities Directive". The value of public procurement in the Republic of Serbia, in 2003, amounted to slightly less than 100 billion dinars, and only in the first six months of 2014, this value amounted to almost 150 billion dinars[2]. Regardless of the difficulties through which the economy of the Republic of Serbia is passing, it is expected that the growth trend in the number and value of public procurements continues and that their relative importance is going to increase in the coming years.

Thus, the importance of public procurement stems from the fact that approximately 10-15% of the gross domestic product is spent on public procurement. That mechanism is one of the most important budgetary expenditure sides. Public institutions have a responsibility to get maximum value for taxpayers' money for everything they procure. Value for money is defined as the optimum combination of whole life costs of a product, service or project, and the quality (or fitness to purpose) to meet the requirements of the customer (user). The maximum value for money means getting the best deal within the set of parameters, and not only the cheapest offer. In doing so, the principles of the internal market are respected, which form the basis of the legal framework. The most important of these principles are the principles of equal

[2] Report on Public Procurement in the Republic of Serbia for the period 01.01.2014-30.06.2014.year, Republic of Serbia, the Public Procurement Office, Belgrade, 2014.

treatment, where all participants in the tender should have equal opportunity to compete for the contract, and of transparency, i.e. obligations of procurers to inform the tenderers why their offer has been rejected.

Public procurement expresses specific interests, due to the specific situation that occurs when the public sector act as a buyer in the market. The public sector is subjected to the requirements of transparency and generally is limited by detailed legislation, administrative regulations and public procurement procedures. The purpose of these restrictions is to try to avoid any abuse of the public sector, which in turn, results in a lack of flexibility and limits the possibility for public purchasers to strategically respond to the market.

Generally speaking, public procurement is treated with special attention, from both common and political public scene, but not enough from the academic community, whose interest has been very limited so far, and without significant range. In particular, research on methodological aspects of the generating and evaluating selection criteria are still scarce and intrinsically limited.

Public procurement decisions often require the simultaneous use of set criteria. One of the problems that most often involves multiple criteria is the selection of one among several proposals. Multi-criteria analysis (MCA) can be used in the evaluation of tenders, and criteria weight is set with regard to the priorities of the procurers who conduct the public procurement (the lowest price, the shortest implementation period, experience in similar projects, etc.). As the multi-criteria decision-making process uses a set of criteria that each may vary according, thus the relative importance to the MCA methods can be used to determine the importance of the criteria used for the selection of the best bid.

The aim is, in that sense, to show that the application of multi-criteria analysis, particularly, procedures based on AHP/ANP methodology, can help government managers to objectively and accurately identify and assess criteria for the selection of the best offer (services, goods, affairs realisation) in public tenders, thus creating the prerequisites for the optimum evaluation of tenders and selection of the best bid. The selection and weighting of criteria for the award of the contract is a critical step in the procurement process since it significantly influences the final decision.

The defined goal is achieved through the implementation of the following tasks:

- Review of the literature on key issues, including the selection of works;
- Illustration of the method and framework for the multi-criteria analysis implementation in the criteria evaluation process, and
- Generating conclusions and recommendations for the criteria and bidders evaluation methodology.

2. Procurement Issues and Literature Review

2.1. Phases of Procurement Process

The public procurement process starts by identifying the needs of the public sector and can last until the end of the life cycle of the purchased assets or services or until the expiration of the contract. Hughes (2005) lists five main steps in the procurement process: identifying needs, defining services, forming the list of suppliers, supplier selection and evaluation of suppliers' performance.

Overall, two phases in the process of the bidder evaluation can be distinguished:

1. determining the eligibility of bidders includes examining the suitability and the ability of bidders to perform the contract which will be awarded at the end of the tender,
2. Evaluation of selected bids and the contract awarding.

The qualification (pre-qualification) is pre-procedure that allows, among those who declare their willingness to participate in the tender competition, elimination of the inappropriate candidates. This procedure is also applied in situations where it is not possible to plan ahead the subject of procurement in terms of volume, quantity and time needed for implementation. At this stage, all bidders who meet the minimum requirements are equal, and the difference between the offers occurs during the bid evaluation by the defined evaluation criteria.

Russsel & Skibnievski (1987) have tried to describe the process of qualification of contractors, along with decision-making strategies and factors influencing the process. The decision-making strategies define the criteria for selection, and their weight depends on the decision of the procurers. First, the decision maker assigns weights to the selected criteria, then it calculates the total points of each contractor, followed by their ranking, so that the resulting list of contractors can be used for their qualification. Russel (1991) investigated the qualification phase of contractors for public projects and concluded that the projects assigned to the lowest bid price had a lower quality of performance and the delay in relation to the projects which are awarded on the basis of specific qualification criteria. A number of researchers, such as Russell et al. (1992), Ng & Skitmore (1999), Wong et al. (2000, 2001), Molenaar & Johnson (2003), Topcu (2004) and Zavadskas et al. (2001) identified the common criteria for qualification and evaluation of tenders. Holt & Edwards (2005) carried out a qualitative analysis that identifies the criteria to be taken into account in the evaluation and selection of contractors. In that sense, multi-criteria evaluation proved to be a suitable means of resolving such problems. Al- Harb (2001), Fong et al. (2000) solved the problem of qualification and final selection of contractors

using the Analytic Hierarchy Process (AHP), which allows dealing with the problem from the multi-criteria aspect. As pointed out by Al - Harbi, the AHP allows group decision making in which group members can use their experience, values and knowledge in order to solve the problem of the contractor qualification, its hierarchical structuring and solving using appropriate AHP model. Contractors' selection model formulated by Fong et al. (2000), helps investors to identify contractors with the greatest potential, giving the ability to achieve very satisfactory results in the final selection of the contractor.

Andruškevičius (2005) proposes the COPRAS multi-criteria method for evaluation of the contractors. Hatush & Skitmore (1998) have proposed a multi-criteria analysis technique for the selection of contractors and evaluation of tenders, based on the theory of utility. Minchin et al. (2005) have proposed an innovative model of the quality system, called Performance Based Rating (QBPR), for the selection of contractors. Lam et al. (2001) proposed Fuzzy Neutral Network (FNN) model, which combines the theory of fuzzy sets and theory of neural networks, for the qualification and selection of contractors. Paul & Gutierrez (2005) studied the contracting of the project from the perspective of the bid price, using a stochastic model. Kandanala et al. (2005) proposed a conceptual model of automation of the offer qualification process in order to increase efficiency and minimize possible human errors and risks associated with this process. Shen et al. (2003) has developed a computer system to support the process of decision-making in assessing the competitiveness of contractors. Competitiveness rates are used to describe the advantages and disadvantages of the contractor, by helping clients in identifying suitable contractors in the qualification phase.

Phase of the contract awarding involves the examination of the merits of the offer. It identifies which of the qualified bidders will deliver the most value for the organization money, and it is based either on the most economically advantageous tender or the lowest price one, depending on the criteria specified by the procurer. Criteria for the contract awarding must be dealt directly and must be proportionate to the subject of the request. The difference between the qualifying criteria and criteria for the contract awarding is essential. Qualification criteria are focused on suppliers and criteria for contract awarding are focused on bids, and procurers must maintain a clear distinction between the two during the procurement process.

Criteria for the contract awarding can be used after the first phase, during multistep procurement, to determine which bidder provides the most economically advantageous tender in order for further establishment of the bidders' ability to make/deliver a job/goods relating to the contract, in order to assess the most economically favorable bid. Choosing the award criteria, i.e.

criteria for evaluation, as well as models for the evaluation, are crucial in order for procurer to get the best possible result from the procurement, i.e. what will optimally meet the identified needs. In order for the supplier to be able to offer and deliver what the procurer requires, the procurer must clearly formulate its wishes and needs in the tender documents.

Purchaser must specify what constitutes additional value for the procurement or what it will lead to the selection of one bid over another. Procurer represents its wishes by models of evaluation in the tender documents. These models differ in the used selection criteria and the manner of their pondering and can be based on the application of multi-criteria decision making, multiple regression, fuzzy sets theory, cluster analysis and multiple discriminant analysis. On the application of these techniques, among others, the following authors have written about Skibnievski & Chao (1992), Banaitis & Banaitiene (2006), Mitkus & Trinkuniene (2006), Ginevičius & Podvezko (2008), Turskis (2008) and Plenkievicz (2009) etc. The basic idea is that the process of the best bid selection is based not only on the price but also on the more attributes that describe the extent to which the alternative offers will reach the defined criteria, so that the best offer will be the one that has the highest combined value realized by all criteria-attributes.

2.2. Procurement Models

Contract awarding is done on the basis of:

- lowest price bid or
- most economically advantageous offer (specifying, in addition to prices, a variety of other criteria, including running costs, servicing costs, the level of after- sales service, technical assistance, environmental characteristics, etc.).

The lowest price as the basis for the contract awarding means that the procurer accepts the offer that meets all the requirements of the procurement at the lowest offered price. This criterion has the advantages that are reflected in the simplicity and speed of implementation, but there are certain limitations, which are reflected in neglecting the qualitative aspects, the life cycle costs of various products and innovative solutions. In the public procurement in which only price is evaluated, quality requirements can be increased in terms of mandatory requirements that should be met, but need not be evaluated. The method of the lowest price is suitable in assessing complex public procurement, in which is difficult to define criterian, but also in simple public procurement, in which analysis of sensitive solutions is not requested. The contract must be awarded to the offer with the lowest price or the procurer may reject the illogically low price offer, which can be excluded following the Directive

2004/18 / EC of the European Parliament from 31.03.2004. The result of using the lowest price as the sole criterion of evaluation is the lower end of the price, because the bidders offer the lowest levels of all parameters to achieve the lowest price. The risk in using the criterion of the lowest offered price is reflected in the possible selection of the offer with somewhat lower quality and lower price, because the bidders are not so motivated to offer quality.

If the procurer wants not only to evaluate and compare the bids at the lowest price, but wants to take other criteria into account as the basis for the contract awarding, the most economically advantageous tender is then applied. When assessing which tender is the most economically advantageous, the procurer may consider different criteria for the award. The selection of the winning bidder, who is awarded with the contract, is simple: most economically advantageous offer that fits all the requirements of the bid package is the one that gives the best value of the money. To the possible extent, all criteria, in addition to the price, which are used in the selection process, should be expressed quantitatively.

The most economically advantageous offer represents a comprehensive approach for assessing the merits of the tenders in relation to the criterion of the lowest price. This approach requires the procurer to form an opinion about the elements that make an offer "most economically advantageous" and then ranks them according to a priority, which allows the procurer to compare the bids that can meet different permutations of the award criteria. The most economically advantageous tender bid offers convenient access in situations where there is a need to evaluate the operating costs, as well as in cases where different procurement parameters significantly change the utility, but not the price.

Table 1 Advantages and disadvantages of public procurement

Model	Advantages	Disadvantages
lowest price	- Simplicity and ease of the procedure - Increased number of bids - Lower the final price	- Neglect of the importance of quality - The possibility of corruption
Most economically advantageous tender	- An inclusive approach - A large number of criteria - Focus on quality	- Complex procedures - Fewer offer - The higher the final price - The possibility of corruption

Source: autors

As some research shows (Nikolov et al., 2012), the bidders do not believe and participate less in the tenders which are measured with multi-criteria, thus increasing importance of non-price criteria implies a smaller number of bids.

Reducing the importance of non-price criteria, for 14 percent, increases the number of bids for 1. The average number of tenders with lowest price as the criterion is 2.75, and in the case of the most economically advantageous offer is 1.79. The reasons for this should be sought in the popular public opinion, that the tenders with the multi-criteria are rigged. The negative relation between the number of bids and the number of criteria is established on the basis of data from a number of empirical studies (Carr, 2012). We have a similar situation in the Republic of Serbia, where the existing Law on Public Procurement (LPP), has introduced several significant innovations in the public procurement system: certification of public procurement officers; electronic advertising on the Public Procurement Portal; quarterly reporting to the Public Procurement Office on conducted public procurement procedures and concluded contracts, etc. At the same time it showed some weaknesses, among which are prescribing too many mandatory conditions for participation in public procurement procedures, which reduces the number of potential participants in the process and restricts competition, as well as underdeveloped criteria for the implementation of certain elements of the economically advantageous tender criterion. Thus in order to improve the public procurement system in general, it is necessary to increase the efficiency of public procurement processes, which can be achieved not only by appropriate system changes and changing legislation, but also by the introduction and application of new methodology, based on scientific principles.

3. Methodology

3.1. Application of Multi-criteria Analysis in Public Procurement

Establishing and pondering the evaluation criteria is an important part of various procurement processes. Selection criteria for the evaluation of bids, is actually the choice of parameters in which bidders compete. When you generate the appropriate criteria at the stage of qualification, it is necessary to formulate them so that they can be used in determining whether or not a potential proposal/supplier suitable, i.e. whether it is directly related to the subject of the contract. Also, it is important that the criteria are sufficiently clearly formulated so as to ensure that the supplier has a precise understanding of what is most important for the award. Identical criteria, however, should not be used in the evaluation phase, i.e in the contract awarding. The criteria and their assigned weights (weight coefficient) will vary depending on the type of goods, services or work that will be carried out. Thorough suppliers' market research, combined with a full understanding of the subject demand, will help in selecting the most favourable evaluation criteria for specific types of procurement. The theory of public procurement uses different definitions (formulation) criteria during the

phases of public procurement (agreement and compliance, differentiation, risk assessment, etc.). Accordingly, the methods for assigning weight coefficients (weighting) criteria may vary through phases, so it is very important that public policy makers clearly and unambiguously identify all phases of public procurement and the criteria that will be used to select and weight selected criteria in the tender documents. In practice, it is accepted that the choice of the tender should be based on the relative importance of all the set criteria, so several approaches are developed in order to accomplish mentioned task. One of the most commonly used approaches in pondering criteria, is according to their relative importance on a relation scale. The distinction between ordinal and cardinal values of weights should be borne in mind. While ordinal values only show that one criterion is more important than the other, giving, therefore, only the order, but at the same time not showing for how much one criterion is more important than the other, cardinal weights indicate the relative importance of the criteria for decision- making, mapping the structure of its preferences in a set of the rational numbers.

In the tender practice, most intuitive approach for the calculation of the overall performance of individual suppliers for each criterion is that the normalised value of the result multiplied by the weights of the observed criteria or so called weighted sum method (Weighted Sum Method, Table 2). Weights, thereby, must proportionally reflect the structure of preferences, so that, for example, the criterion with weight 8, is two times more important than the criterion with weight 4. The obtained value function shows the quality of alternatives, a senior rank implies the greater value alternative. In addition, we should mention the methods of simple additive weight (Simple Additive Weighting), where the results of the performance are multiplied by the weights criterion (Table 2).

Table 2 Methods of evaluation of the bids in public procurement

Method	Formula	Description
Weighted sum method	$V_i = \sum_{j=1}^{m} w_j \times q_{ij}$, i= 1,..,k	V_i – The value of the alternative i; w_{ij} – weight of the criteria j; q_{ij} – normalized value of the alternative i, in relation to a criterion j;
Simple additive Weighting	$V(a_i) = \sum_{j=1}^{J} (w_j v_j)(a_i)$	w_j – weight of the criteria j $v_j(a_i)$ – value of the alternqative a_i in relation to a critertiion v_j

Source: autors

However, the efficacy of this procedure can only take place if the following conditions are met:

a) If the criteria are independent;
b) If the decision-maker has a true understanding of the usefulness of alternative and understanding of different weight criteria;
c) If the weights are scaled constants, i.e. real performance weight converted to a scale (0.1) ;
d) If the weight derived from the actual performance alternative rank
e) If the weights are derived from *trade off* processes, i.e. they are the result of compromises and compensation.

Attribute Analysis (MAA), Multiple Criteria Utility Theory (MAUT) and Analytical Hierarchy Process (AHP) are compared methods to assign weight coefficients (weights) to the selection criteria. (Holt, 1998; Alarcon & Mourgues 2002). Table 3 shows their formulas in order to illustrate the similarity between their functions (Holt, 1998). As shown in Table 3, the above method for evaluating suppliers, are used to calculate the aggregate or composite score for each criterion. The differences between the methods are reflected in the following: 1) MAA and ANP are using the simple scoring for the criteria rating, while MAUT benefit usefulness; 2) ANP applies the comparison of elements in pairs to determine the weight, while MAA and MAUT are using a simple scoring; Mahdi et al. (2002) suggests that a ANP could be incorporated into the MAA or MAUTE, in order to determine the weight criteria. From the point of criteria connection and what Holt (1997) thoughts on the rationalization, objectivity and saving resources, Analytical Network Process (ANP), it seems, could be a suitable method for assigning weight coefficients to the associated attributes.

If the implemented model is economically advantageous tender, the manner of weighting the criteria for awarding the contract must be clearly stated in the tender documents. In the case of the procurement of goods or execution of works, the criteria should be weighted so that the cost of waste is at least 50 %, while in the case of services, the price is, as a rule, less important than the quality. Sub-criteria must not be of purely economic nature, but they must make it possible to determine which offers have the greatest value for money.

What evaluation model will be applied depends on the assumptions of the each procurement, so there is no universally applicable method for all occasions. Although it is generally considered that the relative model evaluation is easier to take (Laver & Larsberger, 2011), it can lead to unexpected and unforeseen results. On the other hand, where can be applied, the absolute model of evaluation increases predictability. When selecting the evaluation model it is

important to know the consequences that may arise, as well as its advantages and disadvantage. It is also important that has been tested in simulations before the final tender documents.

Table 3 Comparison of MAA, MAUT and AHP

Method	Formula	Description
Attribute Analysis (MAA)	$\underset{i=1}{\overset{n}{A}}Cr_j = \sum V_{ij}W_i$	*ACrj* is the aggregate score for contractor *j*; *Vij* is the attribute *i* score with respect to contractor *j*; *n* is the number of attributes considered in the analysis; *Wi* is the weighting indices to *Vi*
Multiple Criteria Utility Theory (MAUT)	$\underset{i=1}{\overset{n}{A}}Cr_j = \sum U_{ij}W_i$	AC*rj* is the aggregate score for contractor *j*; *Uij* is the attribute *i* score with respect to contractor *j*; *n* is the number of attributes considered in the analysis; *Wi* is the weighting indices to *Ui*
Analytical Hierarchy Process (AHP)	$\underset{i=1}{\overset{n}{C}}r_i = \sum c_i V_{ij}$	C*ri* is the composite score for contractor *i*; *ci* is the relative weight for *Vi* with respect to contractor *j*; and *Vij* is the selection criterion *i* with respect to contractor *j*

Source: Holt (1998).

3.2 Analytic Hierarchy Process

Analytic Hierarchy Process (AHP, Saaty, 1980) is an intuitive method for formulating and analyzing decisions, which can be successfully used to measure the relative impact of numerous relevant factors on possible outcomes, as well as to forecast, i.e. to perform distribution of relative outcome probability. As regards the above issues of multiple-criteria decision making and forecasting, assessment of managerial preference plays a key role in the process of solving problems. One of the most attractive approaches in this regard, whose methodological approach of organizing the decision-making elements into the chain of hierarchy received positive confirmation in practice, creating a flexible adjustment of preferences, is the analytic hierarchy process.

The four basic steps in the application of the AHP method in solving problems of evaluation and ranking of alternative outcomes are:

1) Problem decomposition – the development of a hierarchy of interconnected decision-making elements that describes the problem;
2) Pairwise comparison – comparing pairs of decision-making elements, using the 1-9 comparison scale, to obtain the input data;
3) Prioritization – calculating the relative weights of the decision elements, most often using methods of default values;
4) Synthesis – deriving relative weights of the decision elements in order to calculate the ranking for the alternative decision options.

Pairwise comparison is, based on AHP, displayed in the form of a square matrix which gives information about the dominance of each decision element in relation to any other decision element of the same level. The set of pairwise comparison matrices generates a set of local priorities which reflect the relative influence of a set of elements on the element at the level immediately above. This reveals the relative strength, value, desirability, or likelihood of each element compared, by solving comparison matrices. Pairwise comparison of decision elements is done by the 1-9 comparison scale (Table 4), which has, in numerous comparative studies, proven to best simulate human decision making. As far as its efficiency is taken into consideration, this scale is valued not only in numerous practical applications, but also in theoretical comparison with many other scales.

When the assessment is entered for each part of the model, the information is synthesized to demonstrate the general preference and the ranking of alternatives in relation to the main objective of the model.

An important indicator of assessment consistency is consistency ratio, *CR* (Saaty & Kearns 1985, p. 33), whose value should be about 10% or less in order to be acceptable, otherwise there is a need that the decision-maker reviews their assessment by seeking further information.

3.3 Analytic Network Process

The Analytical Network Process (ANP) is a method for decision support developed by Thomas Saaty (2001) and which allows the involvement, quantification and the objectification of all relevant, tangible and untagible factors in the decision-making process, as well as all the existing influences between decision criteria and alternatives. Generalizing the access of supermatrice, introduced in the AHP concept, the ANP allows interactions and feedback within and between the components of the model: in clusters (inner dependence) and between clusters (outer dependence). This feedback successfully includes complex relations, especially in cases of risks and uncertainties. An ANP model consists of two parts. The first part consists of hierarchical control or network of criteria and sub-criteria, that control the

interactions in the system which is studying. The second part is the influence network, among the elements and clusters, whereby one ANP model can have one or more networks. Furthermore, the problem is often studied through a control hierarchy or a system which consists of benefits, costs, opportunities and risk. Synthesized results of four control systems are combined by calculating the ratio of the product benefit and possibilities and product costs and risks, in order to determine the best outcome.

The procedure of applying the ANP model of decision making has five steps (Saaty, 2005):

1) Decomposition of the problem. Decision problem is decomposed into its main components.
2) Cluster formation for the evaluation. After defining the objectives of decision making, also it is necessary to generate the clusters for the evaluation by the criterion, sub-criterion (if it is possible) and cluster alternative.
3) Structuring of the ANP model. The ANP is applied to different decision making problems in the field of marketing, health, politics, military issues, society, predictions, etc. Their accuracy of forecasting proved in impressive applications in the field of economic trends, sports events and other events, whose outcome later became known.
4) Paired comparison and prioritisation. In this step it is necessary to compare pairs of elements of decision making, as well as the synthesis of priorities for all the alternatives. When the paired comparison in the ANP model is performed, the questions are formulated in terms of domination or impact, which is a central concept in the application of the AHP/ANP methodology. If the registry element is known, which of the two elements being compared in relation to it, have a greater impact (it is more dominant) in comparison to that registry criteria?
5) Or, in the case that there is a feedback, which of these two elements is under the higher influence of the registry criteria?
6) Sensitivity analysis of the solution. It is finally possible to make a decision and sensitivity analysis in terms of the impact, which according to the importance of some criteria or sub-criteria on a given solution has the final outcome, and by analyzing determinate how big or small these indicators are.

As the Analytic Hierarchy Process and Analytic network process can be used in solving the problem of choice under uncertainty, or as a tool for predicting (Blair & Saaty, 2010; Azis, 2010; Voulgaridou et al. 2009), etc. Problem of choice typically involves the evaluation of preference of alternative courses of action, while the prediction using the AHP / AMP focuses on performance relative probability distribution of future outcomes.

A good overview of AHP applications and/or ANP, as the extension of AHP, was given by Vaidya &Kumar (2006), Sipahi & Timor (2010), Ishizaka & Labib (2011) and Jayant et al. (2015).

Table 4 The scale of relative significance 1-9.

Intensity of relative importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one relative to the other	Experience and assessment slightly favor one activity over another
5	Essential or strong importance	Experience and assessment strongly favor one activity over another
7	Demonstrated importance	One activity is strongly favored, and its dominance is demonstrated in practice
9	Extreme importance	Evidence favoring one activity over the other is of the highest possible order of affirmation
2, 4, 6, 8	Mean values of two adjacent assessments	When compromise is necessary
Reciprocity of the above non-zero numbers		If an activity has one of the above numbers (e.g. 3), compared to other activity, then the second activity has the reciprocal value (i.e. 1/3), when compared with the other

Source: Saaty, T. L. & Kearns P. K. (1985). Analytical planning, The Organization of Systems, The Analytic Hierarchy Process Series, Vol. IV, RWS Publications, Pittsburgh, p.27.

On the other hand, although many of the problems of decision-making, in particular prediction, the AMP study, this does not necessarily imply that the application of AMP model always gives better results than using the AHP hierarchy. Actually, there are problems that allow the use of both models.

4. Description and Structuring of Problems

4.1. Multi-criteria Weighting Models and Evaluation Criteria in Procurement Process

One of the most important segments of the public procurement tender evaluation is the choice of award criteria, i.e criteria for evaluation, as well as the models for the evaluation , as already mentioned, are of crucial importance

that the customer gets the best possible result from the acquisition, that is what we optimally meet the needs identified. In order supplier able to offer and deliver what the contracting authority requires, the contracting authority must clearly formulate their wishes and needs in the tender documents. Purchasers must specify what constitutes value added for the purchase or what it will lead to the selection of one bid over another. Purchasers represent their wishes with the models of evaluation in the tender documents. According to the EU directive 2004/18EC, in the procurement process, the criteria used for assessing the economic and financial capacity, as well as the assessment of the professional and technical capacity, belong to the so-called criteria for qualitative selection and generally cannot be used at the stage of contract awarding. In order to carry out a comprehensive analysis of the phases in the procurement process, we have, however, ignored the above condition and assumed, that it is an open public procurement procedure (PPL, article.32), which implies that all interested persons may submit bids, which will not substantially affect the final conclusions.

Suppose, in the sense that we have a simple case of the contractor selection for the construction of an infrastructure facility and that after the qualification phase, the remaining three advantageous tender bid: A, B, and C. Also assume that in accordance with the choice of the most economically advantageous tender offer as a type of tender, a set of criterion for the contract awarding is defined and it consists of the following criteria:

- Tender price
- Economic and financial capacity
- Technical and professional capacity
- Time, and
- Reputation and experience

Some of the criteria are described in more detail a set of sub-criteria, namely:

The financial sub-criteria are:

- Financial stability
- Financial status
- Credit rating
- Banking arrangements

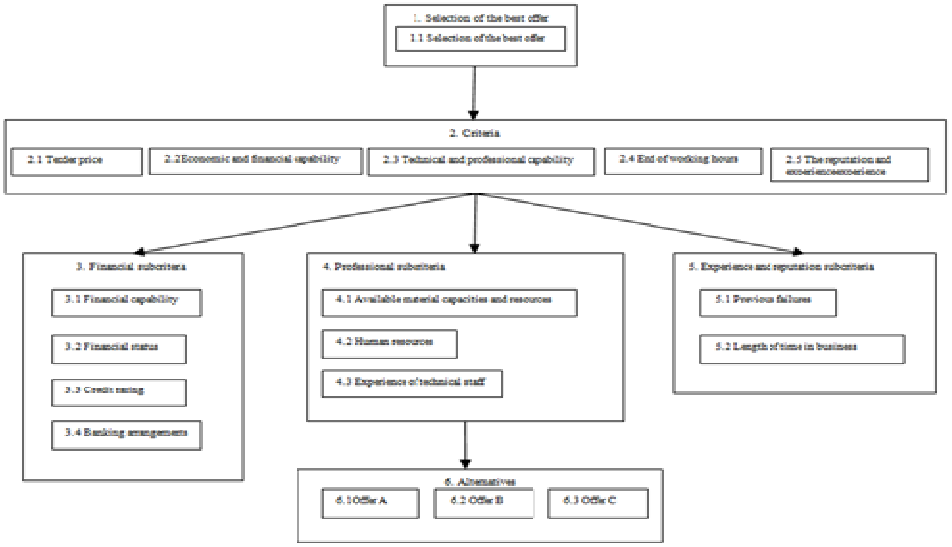
Professional sub-criteria are:

- Available capacities and resources
- Human resources and
- Technical experience of the staff

Sub-criteria of experience and reputation are:

- Previous failures in business
- Length of time spent on the job

Figure 1 AHP model of the economically most advantageous tender



Bearing in mind the main objective and a set of available alternatives, a relatively complex hierarchical structure of the ANP was formed, with the goal at the highest level, criteria at the second level, sub-criteria on the third and alternatives on the fourth level. In accordance with the defined procedure of applying the ANP method, after the hierarchical structuring of the problem (Figure 1), elements of the lower-level decision-making are compared in relation to the elements of a higher level, in pairs, according to a 1-9 scale comparisons. Defined criteria are compared with each other in relation to the main objective of the problem - Selection of the most economically advantageous tender in order to determine their relative importance. When using the method of the most economically advantageous offer, the price, as already noted, may or may not have the greatest significance, or it can be considered in the second phase, after evaluating the applications admissible tenders, as a decisive factor. In this case, we assume that the price of the tender is only one of the defined criteria, whose relative importance is yet to be determined. Criteria quality could also be described in greater detail as a set of sub-criteria according to the specific offer, but for the purpose of simplicity we will also assume that the alternatives are compared with each other only according to the criterion of quality. The relative values of the criteria, obtained by the authors' calculations, are given in Table 5.

4.2. Results of the Models

In developed AHP structure, a total of 53 comparisons of pairs of elements at all levels of the hierarchy were made, according to the scale comparisons 1-9. Identified criteria are mutually in relation to the main objective of the problem - the selection of the best deals (suppliers), which determined their relative importance expressed through the weighting coefficients or priorities (Table 5).

Table 5 The relative importance of the criteria for selecting the most economically advantageous tender, obtained by the AHP methods and software package *Superdecisions.*

Criterion	Priority	Rank
21 Tender price	0.17370	3
22 Economic and financial capacity	0.09512	4
23 Technical and professional capacity	0.05479	5
24 Time for completion of works	0.21609	2
25 Reputation and experience	0.46031	1

Source: authors calculation

After comparing the criteria, it is necessary to prioritiese the sub-criteria, by comparing with each other in relation to the criteria described by the higher level. Thus, the financial sub-criteria are compared in relation to the criterion of the economic and financial capacity and so on. Preferences of the sub-criteria are shown in Table 6. Also, for illustrative purposes, comparison of alternatives, i.e. offers were conducted, assuming that their references from the defined criteria and sub-criteria point of view were available.

Table 6 The relative importance of the sub-criteria obtained by the AHP method

Sub-criteria	Priority	Rank
31 financial stability	0.05582	3
32 financial status	0.02702	6
33 credit rating	0.01914	7
34 banking arrangements	0.05390	4
51 Previous failures in business	0.62862	1
52 Length of time spent on the job	0.12572	2
41 Available capacities and resources	0.03591	5
42 Human resources and	0.03591	5
43 Technical experience of the staff	0.01796	8

Source: authors calculation

Final resulting priorities of the alternatives are obtained thanks to their mutual comparison with criteria and with sub-criteria of higher level, as presented in table 7. As you can see in the table, the highest rang has the bid B, then comes bid A, and the lowest bid C. The gained results reflect the preferences of the hypothetical decision-maker who is in charge of the evaluation, i.e. evaluation of the bid. If the scenarios are more realistic, when it comes to procurements, we have more decision- makers, i.e. the commission for the public procurement, geometric middle can be applied, as a mean of combining and objectification of evaluation in the group decision making situation (Saaty i Peniwati, 2008).

$$w_i = \sqrt[K]{\pi_{k=1}^{k=K} w_{ik}} \qquad \forall \ i$$

where w_i is the final weight of *i factor* and w_{ik}, the relative weight of *i element*, calculated on the basis of *k* evaluator estimation.

Table 7 Final priorities of alternatives obtained by AHP methods and software package *Superdecisions.*

Name	Ideals	Normals	Raw	Rank
61 Bid A	0.722941	0.323276	0.123851	2
62 Bid B	1.000000	0.447168	0.171315	1
63 Bid C	0.513355	0.229556	0.087945	3

Source: authors calculation

In the second case, we have estimated that the dependencies, between elements of higher and lower levels in the specific problem of choosing economically most advantageous bid, are not only one-way and external, but also internal, both between the criteria and sub-criteria. For it is clear that in many cases, the economic and financial stability dictate the price at the tender, as the offer price often defines the quality of goods and services and vice versa. Thus, the inner relationship between certain criteria will have a direct impact on the establishment of internal dependencies and the sub-criteria that describe them. With that in mind, we have established the ANP network structure, in order to solve the mentioned problem, now using the model of the Analytic Network Process, which involves situations in which there is a two-way dependence on the elements of decision-making, as both internal and external. Responding ANP model is shown in Figure 2 and the results obtained through its application in the following tables. In this case, the comparison between 59 pairs was carried out for prioritizing ties that exist between the elements of the ANP model, the small number was expected, given the fact that it is a simple model. From the results it can be seen that there was an inversion of rank, of both criteria and sub-criteria, as

a result of different weights value assigned to the criteria and interactions that exist within and between clusters in the ANP model.

Figure 2. AMP model of the selection of the best bid

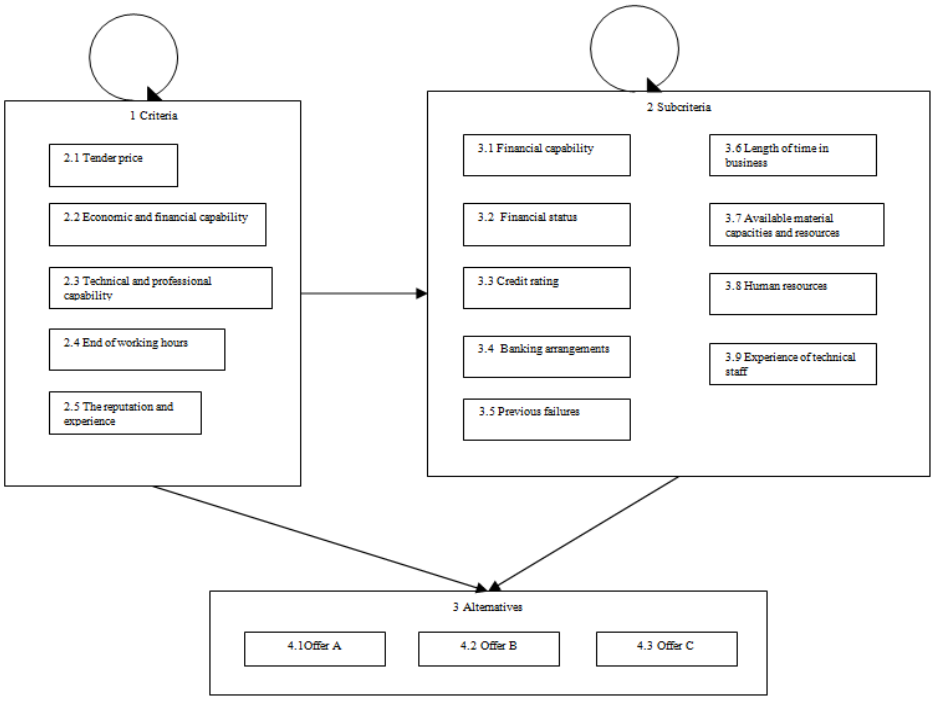


Table 8 The relative importance of the criteria for selecting the most economically advantageous tender, obtained by the AMP methods and software package *Superdecisions.*

Criterion	Priority	Rang
21 Tender price	0.16654	4
22 Economic and financial capacity	0.16051	5
23 Technical and professional capacity	0.27850	1
24 Time for completion of works	0.17193	3
25 Reputation and experience	0.22252	2

Source: authors calculation

Table 9 The relative importance of the sub-criteria obtained by AMP and the methods and software package *Superdecisions.*

Sub-criteria	Priority	Rank
31 financial stability	0.08689	4
32 financial status	0.04205	8
33 credit rating	0.02979	9
34 banking arrangements	0.08390	7
35 Previous failures in business	0.28031	1
36 Length of time spent on the job	0.05606	6
37 Available capacities and resources	0.16840	2
38 Human resources and	0.16840	2
39 Technical experience of the staff	0.08420	5

Source: authors calculation

Table 10 Final priorities of alternatives obtained by the AMP methods and software package *Superdecisions.*

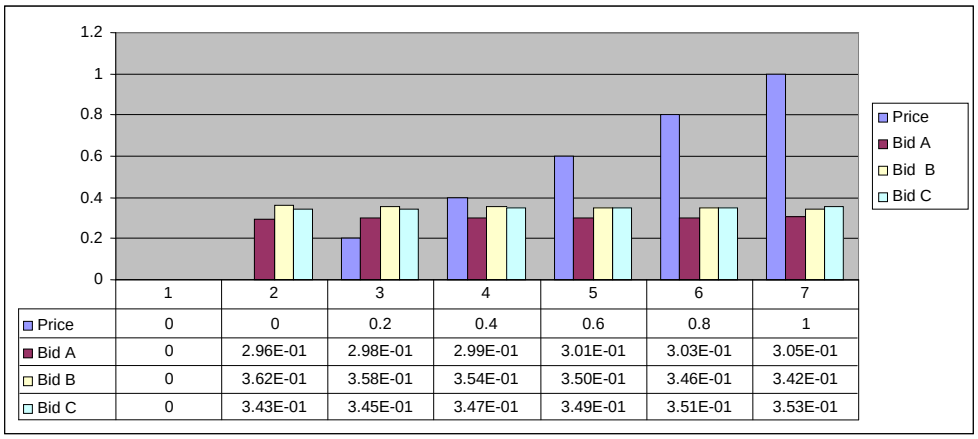
Name	Ideals	Normals	Raw	Rank
41 Bid A	0.812482	0.295106	0.147553	3
42 Bid B	1.000000	0.363215	0.181608	1
43 Bid C	0.940706	0.341679	0.170839	2

Source: authors calculation

4.3. Sensitivity Analysis of the Solution

Sensitivity analysis solutions is a fundamental concept for effective use and implementation of decision making methods and shows how and for how much alternative rang changed, in the event of changes in the relative importance of one or more of the criteria or sub-criteria. From Figure 3, it can be concluded that the growth of the relative importance of the criteria in the tender price from 0.001 to 0.999, has no significant influence on the ranking of alternatives. In fact, only when the relative importance of the criteria of significant start approaching, offer C, gets the highest rank , which points to the fact that the price offered for C, (but not for A and B, Figure 4) in the tender reference is a factor for the procurer who order services . The obtained result is not surprising, given that this criterion is not estimated to be the most important in relation to other criteria, which are in turn, the referential for the other alternatives, offer A and B.

Figure 3 Comparative review of changes in ranking alternative offer in case of the change of the relative importance of the factors in the tender price. (AMP model)



	1	2	3	4	5	6	7
Price	0	0	0.2	0.4	0.6	0.8	1
Bid A	0	2.96E-01	2.98E-01	2.99E-01	3.01E-01	3.03E-01	3.05E-01
Bid B	0	3.62E-01	3.58E-01	3.54E-01	3.50E-01	3.46E-01	3.42E-01
Bid C	0	3.43E-01	3.45E-01	3.47E-01	3.49E-01	3.51E-01	3.53E-01

This conclusion is entirely consistent with the rules and the logic underlying the evaluation of bidders in the procurement process. And when does not apply criterion of the lowest price, it is recommended that price constitutes at least 50 % of the total of the decision, so that with its growth in the relative importance, the bidder with the lower price gets the advantage. Sensitivity analysis of the solutions may be desirable and useful especially in situations where due to changed circumstances in the market, it is necessary to react quickly and include new information that can influence the decision makers, i.e. the procurer and its relationship to the selection of the model of public procurement, as well as its relation to the relative importance of the criteria and / or sub-criteria.

5. Conclusion

The paper presented the methods and framework for using the multi-criteria analysis in the selection and weighting the criteria for the evaluation of the bidders in the procurement process. Two multi-criteria models were developed, and were applied to the hypothetical example of the best bid selection. The simple hypothetical example shows how a complex problem of public procurement can be structured and solved, such as the selection of contractors for infrastructure works (construction of bridges, highways, etc.). In doing so, detailed analysis and the presence of experts in the identification and evaluation of the key criteria for evaluation and contract awarding, are something that is considered to be done. The advantage of this approach compared to the traditional model of direct election and the weighting criteria is the detailed

analysis carried out by the decision maker, thus achieving a more realistic view of the problem, greater objectivity in its solution and eliminating bias as the basis for corrupt practices in the procurement process. We have to emphasize advantages of multi-criteria analysis in this case, when implemented through the method of the Analytic Network Process (ANP), which includes an analysis of the mutual impact of identified criteria, which is in practice often omitted. Application of the Analytic Hierarchy Process (AHP) is a simple and easy to understand for decision makers, managers or experts. However, when it comes to a matter of applying the Analytic Network Process certain preconditions must be met. Questions that need to be asked to the decision-makers, in reference to the comparison of criteria pairs in order to determine their weights and importance, must be carefully formulated to allow the analysis of their mutual influence and their priority. Furthermore, cluster structure, which is characteristic for the ANP application must be well defined to ANP network was as simple to understand and use. This is because, decision-makers in the public procurement process, as a rule, are not familiar with the application of complex scientific methods to optimize decision-making process. The process and manner of asking questions in the application of AHP and ANP method takes time needed to understand the questions and the time for the answers to these questions, which decision makers, as a rule, never have enough.

Analysis of the results reveals certain differences in the criteria weights, obtained by AHP and the ANP model, which has led to rank inversion. Usage of the AHP model allows experts who carried out the assessment to determine the importance of each criterion, while AMP shows not only the importance of the criteria, but seen in the context of their mutual influence, enables deeper reflection on the problems. In this sense, it could be concluded that the way in which AMP generates results - the relative importance of the criteria, the expert closer to intuition than is the case with the AHP method. This, of course, does not mean that the use of AMP is suitable in all situations from the application of AHP, or that always gives better results. Also, the fact that the public procurement process, there are many factors which reduce the impact and importance of other factors, logically justifies the use of the AMP method, compared to the AHP methods. Aggravating circumstance in this respect may be the situation when it comes to complex public procurement, when the number of factors and their mutual influence should be taken into account, which may drastically increase the number of required comparisons and assessment procedures too complicated, too long and uneconomical for practical application.

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PRIMENA VIŠEKRITERIJUMSKE ANALIZE U OPTIMIZACIJI POSTUPKA JAVNIH NABAVKI

Apstrakt: Jedna od ključnih faza u sprovođenju postupka javnih nabavki je izbor kriterijuma koji su povezani sa ponuđačima, a koji imaju za cilj da obezbede da će ponuđači moći da zadovolje zahteve ugovora. Implicitno, izbor kriterijuma uključuje i njihovu evaluaciju u situacijama kada se ne primenjuje kriterijum najniže cene, već se izbor vrši prema kriterijumu ekonomski najpovoljnije ponude. Cilj rada je da pokaže kako donosioci odluka u javnom sektoru mogu da koriste višekriterijumsku analizu za efikasno i nepristrasno sprovođenje postupka javnih nabavki i uspostavljanje objektivnih pretpostavki za dodelu ugovora u skladu sa opšte društvenim interesima. U tom smislu, u radu je predstavljen komparativni pristup Analitičkog hijerarhijskog procesa i Analitičkog mrežnog procesa, kao metoda za podršku odlučivanju, u merenju i evaluaciji kriterijuma za izbor najbolje ponude u postupku javnih nabavki. Razvijeni su hijerarhijski model, sa pet kriterijuma i devet podkriterijuma, i mrežni model, koji uzima u obzir međusobne uticaje kriterijuma, u hipotetičkom postupku javnih nabavki za izbor najboljeg izvođača na izgradnji infrastrukturnog objekta. Izbor najboljeg izvođača, odnosno ponude za realizaciju takvog posla, karakterističan je višekriterijumski problem koji uključuje i kvalitativne i kvantitativne faktore.

Ključne reči: javna nabavka, kriterijumi, evaluacija, težinski koeficijenti, izbor, višekiterijumska analiza.

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