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DEVELOPING AN MCDA MODEL FOR CHOOSING CRITERIA USED IN PROJECT RANKING

Abstract. *In order to select criteria that express a dimension of expected project values, there is proposed a model for the selection of criteria in the area of Portfolio project management. The suggested model is created as an integrated model by combining multi-criteria decision-making methods for simply choosing project selection criteria. The integrated model uses the Analytic hierarchy process (AHP) and The Weighted Aggregates Sum Product Assessment method (WASPAS) for evaluating criteria and sub-criteria, and uses the ABC method to group ranked criteria according to their total value to project selection. This model achieves an efficient and simple selection of criteria in accordance with the strategic goals of the organization. The Model gives direction for effective engagement of limited funds and resources to the projects. The convenience and efficiency of the proposed AHP WASPAS ABC approach are presented through an illustrative case study of selection criteria.*

Keywords*: AHP, WASPAS, ABC, project, criteria.*

JEL Classification: C02, C11, C45, C46, C63

1. Introduction

The traditional organizational structure, in order to survive in the environment conditioning by trends of modern business, has evolved into the form we know today as a project organizational structure or project-oriented organizations. Therefore, the Project-oriented organization has become imperative for survival in a market prone to dynamic changes and conditions.

This organization bases its management and functioning on project management, therefore project management, for that reason, is very present and widespread in scientific papers as a subject of study. Project-oriented organizations base the realization of their strategic goals on the success of project management. This

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organizations, in order to realize their interests defined, first of all, by mission and vision, and then by strategic goals, choose projects that represent effective ways to achieve strategic goals. Project planning and implementation require funds that are limited and irrationally using is not allowed.

Project selection is the process of evaluating individual or groups of projects, and then choosing to implement those that will help achieve the organization's objectives (Meredith et al, 2017),(Rudnik et al, 2021). The challenges thus facing the contemporary organization are how to make sure that projects are closely tied to the organization's goals and strategy, how to handle the growing number of ongoing projects, and how to make these projects more successful (Meredith and Shafer, 2017), (Rudnik et al, 2021).

Research in project selection has shifted towards Project Portfolio Management (PPM) owing to its many benefits (Padhy, 2017), (Rudnik et all, 2021). The challenging task of determining the combination of the projects which can collectively create the maximum business value for the organization is referred to as "Project Portfolio Management" (Jiménez et al, 2017). The multi-project organization brings unique challenges, but surprisingly, despite the complexity associated with the management of multiple projects, traditional project management literature has mainly Put another way, there is a need to expand the research on "project management" to research on "projects" and to pay attention to multi-project contexts, on which too little attention has been devoted so far (Geraldi & Söderlund, 2018).

Project portfolio selection aims to find the best set of projects in order to satisfy the established objectives or requirements without violating indispensable constraints (e.g., resource, time, risk) (Korotkov and Wu, 2019), (Zhang et al, 2020). The main goal of the project portfolio selection is to choose a proper set of projects to allocate limited resources such as equipment, people, time, and budget to them (Mohagheghi et al, 2017). To choose the best portfolio, individual project analysis must be complemented by an evaluation of the interdependencies or interactions amongst the projects—i.e. the effects of a project or a subset of projects on other projects (Alvarez-Garcíaa and Fernández-Castroa, 2018). Accordingly to Mittal et al, 2017, project selection is part of any strategic management framework, and there are various mathematical methods of decision-making available and applied for this purpose (Mittal et al, 2017).

In order to successfully handle these challenges, it needs to establish criteria for the selection project which present the dimension of the organization's goals and strategy, and determine what is expected value of the project. Choosing criteria for selecting projects is an important condition in the phase of project selection because basically choosing criteria will make measuring of project value and will be make choosing on which projects will be allocated organization's resources.

Accordingly to the essential importance of criteria in selection projects, appearance need for determination group of criteria which will ensure successfully selecting a project for gain strategy goals.
Multi-criteria decision-making (MCDM) methods are gaining importance as potential tools for analyzing and solving complex real time problems due to their inherent ability to evaluate different alternatives with respect to various criteria for possible selection of the best alternative (Chakraborty et al, 2020).
When a particular MCDM method is finally recommended for a specific application, it is observed that its solution accuracy and ranking performance are seriously influenced by the value of its control parameter (Chakraborty et al, 2020).

Jafarzadeh et al. also commented on the significant role of criteria in the process of selection of portfolio project management, and in whose paper it was noticed that the most of studies, have predominantly devoted their efforts towards developing models for identifying the best portfolio based on a given set of selection criteria; studies simply pick an arbitrary set of selection criteria without proposing a solution for filtering or prioritizing the many criteria that usually exist during the process of project selection. Nevertheless, provided that in the real world a large number of competing factors do exist when selecting projects over each other, it is necessary to have a mechanism in place to compare the criteria against each other and prioritize them. (Jafarzadeh et al, 2018)

2. Methodology

2.1 The Analytic hierarchy process (AHP) method

The AHP method proved to be one of the most applicable methods of multi-criteria analysis (MCA) and it is mentioned in most of the MCA manuals and guides. (Roman, 2012). It is a multicriteria based decision method that employs hierarchical structures to show the problem and generates priorities for various alternatives on the basis of the user's judgment (Saaty, 1980).

The basic steps of the AHP method determined by Saaty and used by many authors as Ilangkumaran and Kumanan, 2009; Russoa and Camanho, 2015 and Jovanović et al, 2015, are as follows:

1. Creation of a hierarchical structure. Hierarchical tructure is built "from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria) to the lowest level (which is usually a set of the alternatives)." (Saaty, 1980), (Russoa and Camanho, 2015)
2. Creation of comparison matrix. The comparison matrix of elements in one level in relation to elements at a higher level is constructed using individual comparisons translated into scale values. (Jovanović et al, 2015). In AHP comparison of factors can be made using a scale from 1 to 9 if the factors have a

direct relationship and a scale from 1/2 to 1/9 if the factors have an inverse relationship. (Chaudhary et al, 2016).

3. Calculation of priority. Normalized values are obtained by dividing each of the values by the total value of its column (Dobrea, 2006). Then the comparison of the criteria is transformed into weight coefficients. These weighting coefficients are calculated as the average of the normalized values in each row (Kj), and must satisfy the condition ∑Kj = 1. The best alternative is the one with the highest value (priority) (Ilangkumaran and Kumanan, 2009).

4. Calculation of consistency index and ratio. The consistency of the rating for each class of distance from roads can be tested by the calculation of a Consistency Index (CI) and Random Consistency Index (RI) (Saaty, 1980).

2.2 The WASPAS method

In their paper since 2012 Zavadskas et al., proposed integrated The Weighted Aggregates Sum Product Assessment method (WASPAS) that purpose was being widely accepted as an efficient decision-making tool with mathematical simplicity and capability to provide more accurate results as compared to WSM and WPM methods. The weighted sum method is used for its clarity and its simplicity (Ben Mena, 2000).

WASPAS method is, the first of all, created to give more precise results of multicriteria analysis, combining two simple methods thus overcoming deviation in the result of alternatives ranking. As is authors himself noted in his papers, two combined methods separately can provide the different results of the ranking, and his combining in WASPAS method, this deviation overcoming. Appling of this integrated method is very suitable for qualitative and quantitative data in process of decision making, and especially is easily understandable decision-makers (DMs) from different areas.

The method provides the possibility for using different scales for marks as an expression of preferences of decision-makers that use very efficiently as input data at the ranking process. The simplicity of applying this method gives a huge space for its implementation in different processes of decision making and ranking alternatives in different areas of business. Also, because of the benefits of WASPAS method for quantitative and qualitative, as for their combination, with reliability and accuracy of obtained data. Applying of WASPAS method as a combination WSM and WPM methods, have several steps (Zavadskas et al,2012):

Step 1. Create an evaluation matrix

Step 2. Normalization of evaluation matrix – Normalization is applied by using Eq. (1) or Eq. (2) depending on preferences of criteria (maximization or minimization) using value xij that is performance value of alternative i according to criteria j and values max xij and min xij that is maximal and minimal value of xij (Zavadskas et al,2012).

$$\bar{x} = \frac{x_{ij}}{\max i \ x_{ij}}$$

If $\max_i x_{ij}$ value is preferable (1)

$$\bar{x} = \frac{\min i \, x_{ij}}{x_{ij}}$$

If $\max_i x_{ij}$ value is preferable (2)

Step 3. The total relative importance of i-th alternative, based on weighted sum method (WSM), is calculated using Eq. (3) (Zavadskas et al.,2012):

$$Q_i^{(1)} = \sum_{j=1}^{n} \bar{x}_{ij} . w_j \tag{3}$$

Step 4. The total relative importance of i-th alternative, based on weighted product method (WPM), is calculated using Eq. (4) (Zavadskas et al.,2012):

$$Q_i^{(2)} = \prod_{j=1}^{n} \bar{x}_{ij}^{wj} \tag{4}$$

Step 5. The total relative importance of i-th alternative, based on WASPAS method is calculated using Eq. (5) (Zavadskas et al.,2012):

$$Q_i = Q_i^{(1)} + Q_i^{(2)} \tag{5}$$

2.3 ABC method

ABC or Pareto diagram is a graphical method for the analysis of the systemic factors, errors, and causes of similar problems and values in sense of ranking the phenomenon according to the degree of importance, based on established criteria, identification of critical areas of the observed magnitude from the point of frequency and direct efforts in critical areas for more efficient problem solving or concentrate on areas that give greater participation in the effects. (Živković and Đorđević, 2013). Some of the earliest formal work was undertaken by the Italian economist Vilfredo Pareto (Pareto, 1971). He theorized that a small percentage of the population of a country creates the majority of its output (Flores and Whybark, 1986). The numbers have evolved, but his legacy remains with us as the 80-20 rule (Korbert, 1980). Pareto thought that his 80-20 observations were generalisable but was never able to prove definitely that this distribution would hold over all applications (Flores and Whybark, 1986). In this paper, the Pareto diagram is used to select a group of criteria and their categorization according to the ranking list of criteria obtained using the WASPAS method. There are determined the share of each criteria in the sum of total value using Eq. (6) (Živković and Đorđević, 2013):

$$Fi = \frac{Qi}{\sum Qi} \tag{6}$$

After the obtained shares are expressed as a percentage, the cumulative values fi calculated using Eq. (7) (Živković and Đorđević, 2013):

$$Ci= f1+ f2+....fn \tag{7}$$

2.4 AHP-WASPAS-ABC Model

A project-oriented organization may have a range of projects that offer some value or perhaps the organization has the capacity and resources for starting each of these projects, individually. Although maybe an organization has the capacity to implement it and has managerial competencies that can bring it out or each of the projects promise financial gain, organizations due to limited resources will certainly not choose everything but will choose those that have the highest value defined by criteria. What are the criteria according to which the selection of projects will be performed is the question on what the AHP-WASPAS-ABC method is based on and with the aim to the organizations that initiate the selection process using this model. In the formation of a model was strived to the ease of application so that decision-makers who do not know enough MCDA methods can easily get acquainted with the basic postulates of this model and use it in an easy and understandable way. AHP-WASPAS-ABC model is constructed as a combination of AHP method as the most used method for determination of weight criteria, WASPAS method as a suitable method for evaluation criteria within groups of criteria, and ABC method for categorizations importance of criteria. Evaluating of criteria within of groups of criteria is made as follow:

Step 1: Identifications of criteria and subcriteria – The procedure of applying the proposed model is based on the formation of a universal list of criteria identified through an extensive review of the literature. The universal list of criteria consists of groups of criteria, and each group consists of criteria, and forming of the group is based on the type of criteria. The universality of the list is reflected in the spectrum of criteria that appear in the literature and is unrelated to the field of projects, i.e. The list contains criteria that are used in different areas, and the organizations will, when applying the model, make a selection of those criteria that reflect their strategic goals and interests.

It is very important that the universal list of criteria contains different criteria that are widespread in all areas in which project-oriented organizations operate in order for each organization to single out criteria that are consistent with the type of projects which will be selected. Therefore, decision-makers, using the proposed model, select from the initial universal list of criteria the criteria they consider that is suitable for the type of projects that their organization plans and which will be used for determining project to which will make allocation of resources

Step 2: Form a panellist for evaluation and gathering decision makers marks – is a very important step because it directly depicts the rough assessments of the decision-maker. Therefore, it is necessary to define the scale that will be used to represent the values in the initial decision matrix. As already mentioned, each of the criteria in the universal list of criteria belongs to a certain group of criteria, each of the groups has a weighting coefficient that will use in the evaluation of the criteria that belong to it. Therefore, decision-makers determine a weighting factor for each group, where the sum of all weight coefficients determined by DMs of the groups in the sum must give the value 1. The criteria within each of the groups are evaluated by decision-makers using a Likert scale from 0 - it has no significance -to 5 has absolute significance. These marks are assigned by decision-makers through a survey form that contains a universal list and instructions for evaluation.

Step 3: Obtain subjective weights of criteria by using AHP - Each group of criteria has its own weight coefficient, where the sum of all weight coefficients of the groups in the sum must give the value 1. Weight coefficients are obtained by applying the AHP method, and the weight coefficient of each group is determined as the average value of weighting coefficients obtained by each of the decision-makers.

Step 4: Calculate the mark average of sub-criteria – The marks of the criteria within the group which will be used to construct the initial matrix are obtained as the average value of the marks obtained from each of the decision-makers. As already mentioned, marks are determined according to the Likert scale 0-5, and value which will be an element of the initial evaluating matrix determine as the average of all marks which give decision-makers, for specific criteria.

Step 5: Construct an evaluation matrix with criteria and subcriteria – The formation of a decision matrix uses the values obtained in the two-step process. The initial decision matrix in this model is specific because it consists of parts that represent each of the groups. Each part of the initial decision matrix has one column representing the group and its weighting coefficient and rows depending on the number of criteria that the given group contains, and their values were obtained as presented in the step 4.

Step 6: Normalized evaluation matrix– In this step, the matrix normalization will be performed by applying the formula for max value using Eq. (1) or (2) that corresponding to the nature of the criterion values that tend to the maximum possible value is used. The weight coefficient obtained by the AHP method is used for the determination of the total value.

Step 7: Calculating total relative importance of subcriteria within each group by using WSM method – Values obtained using WSM method applying Eq. (3).

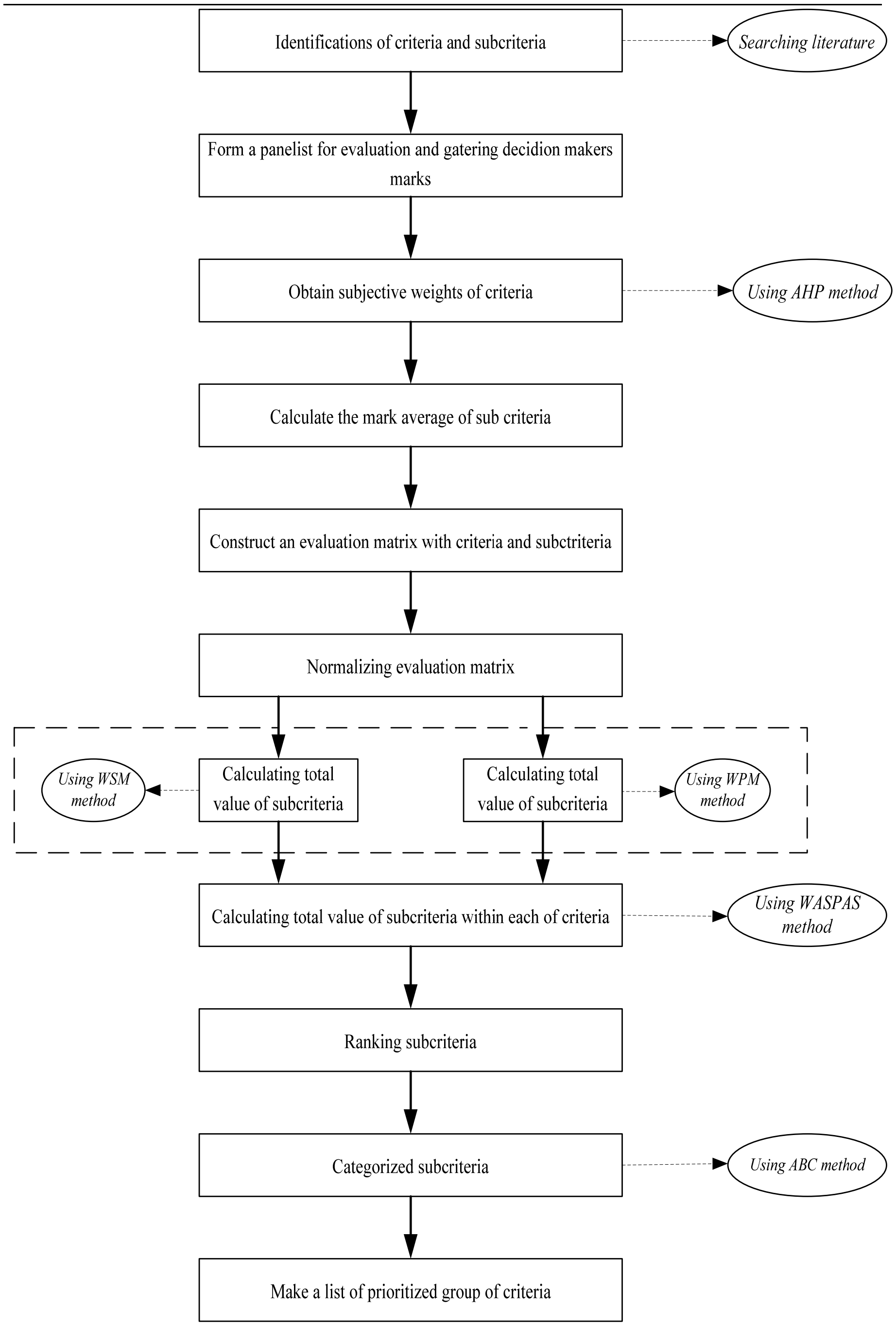

Figure 1.The proposed AHP-WASPAS-ABC method

Step 8: Calculating the total value of subcriteria within each group by using WSM method – Values obtained using WPM method applying Eq. (4).

Step 9: Calculating the total value of subcriteria within each group by using WASPAS method – Values determined by applying WASPAS method based on integration WSM and WPM methods using Eq. (5).

Step 10: Ranking subcriteria – According to the obtained total value, each of the criteria gets its own rank, where the best-ranked criterion has the highest total value, which means that the ranking takes place in descending direction from the highest value to the lowest.

Step 11: Categorized subcriteria by using the ABC method – The obtained ranking list of criteria and total values is further used for their categorization according to the ABC method. Categorization is performed by using the total value to calculate the share of each of the criteria in the sum of the total values. Then the obtained share is used to calculate the cumulative values, all on the basis of a ranking list, i.e. on the basis of ranking from the highest to the lowest value.

Step 12: Constructing a list of priorities ranked criteria by using the ABC method. Groups of criteria got by using ABC method present group A which is 20% of total value and this group of criteria is the most important for selecting projects. In group, A is the criteria about which all projects must have 100% known data. Groups B & C is 80% criteria about which all projects in selecting could have known data but it is not most essential for selecting.

3. Case study

In order to present the process of applying the developed model of AHP-WASPAS-ABC method, the list of 16 criteria categorized in 4 groups is identified by searching literature and chosed as the most commonly used. Process of evaluating and categorization criteria are made by using presented steps of applying the AHPWASPAS-ABC method in Fig. 1. The evaluation presented in follow is made according to values determined by 6 managers from project-oriented manufacturing companies which given their marks to 16 criteria and 4 groups of criteria. First of all, it was necessary to identifications a group of criteria and sub-criteria that will be used for evaluation.

This list of criteria is constructed as a result obtained by research of literature and choosing the most common criteria as a sample for presenting functional of the proposed model which is presented in Table 1. Evaluation of group of criteria and subcriteria were made by using instruction for evaluating presented in Fig. 1 as step 2. After gathering given values by the decision-maker, first of all, it is determined weight coefficients of each group of criteria by using the AHP method. The weight coefficient of each group is determined as the average value of weighting coefficients obtained by each of the decision-makers and determined weight coefficients is presented in Table 2.

Table 1. Group of criteria and subcriteria

Group of criteria	**Subcriteria**
A Management and organization	A1. Management ability for organizes and controls new processes
	A2. Project team (qualifications)
	A3. Expected market share of output
	A4. Expected duration of the project
B Technical criteria	B1. Needs in the use of raw materials
	B2. Assessment of future production facilities and availability of production equipment
	B3. Expected output quality
	B4. The need to apply new technology
	B5. Degree of capacity utilization
C Financial criteria	C1. Return on investment time
	C2. Expected profit
	C3. Necessary investments
	C4. Payback period
D Administrative criteria	D1. Environmental system certification (ISO 14001)
	D2. Permits required
	D 3. Law restrictions

Table 2. Weight of criteria

	Group of criteria	Weight
A	Management and organization	0.27
B	Technical criteria	0.24
C	Financial criteria	0.26
D	Administrative criteria	0.23
	Total:	1

After determine the weight coefficient, it is necessary to determining the value of each of the subcriteria. The expert assessments assigned to the sub-criteria within each group are expressed on a Likert scale of 0-5 as was already noted. The values assigned by the mentioned experts were transformed into one average value as presented in Table 3. According to determined weight coefficients of each group of criteria and determined average value of each of subcriteria basic on decision-makers evaluation, it is made normalization of evaluation matrix. Then it was made calculating the total value of subcriteria within each group by using the WSM method using Eq. (3) and using the weight coefficient obtained by the AHP method. Also, as in the previous step, it is made calculating the total value of subcriteria within each group by using the WPM method using Eq. (4) and using the weight coefficient obtained by the AHP method. Basically on total values determined by using WSM and WPM method, is determined total value using WASPAS method with the value of λ=0,5.

Table 3. Decision makers evaluations

Criteria	Wi	Subcriteria	DM 1	DM 2	DM 3	DM 4	DM 5	DM 6	Av.
A	0.27	A1	5	5	4	4	5	5	4.67
		A2	5	5	4	5	4	5	4.67
		A3	3	3	3	5	3	4	3.50
		A4	5	5	4	3	4	3	4.00
B	0.24	B1	5	5	4	4	4	4	4.33
		B2	5	5	2	3	4	5	4.00
		B3	4	4	5	5	5	5	4.67
		B4	1	1	4	5	3	4	3.00
		B5	4	4	4	5	5	5	4.50
C	0.26	C1	5	5	3	5	5	5	4.67
		C2	4	4	5	5	4	4	4.33
		C3	4	4	3	5	5	5	4.33
		C4	4	4	5	5	5	4	4.50
D	0.23	D1	5	5	4	3	4	5	4.33
		D2	5	5	2	5	5	5	4.50
		D 3	5	5	2	5	5	5	4.50

The result of determining total values is presented in Table 4. Then the total value Qi which is determined by using WASPAS method is used for ranking of criteria.

According to the determined total value, criteria was ranking where on the first place is criteria with the highest total value. Rang list in follow was used for categorization criteria according to the ABC method. Categorization was made by determining the share of each of the criteria in the sum of total value Qi expressed in percent Eq. (6) and calculating Cumulative value Eq. (7). Categorization criteria by using ABC method express group A which is 20% of total value and this group of criteria is the most important for selecting projects. In group, A is the criteria about which all projects must have 100% known data. Categorization criteria by using ABC method express group A which is 20% of total value and this group of criteria is the most important for selecting projects. In group, A is the criteria about which all projects must have 100% known data.

Table 4. Computational details obtained on the basis of WASPAS method

Criteria	Wi	Subcriteria	Xij	Norm. Value $\overline{x}$	WSM Q_1	WPM Q_2	WASPAS Q_i
A	0.27	A1.	4.67	1.00	0.270	1.000	0.635
		A2.	4.67	1.00	0.270	1.000	0.635
		A3.	3.50	0.75	0.203	0.925	0.564
		A4.	4.00	0.86	0.231	0.959	0.595
B	0.24	B1.	4.33	0.93	0.223	0.982	0.603
		B2.	4.00	0.86	0.206	0.964	0.585
		B3.	4.67	1.00	0.240	1.000	0.620
		B4.	3.00	0.64	0.154	0.899	0.527
		B5.	4.50	0.96	0.231	0.991	0.611
C	0.26	C1.	4.67	1.00	0.260	1.000	0.630
		C2.	4.33	0.93	0.241	0.981	0.611
		C3.	4.33	0.93	0.241	0.981	0.611
		C4.	4.50	0.96	0.251	0.991	0.621
D	0.23	D1.	4.33	0.96	0.221	0.991	0.606
		D2.	4.50	1.00	0.230	1.000	0.615
		D3.	4.50	1.00	0.230	1.000	0.615

Groups B & C is 80% criteria about which all projects in selecting could have known data but it is not most essential for selecting. Categorization of criteria determined as noted is present in Table 5. Via implementing the process of the proposed model of the AHP-WASPAS-ABC method, a list of selected criteria is obtained that is of the greatest importance and primary in the project selection process. The best-ranked criteria contained in group A are the criteria that, in the opinion of managers in production organizations, are the most important for project selection. Given that the process of applying the AHP-WASPAS-ABC method was carried out on the basis of assigned values by 6 managers from production organizations, the results were obtained and expressed as a group of the most important criteria for project selection represent goals and interests characteristic for production companies.

In the first place in the priority group is the criterion Management ability for organizations and controls new processes, which for production organizations means a prerequisite for successful development of the process for which the technical conditions themselves have no value without adequate managerial skills and competencies. The second-ranked criterion is the Project team (qualifications) which supports the first ranked criterion, and in third and fourth place are the financial criteria Time for Return of investment and Payback period whose main characteristic is the time necessary to achieve the desired financial result provides manufacturing companies with timely funds to invest in a new reduction process.

Table 5. Categorization of criteria using ABC method

Rang	Subcriteria	Qi	Udeo %	Kumulativ	Group
1	A1.	0.6350	6.5471	6.5471	
2	A2.	0.6350	6.5471	13.0941	
3	C1.	0.6300	6.4955	19.5896	
4	C4.	0.6210	6.3996	25.9893	
5	B3.	0.6200	6.3924	32.3817	A
6	D2.	0.6150	6.3409	38.7225	
7	D3.	0.6150	6.3409	45.0634	
8	B5.	0.6112	6.3017	51.3651	
9	C2.	0.6112	6.3017	57.6668	
10	C3.	0.6110	6.2996	63.9664	B
11	D1.	0.6060	6.2522	70.2186	
12	B1.	0.6030	6.2171	76.4357	
13	A4.	0.5950	6.1377	82.5735	
14	B2.	0.5930	6.1109	88.6844	
15	A3.	0.5640	5.8140	94.4984	
16	B4.	0.5340	5.5016	100.0000	C

On the fifth place is the criterion: Expected output quality, which by its positioning in the priority group confirmed the role of quality as an important factor in achieving the desired results of projects. In the presented case study, the AHP-WASPAS-ABC method confirmed its functionality through successful evaluation and selection of a group of criteria using the opinion of experts from project-oriented companies in the field of manufacturing activities .

4. Conclusion

Proposed MCDM technique AHP-WASPAS-ABC for selections chosen group of criteria for project evaluation has a goal to provide a model which will be used for selection criteria as an effective response to challenges in project management which managers have to handle. Model AHP-WASPAS-ABC is constructed to select criteria from groups of criteria by expert's opinion that will be used for ranking and choosing projects according to the main goals of the organization. In order to present users of the proposed model, this paper is made the ranking of 16 criteria from 5 groups evaluated by 6 experts from manufacturing companies. According to their marks was made evaluation by using the proposed model AHP-WASPAS-ABC method. The best ranking criteria with a 20 % share in total value, noted as group A is criteria: A1. Management ability for organizes and controls new processes, A2 Project team (qualifications), C1. Time for return investment, C4. Payback period B1. Needs in the use of raw materials. This group of criteria, in this case, the study is the most important which means that projects most have the very precise and reliable data for this criteria because of its value. The AHP-WASPAS-ABC model presents a method easy for use by managers in project-oriented organizations who need an efficient and simple way for a found a solution as a response to challenges in contemporary business conditions. Although this method is proposed for choosing a group of criteria for selecting projects it could be used to found solutions for many other challenges that are with similar nature and concept.

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