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3N-AHP Model, the New Multiactor Multicritera for the Selection of Optimal Corridors of the Line Infrastructure Facilities

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Abstract

In this paper is developed a complex model for the evaluation and selection of the optimum spatial solutions of the corridor line infrastructural facility, which is characterized by multiactor and multicriteria approach. The model is based on the multiactor multicriteria analysis methodology (MAMCO - The Multi Actor Multi Criteria Analysis Methodology) where the relevant decision-making actors, verified by stakeholder analysis (The Stakeholdes analysis), based on the criteria of evaluation that are sorted in the proper hierarchy and whose relevance is confirmed by the factor analysis (the Factor analysis) using the evaluation and ranking of alternatives of the AHP method (the Analityc Hierarchy Process), which was selected by intelligent access with the help of decision tree (decision Tree), offered from a set of alternatives to choose the optimum solution, and the accuracy of their selection check by sensitivity analysis (sensitivity analisys).

Keywords: Decision-making criteria; factor analysis; hierarchical model; optimal solution; line objects.

1. Introduction

The choice of model for evaluating the variant solutions corridors of the infrastructure facilities, like the problems that it solves, is the multicriteria problem. Since there is no ideal, but only the optimal solution, it is clear that any chosen model for evaluating the variant solutions will have certain, smaller or larger defects [1].

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For most of the existing models are observed certain shortcomings that either significantly affects the objectivity of the process of selecting the optimal solution or affect its essential validity of the model and make it unusable.

A large number of existing models, though are based on analysis of more than one criterion, still are single criterial, because the evaluation of alternatives are carried out individually by each criterion. Very often, the criteria (and subcriteria) adopt evaluations without a valid explanation of their relevance. Very often the evaluation criteria (and subcriteria) are being adopted without the proper explanation on their relevance. Random selection of criteria, even if some of them were actually relevant are leading to wrong selection of optimal solutions.

Given that the infrastructure facilities usually are the public goods, it is very important who is in fact a relevant decision maker in the process of selecting the optimal solution. Wether the decision maker is exclusively a competent state institution, a designer himself or the adopted decision made should be the product of comprehensive decision-making process in which all interested stakeholders in a certain way would express their requirements under one of the alternatives. Unfortunately, most of the studied models speak exclusively about the "decision maker", in fact, without specifying who “he” is.

It is often the case that, without sufficient consideration of the nature of the problem which is going to be solved, chooses an inadequate method for decision-making, usually on the basis of what is easiest or most easily applied to a given problem or is the "trendy".

In terms of these shortcomings, there is a need to develop the fuller, more comprehensive models, completely new or as an upgrade of existing "healthy" models.

In this paper is developed a complex model that is characterized by multiactor and multicriteria approach. The model is based on evaluation criteria that are sorted in the proper hierarchy and whose relevance is verified by scientific methods. Valuation method is selected by an intelligent access with the help of decision tree. The model predicts the sensitivity analysis of selected optimal solution to change the meaning of some (or all) of evaluation criteria.

2. Description of the problem

The task of the designer (analyst) on the level of development of general infrastructure facility project is to develop such a project and a technical document that will contain the answers to many questions, among others, the following: which is the best, respectively, the optimal macrolocations and what is the general layout of the building?

The process of planning and designing of line infrastructure facilities is extremely complex. That is why it can hardly be hardly and fully described a single mathematical model. Therefore, for each parts of the process is formed a separate mathematical model.

Thus, the entire process can be divided into three main parts [2]:

- generating of alternatives,
- evaluating and ranking of alternatives and
- decisions to the best solution.

The analysis of existing models for the evaluation and ranking of alternative corridors of the infrastructure facilities led to the conclusion that in most models there are certain shortcomings that significantly affect the objectivity of the process of selecting the optimal solutions. If these shortcomings would be corrected, the model would be able to provide a much clearer picture on the importance of particular criteria for the selection of optimal solutions. Upgrading of individual models would enable to obtain a clearer picture of interdependence criteria, depending on the alternative choice of their importance, and vice versa, the impact of the election on alternative, respectively, the importance on meaning of individual criteria. A large number of existing models, though is based on analysis of more than one criterion, in essence are still single criterial because the evaluation of alternatives is carried out by each criterion separately. On the other hand, a certain number of models, though are essentially multicriterial, somewhat unjustifiably are forcing certain groups of criteria (lately, mostly environmental).

From the point of application of the model of decision-making in the process of selecting the optimum spatial solutions of the line infrastrukrutnih facilities, as well as object types that are most commonly public goods, it is very important who is in fact the relevant decision-maker. Does the decision maker is exclusively the competent state institutions, a designer himself or approved decisions should be the product of comprehensive decision-making process in which all interested stakeholders in a certain way would express their requirements under one of the alternatives. Unfortunately, most of the studied models speak exclusively about the "decision maker", without specifying who "he" is in fact. And when "it" is going to be specified, still remains a dilemma when, at what stage and how to include it in the decision-making process, given that all stakeholders do not have the same weight from the point of impact, interest and importance to the success of the project. Even when we add to it the formal and legal responsibility to make decisions, it becomes clear that it is valid, scientifically based analysis of stakeholders and decision-makers as well become indispensable too.

Analysis of existing models has shown that very often the evaluation criteria (and subcriteria) are adopted without a valid explanation why they are particularly the relevant criteria for the selection of optimal solutions. An approximate selection of certain criteria, even if they really were individually relevant, lead to wrong selection of certain alternative solutions designated as an optimal for a number of reasons: (i) they are not relevant evaluation criteria, (ii) they are relevant criteria for evaluation but are unjustifiably separated from the group other relevant criteria, and are therefore given more importance (weight) than they really belong, (iii) if all criteria are considered relevant, due to wrong hierarchy among them (the wrong clustering, grouping) some criteria receive more, others less weight of really belonged ones.

It is often the case that, without sufficient consideration of the nature of the problem which is being solved, chooses an inadequate method for decision-making, mainly on the basis of what is easiest or most easily applied to a given problem or is the "trendy".

The mentined problems are very often the cause of errors that occur when making planning and project documentation or are the cause of wrong decisions made on the basis of insufficient or poor collected information, scientifically insufficiently based analysis, wrong or insufficient responsibly conducted processes of making these important decisions. This is evidenced by many of the actions of infrastructure networks in the Republic of Serbia, but also elsewhere in the world.

In this paper is developed a complex model for the evaluation and selection of the optimum spatial solutions of corridor of the line infrastructure facility, which is characterized by multiactor and multicriteria approach.

Model during testing demonstrated the ability to treat all questions and to provide answer which of the possible alternatives is the best possible or optimal.

3. Defining of the new model

It is practically impossible to form a mathematical model and optimization algorithm that would in detail cover the whole complex system. Rather separately are being analyzed parts of the system (subsystems), and then, on the basis of the results obtained and the interaction between subsystems, is being considered the whole system. The decomposition of complex systems can be spatial, temporal or according the purpose of the system. Over the system which is obtained by decomposition can be carried out according to the same re-decomposition or according to the second principle. Designated decomposition can be applied in multi-purpose systems when one or several special purpose are observed, [3].

Within the present work has been developed and tested a complex model of decision-making in the process of selecting the optimum spatial solutions (corridor) of the line infrastructure facilities, which is based on the decomposition of a comprehensive model of iterative design process of the line infrastructure facilities (Fig. 1a) and separating algorithm subsystem evaluation and ranking of possible alternatives (Fig. 1b).

The aforementioned algorithm with the help of the multiactor multicriteria methodology analysis MAMCA (The Multi Actor Multi Criteria Analysis methodology) [4] is presented in (Fig. 2) and on the application of a method of "soft" optimization, Analytical Hierarchy Process (AHP - The Analityc Hierarchy Process) [5-7].

During the model definition the emphasis is put on the elimination of gaps noticed by analysis of existing models. The proposed methodology provides a comprehensive and systematic problem solving in the decision-making process in the selection of the optimum spatial solutions of linear infrastructure facilities in accordance with the adopted criteria and by ensuring timely and effective participation of stakeholders, and used as a decision-maker in the individual phases.

The proposed optimization model is compex and largely comprehensive. It consists of six steps which are essentially complex as well as the model. At each step is defined a special way (model) for solving of particular research problems and later integrated into a comprehensive model.

The model is based on the multiactor multicriteria methodology analysis (MAMCO - The Multi Actor Multi Criteria Analysis Methodology) where the relevant decision-making actors, verified by the stakeholder analysis (The Stakeholder analisys), based on the criteria of evaluation that are sorted in the proper hierarchy and which confirmed the relevance factor analysis (the Factor analysis) using the evaluation and ranking of alternatives of AHP method (the Analityc Hierarchy Process), which was selected by intelligent access with the help of decision tree (decision Tree), offered from a set of alternatives to choosing the optimum solution, and the accuracy of their selection check with the sensitivity analysis (Sensitivity analisys), (Fig. 3).

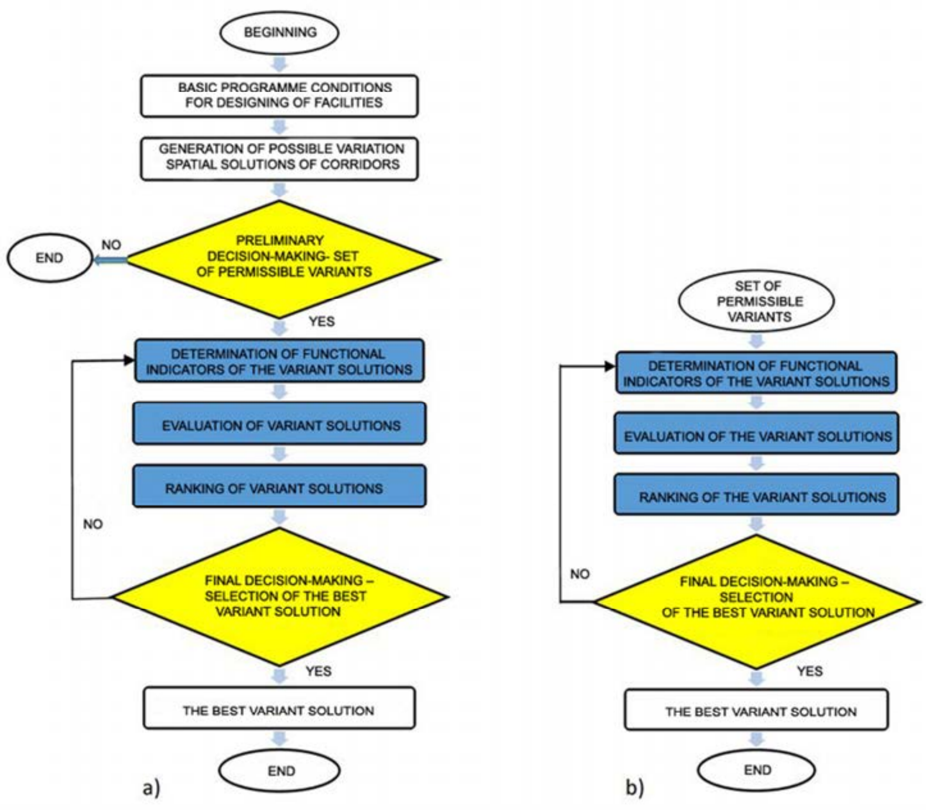

Fig. 1. Algorithms optimization of the design process of the infrastructure corridor facilities: a) iterative model of the complete design process; b) a separate subsystem evaluation variant.

The proposed optimization model is complex and strives to be comprehensive. The model consists of six steps that are, in essence, the same complex as well as the model. The model was symbolically named 3N-AHP and indicates that the AHP method can be applied to all three levels of decision-making (strategic, tactical and technical).

Steps models are:

Step 1

The defined model in the first step envisages implementation of analyzes of the stakeholders (Stakeholder analysis, [8]), and then are determined their relevance, their importance and are determined the mutual relations. In this way is achieved the involvement of relevant stakeholders, but also prevent the harmful effects of those who are opponents of the project.

Step 2

In the second step is carried out analysis of indicators of evaluation (criteria and sub-criteria), or form a set of preliminary criteria making four parts.

The first part of the elements of the set are identified on the basis of physical, functional and other characteristics of the object (or system) that is the subject of consideration. In the framework of the defined model, since is preferred its application to all of the line infrastructure facilities, this part of the preliminary set of criteria is defined at the beginning of the process of derivation criteria.

The second part of an element of this set is defined on the basis of research (scientific and practical) and analysis of the literature that treats a given area [9].

The third part of the set was identified on the basis of previous experience in similar projects, where these criteria proved their relevance.

The fourth, and final, part of the set is defined on the basis of the expressed needs, expectations, interests and concerns of interested stakeholders (stakeholders) through surveys or interviews.

Corridors of almost all infrastructure line facilities have many common characteristics that are reflected in the criteria, and therefore most of the criteria that describe the corridor of a line facility can be used as a set of preliminary criteria for the corridor of another and different line facility. The reason for this is the fact that the relevance of the criteria from the preliminary set is estimated in the next step, Step 3, of the complex model of 3N-AHP.

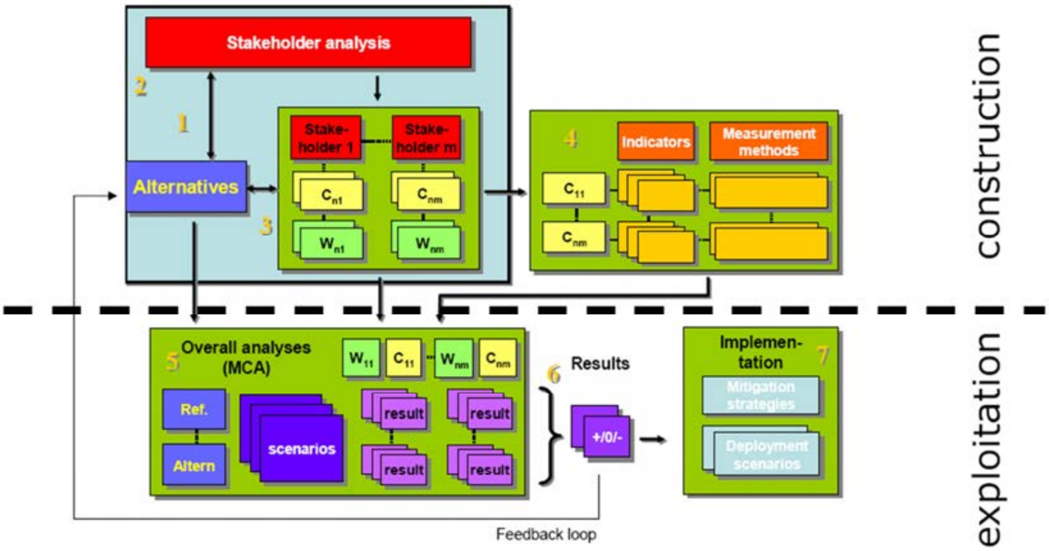

Fig. 2. MAMCA - The Multi Actor Multi Criteria Analysis methodology [4]

Step 3

In the process of determining the relevant indicators, Step 3, of the 3N-defined models of AHP provide the application of combined methods of investigation that would include the following methods:

- survey, with which are collected data from relevant stakeholders
- descriptive statistics for data processing and
- factor analysis [10], to reduce a set of data collected by the survey, and defining a set of relevant criteria needed for the development of AHP model evaluation and ranking variant corridor of infrastructure facilities.

The result of the implementation of Step 3 is a set of relevant criteria (factors) and verification (or possible refutation) of the defined models.

Step 4

Based on the characteristics of each method of VKA respectively, is formed the decision tree to select the appropriate methods in solving certain multi-criteria problems, and is using it, according to the characteristics of the problem to be solved was made selection of VKA methods.

Decision tree (Decision Tree) is graphically presented techniques for decision-making, by which is implied a set of related branches, where each branch represents either an alternative or decision or condition. By common convention, the knot shown by square is an alternative decision-making (decision node), and the circle represents a state (node capabilities).

Given that the proposed model implies that the possible alternative solutions are explicitly defined, and that it is necessary to define their full order, without being defined by a matrix of decision-making, but that remains to be done during the process of decision-making with the help of decision tree is achieved the selection method of AHP.

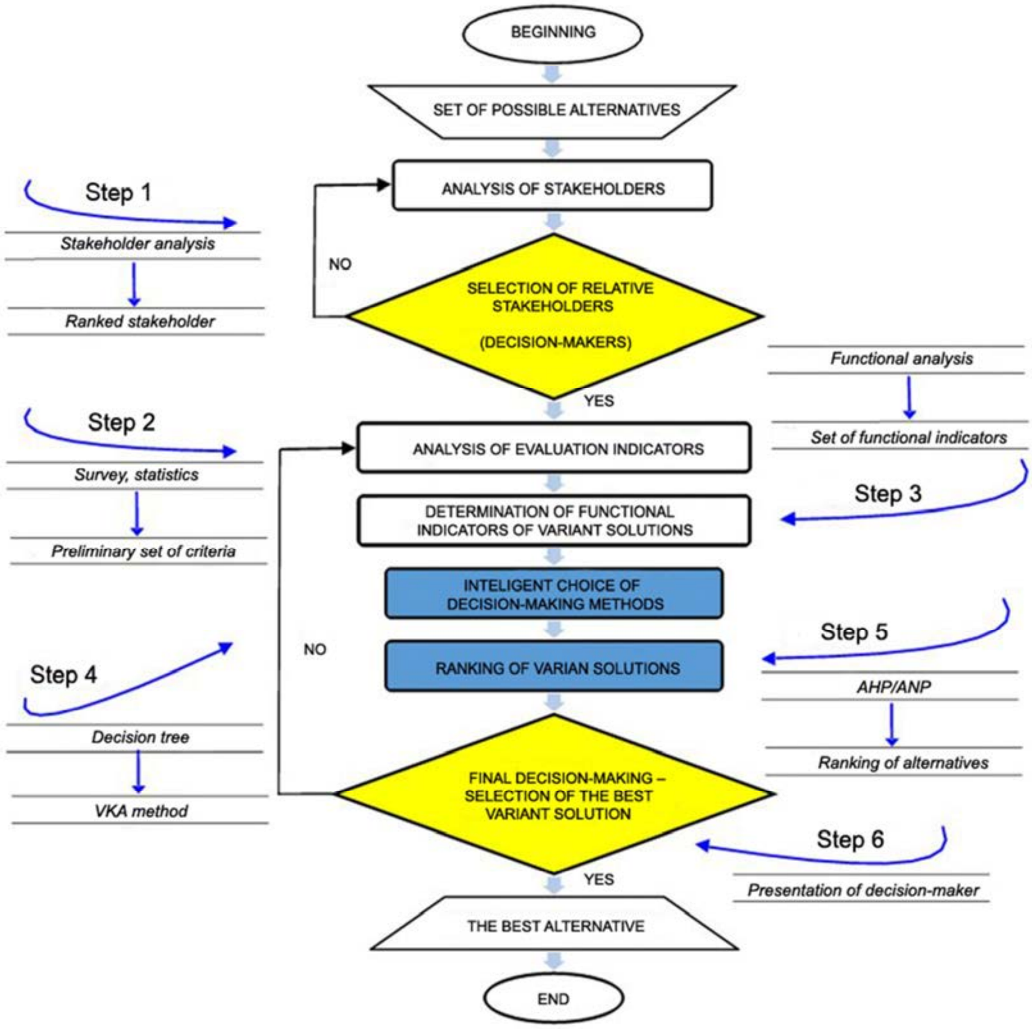

Fig. 3. Compound (general) algorithm models of 3N-AHP for the selection of optimal solutions

Step 5

AHP is a relatively commonly used method in decision-making with a number of criteria and alternatives, but very little used in the process of selecting the optimal solution of the line infrastructure facilities. Functional mapping of the different aspects and possible solutions in the decision-making elements within the hierarchical structure of any required AHP, even very complex problems can be relatively easily solved in a short time, if you observe the principles and methodology of AHP.

Popularity of AHP method in the world originates primarily from its fundamental quality: "always in pairs to be compared only two elements of decision-making and thereby use simple semantic scale only with five degrees of gradation of basic importance (equal to, less important, more important, a very much more important, absolutely importantly) "instead of comparison with a standard measurement unit (kg, sec, m). In this way, the method is closer to the man who basically has no interest at all to "mathematics" to which the AHP is scientifically based and recognized.

Deciding with AHP method is performed in four basic steps (Fig. 4):

- Step 5.1: Structuring of problems (development of hierarchical models), according to the rules and AHP methodology
- Step 5.2: Comparison of elements of the same level in pairs, with the help of Saaty scale
- Step 5.3: Ranking alternatives to the weight and determining the best ranked solution, and
- Step 5.4: Sensitivity analysis solutions, or checking how alternatives to the status of first ranking is stable in relation to the change in weight of some or all of the criteria for a certain percentage (± 5%).

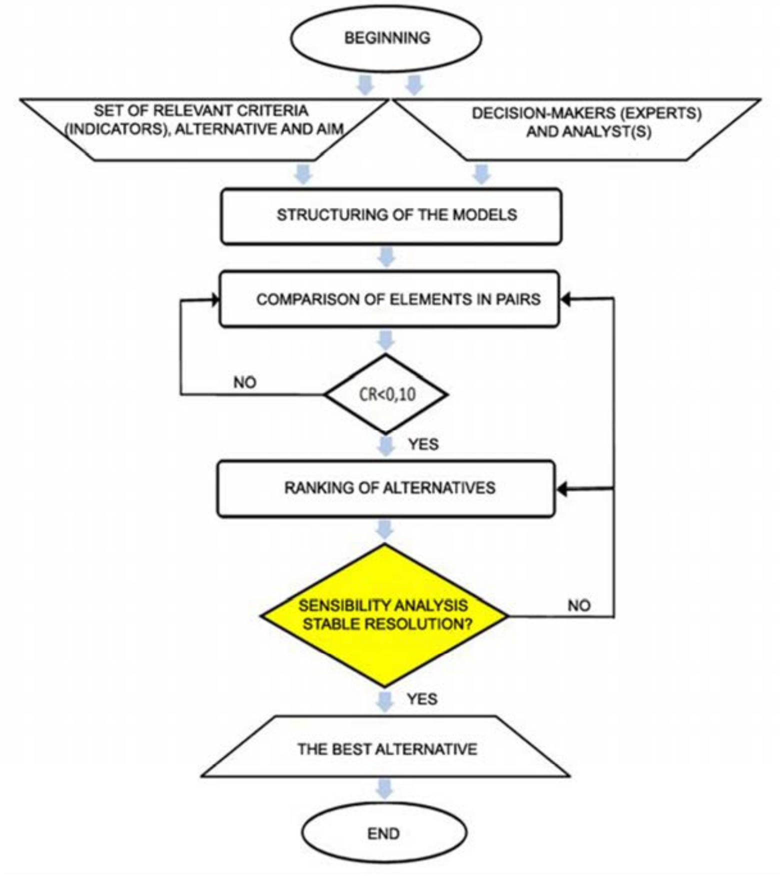

Fig. 4. The developed algorithm of the Step 5

An important feature of the method of AHP is a sensitivity analysis of the final solution. This analysis is easily done using software packages (software) for decision support.

Sensitivity analysis helps the analyst (and decision makers) to examine different sets of alternative solutions. The sensitivity analysis shows the relation between changes in priorities as a function of an alternative character attributes, ie criteria.

Step 6

It is clear that in practice are rare cases when there is a perfect solution task of VKO. The differences in the criteria, and particularly their complete or partial contradiction, represent the essence of the problem of VKA. That is why the concept of a perfect solution very limited theoretical and in practical significance.

However, policy makers in the end should eventually adopt any solution. The decision accepted by the decision maker is called the best or preferred solution. VKO task is to help the decision maker to choose the solution that he considers as the best in a given problem. Therefore, efforts to solve the set of multi-criteria problems are often called multi-criteria analysis.

Depending on how and when the decision maker is involved in resolving the problems there are three different basic approaches, respectively, three groups of methods of solving:

- the posterior approach,
- priori approach it and
- interactive and cooperative approach.

The model has been successfully tested in practice where it got its verification and confirmed the validity.

4. Conclusion

The defined model, like any other after all, does not include all the complexity of reality, but only those features and components that are of interest to specifical study. Due to the complexity of the physical situation in the real system are distinguishe only significant features of physical objects. In modeling, optimization and use of the results should be kept in mind the following:

- model is only one possible approximation to the real system. Its level of detail depends on the task and optimization methods that are used. A model that would incorporate all the details of a complex system would be cumbersome and practically useless for optimization,
- task model is that it helps the researcher, and not to replace it, or to free him of responsibility for decision-making and
- model can not produce entirely new information about the system, but allows it to be based on existing data to better understand the system and its behavior.

Accordingly, the developed mathematical model of 3N-AHP is a model that properly describes the real system and as such can be applied to solve problems choosing the optimal solution of linear facilities corridor.

The model is especially helpful in overcoming the difficulties in making a decision regarding the inclusion of relevant stakeholders, selecting relevant methods and relevant decision-making criteria, whose relevance is validated by scientific methods. Further researches should be continued in the direction feedback determination of interdependence of the decision making criteria and possible alternative solutions.

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