DECISION SUPPORT CONCEPT TO MANAGEMENT OF CONSTRUCTION PROJECTS - PROBLEM OF CONSTRUCTION SITE SELECTION

Nikša Jajac
University of Split, Faculty of Civil Engineering, Architecture & Geodesy
Matice Hrvatske 15, 21 000 Split, Croatia
E-mail: njajac@gradst.hr

Ivana Bilić
University of Split, Faculty of Economics
Cvite Fiskovića 5, 21 000 Split, Croatia
E-mail: ibilic@efst.hr

Ante Ajduk
University of Split, Faculty of Civil Engineering, Architecture & Geodesy
Matice Hrvatske 15, 21 000 Split, Croatia
E-mail: ante.ajduk@gradst.hr

Abstract

The aim of this paper is to present Decision Support Concept (DSC) for management of construction projects. Focus of our research is in application of multicritera methods (MCM) to decision making in planning phase of construction projects (related to the problem of construction sites selection). The problem is identified as a significant one from many different aspects such as economic aspect, civil engineering aspect, etc. what indicates the necessity for evaluation of multiple sites by several different criteria. Therefore, DSC for construction site selection based on PROMETHEE method is designed. In order to define the appropriate criteria, their weights and preference functions for the concept, three groups of stakeholders are involved (investors, construction experts and experts for real estate market) in its design. AHP method has been used for determination of criteria weights. The model has been tested on the problem of site selection for construction of residential-commercial building in four largest cities in Croatia.

Key words: *Decision support, Construction site selection, Project management, PROMETHEE, AHP*

1. INTRODUCTION

In the management of construction projects special attention should be given to the planning as the most important phase of decision making process. In this research we put our focus on decision making that exist during the planning (investment project of construction of a building), decision making about the location, as a significant problem of construction site. Underlying reasons for the existence of this problem arise from: specific conditions of construction industry (products/buildings are inseparable from the location; location has a strong influence of building design and structural characteristics and thus the execution of the project); desires and attitudes of investor and finally influence of socio-economic environment to the planning process. According to the all mentioned above it is very easy to conclude that decision making about location of investment is complex, low structured and multicriteria problem. Further elaboration of the problem leads us to the conclusion that establishment of the concept for decision support is necessary in order to improve this important part of the planning (site selection) in management of construction projects. The concept which will be introduced in this paper is based on the usage of the multicriteria models (based on the use of multicriteria methods). This approach is supported by many reasons, such as: a number of possible solutions, the size and diversity of the analyzed aspects of the problem (investor, building and socio-economic aspects) which should be taken into consideration, the need of engaging multiple experts for dealing with each of these facets of the problem (extremely wide range of necessary knowledge that usually surpasses knowledge of one person/investor) and high level of conflict that occurs due the desire to satisfy every aspects of the problem with the only one selected solution.

Furthermore, each of previously mentioned reasons produces a number of different criteria for evaluation of potential alternative solutions/locations. Such set of numerous different criteria and stakeholders involved in decision process indicated the weak structuring of issues to be decided upon. All stated before in the elaboration of decision making process issue justifies the choice of decision support as the correct approach with the purpose to increase quality of decision making in planning process. Application of decision making process enabled organized analysis of all aspects of the problem through the introduction of all relevant stakeholders in process, with the accent of adaptability of this concept for inclusion of investor in the process of preparing investment decisions. Involvement of investor in an early stage of this process ensured investors confidence in the output of this concept creation, and incorporation of opinions from all involved stakeholders. Output of the concept represents basis for making his final decision. It is important to emphasis that the concept figures as assistance for decision makers in decision making process. Assistance is reflected in a simple and concise presentation of the results of processing of a huge number of relevant information and data from all aspects of the single segment of the construction planning (which, in this case refers to the selection of location). Thus, the results presented in this way are referred as the basis for decision making.

According to the previously mentioned problems and obstacles related to the decision making process of construction sites selection, for this purpose observed as an investment, in the following parts of our paper a specific concept, support for decision making will be presented. The concept will be grounded on applying Preference Ranking Organization Method for Enrichment Evaluation - PROMETHEE (Brans et al. 1984) and Analytic Hierarchy Process - AHP (Saaty 1980) multicriteria methods which will be used to compare the possible locations of the construction site. The Concept intended to support managers of construction projects during the planning stages of these projects.

Similar examples of concept formation and decision support systems in the planning of various projects can be found in the works of the following authors: Jajac et al., 2009 - Introducing multicriteria methods to maintenance planning of investments in urban infrastructure projects and Jajac et al., 2010 - presenting integration of multicriteria methods decision support concept for urban road infrastructure project management. Since this is a problem that has spatial characteristics, as well as most of the problems in the field of civil engineering, work of Marinoni, (2005), and Mladineo et al., (1993) is also interesting, those authors combined multicriteria methods and Geographic Information Systems (GIS).

2. DECISION SUPPORT CONCEPT TO PROBLEM OF CONSTRUCTION SITE SELECTION

Figure 1, present architecture of generic Decision support concept for the problem of construction site selection which stands as an important segment of planning phase within management of construction projects. Application of the concept begins with identification and gathering together all stakeholders on investors' initiative (activities of investors are marked with solid line without color). In the next step all stakeholders simultaneously performed two activities (activities of all stakeholders are marked with solid lines and gray colored). The first activity is to define the main goal, its objectives and the criteria, and they all together formulated a hierarchical structure of goals. At the top of the goal hierarchy is the main goal, and the first hierarchical level is made up of objectives that, i.e. goals which support main goal (realization of all these objectives means that main goal will be reached). Objectives also have their supporting objectives. We used to say that the objectives are composited of supporting objectives. These supporting objectives have theirs supporting objective and it is going on like that all the way to the level where they can no longer be divided. Typically for such kind of indivisible goals is to measure the level of their achievement i.e. they are measurable. Indivisible and measurable goals we used as a criteria. In the second activity we generated a set of alternative solutions for the problem – a set of several possible locations for the building. AHP is applied to determine the hierarchy of the goals and to rising of the weighting by more scenarios (where the number of scenarios corresponds to the number of the groups in which are stakeholders divided). The technical part of determining the weights is carried by expert of AHP, and the relationship between the importances of the goals at the same level, stakeholders unanimously (group decision about the relations important targets). Identified the importance of goals last hierarchical level objectives (criteria) are the criteria weights. In addition to the criteria in determining the weight and stakeholders involved in determining the preference function for each criterion and evaluation of all alternatives by all criteria that establish the decision matrix.

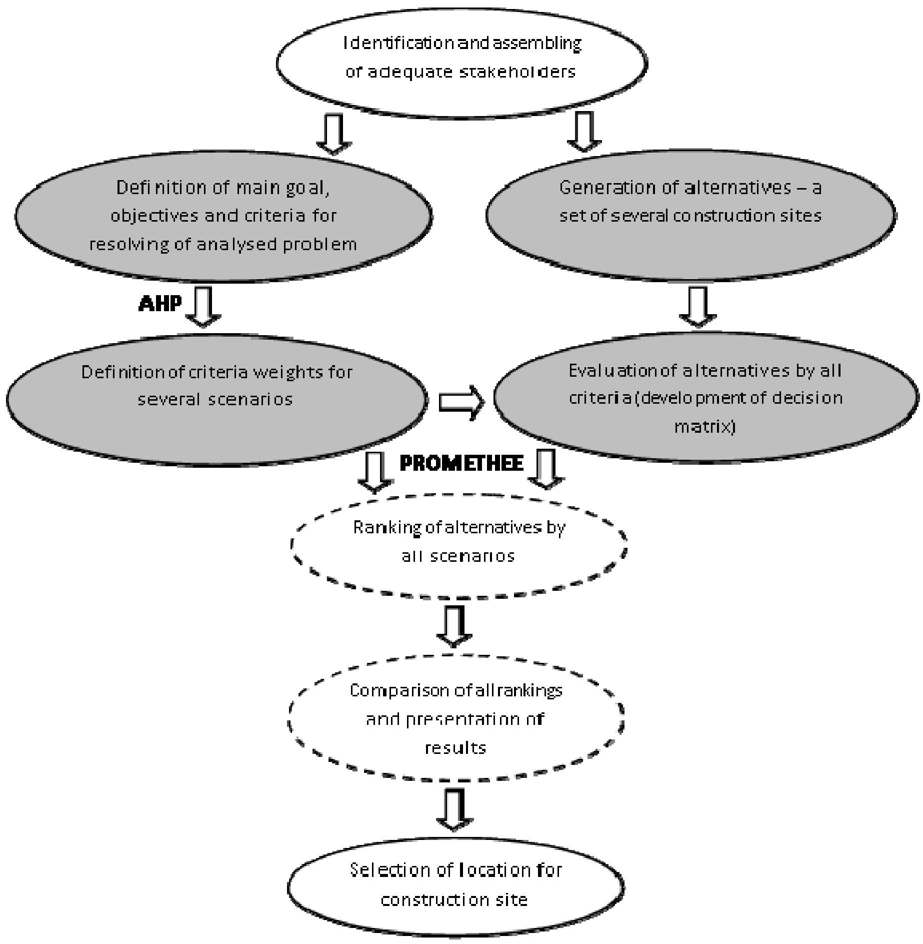

Figure 1: Architecture of generic Decision support concept to problem of construction site selection

PROMETHEE method expert (whose activities are marked by non-colored dashed lines) formed multicriteria model by usage of: defined criteria (their weights and preference functions), and the evaluation results of all alternative solutions according to all established criteria (decision matrix). Because of existence of multiple sets of weighting criteria, model processed multiple scenarios and gets more rankings. In further phase obtained rankings are compared and outcomes are presented to the decision maker/investor. Leaded by presented results, investor make his final decision, precisely he selects the construction site location. Construction site selection process is concluded when investor selects the location for the construction site.

During the concept design phase, high level of attention is paid to the choice of appropriate multicriteria methods. It is the most important that a chosen methods (and thus the whole concept) are “user friendly” and above all understandable to users. The reason for this is the need to ensure users’ trust in the results that concept provides (because trust comes from understanding and from the sense of usefulness of applied methods for the users’). The trust is ensured through the selection of AHP method for criteria weight determination, and PROMETHEE method for ranking of the alternatives because engaged experts and decision-maker considered these methods as understandable and in that appropriate manner for resolving presented tasks.

3. CONSTRUCTION SITE SELECTION – CONCEPT VALIDATION

With the aim to validate presented concept, one constructing-investment company from Split was chosen, precisely its activity of planning to undertake the project of building construction (in which site selection is an important part). A main characteristic of the company is that its top manager is also hundred percent owner of the company, thus; consequently it appears that the company is investor of the planning project. More specifically, the core business of the company is to build facilities for other clients. In recession period, sometimes this company act as investor, with the purpose to employed their work forces between two contracted works for others. The company operates across the Croatia and has a long tradition and extensive experience in construction business. For all above mentioned purpose we consider the problem of selecting construction site for the residential-commercial building. Validation process started with identification and assembling of adequate set of stakeholders. Three groups of adequate stakeholders were identified as follows: experts for construction (two civil - engineers already employed by the company), experts for socio-economic issues (two experts for real estate market) and represents of investors (company owner and his financial consultant).

All stakeholders were informed about the task in advance (the choice of location for the construction of residential-commercial building). It is decided by the investor (owner of the company) that same construction (in terms of use, dimensions, structural features and standard equipment) will be built on each of analyzed locations for construction site. That was done because the company has already built such a building (which means: the company owns a significant portion of project documentation; proper resources and necessary experience to build such a facility; less risks and low costs) as well as to ensure comparability of analyzed sites and to draw attention to influence of their characteristics on the realization of project. At the joint meeting of all stakeholders the main goal is defined (the best location for the construction site). In next step decision board generated objectives and criteria, as base for creating the hierarchical structure. The hierarchical structure, which derived from that step is shown in Figure 2, and below the figure detailed information regarding its formation are presented below.

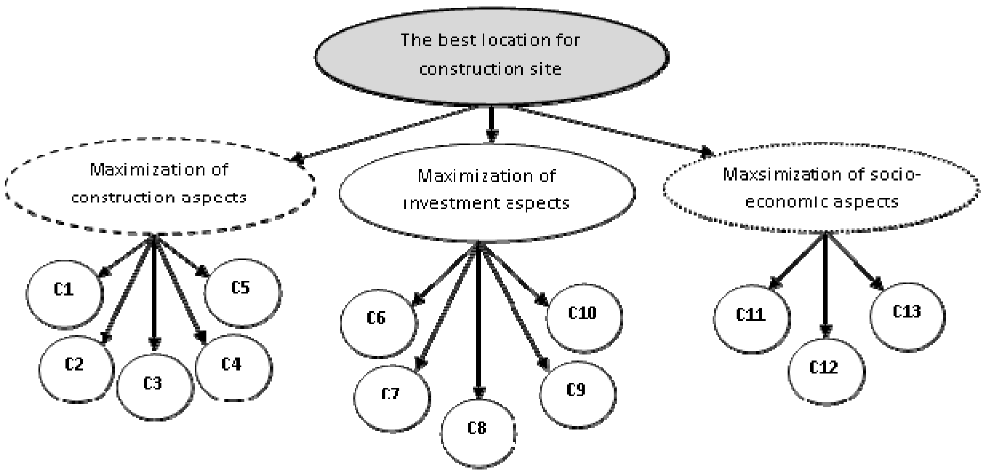

Figure 2: Hierarchical structure of the goals (with criteria)

Group decision-making process started with brainstorming session with all stakeholders included: using “A wish list” procedure (meaning: at the beginning all involved stakeholders are free to suggested objectives, after that all suggestions are subject of discussion to ensure their alignment, what resulting in final proposal of the adopted objectives) three objectives are determinate and they are related to the maximum realization of construction, investors and socio-economic aspects of selected solution. These three objectives are supporting for the achieving of main goal. The above-mentioned procedure was made to determine the objectives of next level (second level). Second (last) level of hierarchical structure is made from objectives that support the achieving of objectives from the first level. Their characteristics are further indivisibility and measurability as well as acceptance by stakeholders as a set of criteria for evaluating alternative solutions. Criteria are marked on figure with

Cn, where n=1,...13 represent a number of criteria. Construction experts' generated criteria C1 to C5, investors generated criteria from C6-C10, and finally socio-economic experts generated criteria from C11 to C13 (all stakeholder groups used "A wish list" procedure for generation of criteria, all accepted criteria are defined and unanimously adopted).

Table 1: Criteria and preference functions

Criteria label	Criteria name	Short description of criteria and of technique for evaluation of investment solutions	Preference	
			min/ max	function
C1	**Constructability**	Constructability related to excavation and foundation works; Expert assessment – grading 1(worst) -10 (best)	max	V-shape
C2	**The time required for construction**	Expected duration of construction in accordance to dynamic plan and to bill of quantities - months	min	Linear
C3	**The time required to obtain building permits**	Expert assessment of expected duration - months	min	Linear
C4	**Landfill for excavation material**	Expert assessment that takes into account landfill distance, duration of driving cycle and disposal costs – grading 1(worst) -10 (best)	max	Linear
C5	**Outsourcing**	Expert assessment of required outsourcing to complete the construction – expressed in %	min	V-shape
C6	**Construction cost**	Expressed in EUR/m^2	min	V-shape
C7	**Costs of land acquisition**	The amount includes the cost of land acquisition and other related costs – in EUR/m^2	min	V-shape
C8	**Utility contribution cost**	Expressed in 1.000 EUR	min	V-shape
C9	**Amount of investment**	The amount includes the cost of preparation of project documentation, cost of construction on a "turnkey", cost of land acquisition and other costs – in 100.000 EUR	min	V-shape
C10	**Profit**	Expected profit expressed in 100.000 EUR	max	V-shape
C11	**The quality of utility infrastructure**	Experts assessment that takes into account the existence and quality of all types of utility infrastructure (water supply system, sewage system, electrical system and waste management system) – grading 1(worst) - 10 (best)	max	V-shape
C12	**The attractiveness of the location**	Experts assessment that takes into account attractiveness of the building for future users according to its use and location – grading 1(worst) -5 (best)	max	V-shape
C13	**The probability of selling a property**	Experts assessment that takes into account the probability of selling a property in 5 years starting from the completion of construction – expressed in values between 0 (meaning – no chance) I 1 (meaning –doubtless)	max	V-shape

For a purpose of clarity and visibility of the Figure 2, only labels of criteria are presented on, full description of criteria is presented in Table 1 which consist full names of the criteria, and description (which includes the description of the evaluation of alternatives/variants of locations for each criteria). In addition, in the Table 1, the way of formatting the preference for each of the criteria is shown. Number of criteria that requires a minimum is seven, while maximum was searched for six criteria. Preference functions are selected for each criterion separately and each of these functions represent a way of forming preferences of the decision maker between the two locations for the construction site by one criterion (with the respect of difference in the value of their score according to this criterion). V – Shape function of preferences is prevailing (used with 10 criteria). Linear - Shape (variation of V-Shape with area of indifference) is used for the three observed criteria. The choice of only two types of preference functions solely depends on the characteristics of identified and used criteria. Furthermore, thresholds for these functions are not introduced because engaged experts and decision-makers consider important, even small differences in evaluations of analyzed construction sites by each criterion.

Importance of the criteria (weights of the criteria) where then determined by each group of the stakeholders, separately. In this way three scenarios of the problem are created as follows: construction (SC1), investor (SC2) and socio-economic (SC3). AHP has been used to determine the weights of the criteria. AHP is method used to determine the importance of the objectives/criteria of lower level in the achievement of an objective from of the higher level. It starts from the top of the hierarchy (the main goal) to the bottom (to the level of criteria). Weight of each criterion is expressed by its percentage share of the total weight of all criteria, which is 100%. Three sets of the criteria weights (scenarios) have been generated and they are presented below in the Table 2.

Table 2: Criteria weights for 3 scenarios

Criteria (C)/Scenarios (SC)	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
SC1	11,2	11,9	6,1	10,2	10,2	5,9	6,2	5,9	7,5	9,5	7,6	3,5	4,3
SC2	4,9	8,1	8,2	2,7	5,8	9,7	9,7	9	11,3	14,9	1,2	4,6	9,9
SC3	3,1	2,9	5,1	1,9	3,7	7,9	8	4,2	9,2	13,5	9,7	13,9	16,9

The weight distributions for the three scenarios (shown in Table 2) are expected. Specifically, construction experts consider as the most important criteria C1 to C5, those criteria gives importance to civil engineering aspects of the problem (most important are C1 – Constructability and C2 - The time required for construction), as the most important criteria investor considered C6 to C10; (especially C10 – Profit) related to the evaluation of the financial aspects of the projects. Socio-economic experts pointed out criteria from C11 to C13 as most important (particularly C13 - The probability of selling a property), those criteria take part in evaluation of the sales probability for potential location, although, they considered group of criteria from C6 to C10 as important, because of their economic nature.

Stakeholders also took part in the analysis of the potential location for the current and future company's investment and thus, they created a set location – alternatives between which to select one. The set has four different site locations/plots for construction site. The observed sites are located in the four largest cities in Croatia as follows 1 – Osijek; 2 – Rijeka; 3 – Zagreb and 4 – Split. Plots at four locations/cities are not equal in the term of area/surface but all are eligible for the construction planned facility (zoning requirements are fulfilled for all locations). The largest location is situated in Osijek, and the smallest in Split. None of this site is under ownership of this investor.

Once you have defined alternative solutions, i.e. construction site locations and criteria, it is necessary to perform the evaluation of each alternative according to each criterion. GIS (Geographic Information System) has been used as a tool for evaluating the sites according to criteria of C4, C11 and C12 due the spatial determinants of evaluation according to these criteria. All reviews together make the decision matrix and are presented in Table 3.

Table 3: Decision matrix

Criteria → / CS Locations ↓	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1 Osijek	9	15	12	10	40	579,6	49	238,7	28,8	19,4	7	3	0.7
2 Rijeka	6	19	18	3	45	589,1	119	312,6	31	35,9	10	5	0.95
3 Zagreb	7	19	24	4	25	594,5	116	439,2	31,8	67,5	10	3	0.8
4 Split	6	17	20	5	5	590,1	155	428,1	33,9	50,6	5	5	0.8

Decision matrix, as it is shown in the Table 3 consist 13 columns and 4 rows. Each column gives the evaluation of alternatives regarding the one criterion. Assessment of alternatives across all the observed criteria is presented through the rows. By using software Visual PROMETHEE multicriteria data were processed with the usage of multicriteria method PROMETHEE II, and three priority rankings are generated (for each scenario one ranking) for observed locations for constructing site. Method PROMETHEE II provides ranking by mutual comparison of all locations with every criterion regarding the respect to stakeholders' attitudes which are expressed through the weights assigned to the criteria and selected preferences functions. These three rankings and their comparison is shown below in Figure 3.

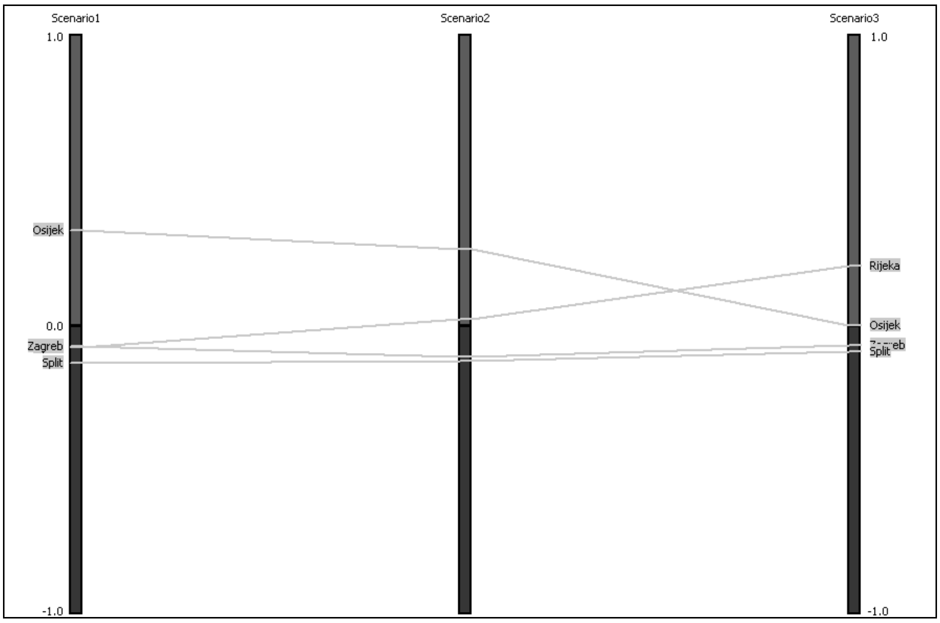

Figure 3: Three rankings according to three different scenarios and their comparison

Previous Figure 3 showed the rankings for the three scenarios, the first, from the left is the ranking according to the Scenario 1 – is determined by the attitudes of construction experts, the second is the ranking by Scenario 2 – is scenario determined by the attitudes of investors, and the last, third is the ranking by Scenario 3 - is determined by attitudes of socio-economic experts. Significant dominance is on the location of Osijek as a location for the construction site (in two of three scenarios, precisely for Scenario 1 and Scenario 2), furthermore, according to Scenario 3 the highest scoring is for location of city Rijeka. Zagreb (according to Scenario 1); Rijeka (according to Scenario 2) and Osijek (according to Scenario 3) were placed on the second place. It should be important to emphasis that the locations of Zagreb and Rijeka have almost the same score (with the minimum advantage for location of Zagreb in comparison of Rijeka, according to Scenario 1). According to the all observed scenarios Split has the lowest score.

Previous picture and explanation represent a basis for decision-making, and they were presented to the decision-maker/investor. Based on the presented information-basis for decision making investor selects Osijek as the location for the construction site in this investment cycle and location of city

Rijeka is involved in acquisition plan for the next investment cycle. On observation is extremely interesting, the sites that promise the highest profit (Zagreb and Split, particularly Split as a most convenient operational point for investor) are completely discarded from current and future investment cycle plans. All this lead us to the conclusion that, (at least in the case of Split site) there is a need to search for a better location in Split than this one which was the subject of this analysis.

4. CONCLUSION

With application of this approach it is possible to overcome most of the problems encountered when solving poorly structured problems such as selection of the location for a construction site, particularly the selection of the location as a part of one investment planning. Usage of multicriteria methods as an approach to problem solving has identified a number of methodological and project managerial advantages of this approach in the planning of investment construction. The advantage is primarily manifested in full cover of all available information related to the planning and processing by appropriate stakeholders. The result of this is increasing in the quality of investment planning with organized involvement of investors and all other relevant stakeholders in decision-making (all involved in all phases, and the investor make final decision based on the documents prepared for the decision, which give him an objective analysis of the problem in a simple way).

According the all presented in this paper it is easy to conclude that the research goal of this paper has been achieved, which means that we established useful concept for decision support in the management of construction projects and the management of the planning of construction site location. By using multicriteria methods such as AHP and PROMETHEE as the basis of the concept it is possible to understand the problem while respecting the construction industry, investor desires and attitudes, and socio-economic framework in which the plan will be implemented.

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