

## APPLICATION OF MULTICRITERIA METHODS TO PLANNING OF INVESTMENT PROJECTS IN THE FIELD OF CIVIL ENGINEERING

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### Abstract

In this paper we present a new approach for the planning of an investment project in the field of building construction. The focus is in shaping of the concept that serves to facilitate decision making about investments through providing support to investors' when they are dealing with a problem - selection of a solution for investment project. The concept is based on the combined use of several different criteria, conventional methods for the evaluation of investment projects and multicriteria methods (PROMETHEE and AHP). Selected criteria encompassed economic, social-administrative, construction-functional and spatial aspects of selection problem. The determining criteria weights process is carried out in two steps. In the first step the AHP method is used to obtain the primary weights. The second step allows interactive involvement of investor in the process of solution selection (an investor-subjective approach to the problem). Presented approach is tested on the planning of investment project in Croatia.

**Key words:** *Multicriteria methods, Project planning, Investments, PROMETHEE, AHP*

## **1. INTRODUCTION**

Planning of an investment project in the field of civil engineering is very complex and demanding task. Complexity of this task becomes higher when dealing with an investment problem, which is related to selection of solutions for the investment in construction of a building. That is because of several different aspects (such as economic, construction-functional, social-administrative and spatial) which need to be covered during planning. Furthermore, a large number of different aspects also indicate complexity of decision making process related to the planning of this kind of investment project. The decision making process is characterized with evaluation of available investment project solutions by several different (according to their origin, meaning and importance) and often conflicting criteria. All above mentioned aspects of investment planning were sources for identification of relevant criteria. Except, above mentioned the role of investor (which is, and always must be, the final decision maker in selection process of investment project solution) who makes decision making process/investment planning even more complex. That is because of the fact that investors are usually faced with insufficient personal level of knowledge that is required to cover all aspects of analyzed problem by themselves. It is normal situation and it would be unrealistic to expect from an investor to be familiar with all relevant aspects required for evaluation of all investment project solutions. Moreover, comparing multiple investment project solutions according to the several different criteria is excessively demanding task for an individual.

This problem can be partially overcome with inclusion of several adequate consultants in decision making process. They can cover all aspects of problems (ensuring a sufficient level of relevant knowledge) but each from their own point of expertise, what usually results in several conflicted recommendations about investment project selection. Thus, economic experts will recommend investment project solution - project that can produce highest return of invested funds in shortest time. Civil-engineering experts will recommend solution which covers highest level of constructability that matches all highest technical quality standards. Finally, social-real estate market experts will recommend solution which ensures sustainability of the real estate value (according to the availability of different urban infrastructure systems, spatial planning and administrative acts) and a high level of sale attractiveness (meaning - easy to sell in a short period). A unique solution that can meet all these recommendations as well as requirements of investor is impossible to find in the real business world. The best substitute for such a solution is a compromise solution. Compromise solution is one that takes into account the recommendations of all experts and meets the requirements of investor as much as possible. Shaping of concept that serves to facilitate the selection of a compromise solution for an

investment project within investment planning (in the field of civil-engineering) is in the focus of this paper/research.

The concept is based on the combined usage of several different criteria, conventional methods for the evaluation of investment projects (such as: Internal Rate of Return – IRR, Net Present Value – NPV etc.) and multicriteria methods. This approach for planning of investment projects is particularly valuable in the time of recession when other criteria that are different from financial ones can have a significant impact to the final outcome of the investment project.

Many authors have dealt with the problems of investment planning in the civil-engineering /construction industry but research presented in their papers shows partial approaches to analyzed issue. Papers which deal in the above mentioned and which are using multicriteria approach to planning of investment project in the field of civil engineering we can find in work of Giuliano, 1985 - introducing a multicriteria method for transportation investment planning, Teng & Tzeng, 1996 - presenting fuzzy multicriteria ranking of urban transportation investment alternatives, Anagnostopoulos et al., 2005 - presenting how multicriteria methods can be implemented in planning of water resource projects, Jajac et al., 2009 - introducing multicriteria methods to planning of maintenance investments projects in urban infrastructure. Although, this is a problem that has spatial characteristics, papers dealing with combination of multicriteria methods and geographic information systems (Marinoni, 2005 and Mladineo et al., 1993) are especially interesting too.

## **2. CONCEPT FOR PLANNING OF INVESTMENT PROJECT IN THE FIELD OF CIVIL ENGINEERING**

Figure 1 shows architecture of generic concept for the planning of investment projects in the field of civil engineering. Application of concept begins with identification and gathering together experts stakeholders (by investor). After that, experts must be divided into three groups as follows: economic experts, social-real estate market experts and civil-engineering experts. Investor (s) represents fourth no-expert stakeholder or group of stakeholders which are involved in final criteria weights determination but not in the process of generating criteria. Investor is also involved in determination of several adequate constrains necessary for final selection of alternative project solutions.

Experts are also involved in determination of main goal, objectives, criteria and primary criteria weights. Their work begins with definition of main goal (suggestion - take as a main goal: The best investment project or group of projects) and its objectives through brainstorming. Only experts are involved in establishment of goal hierarchy structure. Establishment of goal hierarchy structure provides better understanding of interrelations between main goal and generated objectives (as well as

between objectives and their sub-objectives etc.) ensuring higher quality of objectives generation process. Process of objectives generation is carried on until criteria are determined. In fact, when it is impossible to generate sub-objectives of an objective (meaning: divide an objective in its sub-objectives) and when that objective is measurable then objective becomes a criterion. Criteria established in this manner will be used for evaluation of possible investment solutions/alternatives of the investment projects.

In line with establishment of goal hierarchy, generation and analysis of possible investment solutions/alternatives is conducting. Possible impacts (derived from the meaning of criteria) on those alternatives must be analyzed to. After analysis is done, set of possible solutions for investment project is defined. Between alternatives within this set a compromise solution will be selected. Compromise solution will represent an investment plan.

Next step is evaluation of all alternatives per all criteria and selection of adequate multicriteria method (suggestion - use PROMETHEE I. and II, Brans et al., 1984) for their comparison. Comparison must be based on harmonized opinion of all experts (expressed by primary weights of criteria and their preference functions). This harmonized opinion must reflect equal respect to their individual opinions. Determination of criteria primary weights is performing by AHP method (Analytic Hierarchy Process by Saaty 1980). Comparison of alternatives by PROMETHEE I, II results in their priority ranking for inclusion in the investment plan. This is only primary ranking because in process of determination of criteria weights investor opinion was not taken into consideration. Primary ranking in fact offers an objective-expert approach to the problem and it is a basis for investor decision making. It is presented to investor at the beginning of second step.

Second step allow interactive involvement of investor in the process of solution selection (an investor-subjective approach to problem) through enabling an immediate changing of weights (walking weights) and observation of output (ranking) changes. When investor is satisfied with criteria weights, final ranking is determined. However, the best ranked alternative should not be selected as investment project solution. This is due the number of influences related to the planning of investment projects (in the field of civil engineering) which need to be covered before final selection of investment solution - definition of investment plan. Those influences are related to opinion of investor (about investment planning) which is not covered by criteria, to availability of required resources (especially financial resources) and to dynamic and spatial nature of real estate market (which derives from functional and spatial interconnections between investment alternatives). Therefore, it is necessary to define and introduce several constrains which can cover all above mentioned influences. Introduction of constrains by PROMETHEE V method (combination of PROMETHEE II method and (0-1) linear

programming) makes possible selection of one or more alternatives. Finally, selected investment solution or group of solutions becomes investor's investment plan for next investment cycle.

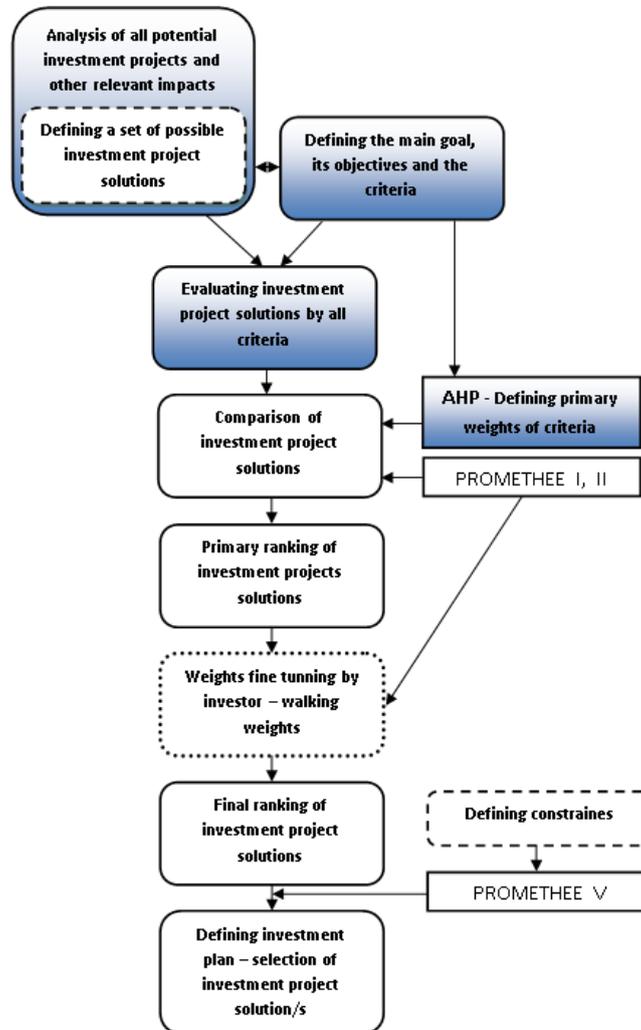


Figure 1: Concept for planning of investment project in the field of civil engineering

With dashed line (Figure 1) we marked activities in which all stakeholders are involved; with dotted line we marked activities in which only investor (group of investors) is involved, and finally grey fill with solid line represents activities in which all experts (expert stakeholders and experts for multicriteria methods) are involved. Activities with only solid line (no fill) are those in which only experts for multicriteria methods are involved.

By application of presented concept, before each investment cycle, it is possible to improve a quality of investment planning in the field of civil engineering. If investment plan for second investment cycle must be created from set of solutions which were not included in the investment plan for first investment, cycle concept must be applied again from the start. This approach (concept) for planning

of investment projects in the field of civil engineering is adaptable to changing conditions and to customizations required by investor.

### **3. PLANNING OF INVESTMENT PROJECT IN CROATIA - CONCEPT VALIDATION**

Worldwide planning of investment projects in the field of civil engineering is mainly based on usage of economic methods (only) for assessment of investments financial parameters. Planning in Croatia is not different. Different approach is usually reserved for complex construction projects like those in utility infrastructure. The reason for this is obvious need for a broader analysis than just financial. Introduction of proposed concept allowed application of the knowledge and skills concerning the planning of complex investment projects on simpler and less demanding construction projects. That does not exclude the possibility to use proposed concept in both large and complex construction projects. The proposed planning concept is appropriate for smaller and simpler investment projects in Croatia. Majority of these investment projects decision makers, owners of construction companies, (that will realize the investment plan - construct a building) are investors at the same time what is particularly expressed in times of recession. With this approach, construction companies used to employ their own capacities till the moment when they will be able to ensure favorable contracts to work for other investors.

To validate the presented concept the construction-investment company from Split (which operates across Croatia and have comprehensive experience in construction of buildings) was selected. A company's owner (and top manager) decided to invest in the construction of a residential-commercial building for sale and started with investment planning. Company employees, responsible for the investment planning, conducted an analysis of potential investment projects (projects with available financial-technical documentation). They created a set of projects from which investment plan should be derived. A set consists of four different solutions of investment projects as follows: luxurious villa near city of Split, hotel in Rabac, residential-commercial building in Osijek and residential-commercial building in Zagreb (Figure 2).

That investment projects varied in many characteristics. The biggest buildings are located in Zagreb and Osijek, smaller hotel is in Rabac, and the villa near Split is the smallest building. On the other hand, villa and hotels, as luxury buildings have special requirements in construction and equipment, while residential and commercial buildings are more or less ready-made constructions that require a standard level of equipment. An important difference between these four solutions for investment project comes from their locations (due to differences in the land prices and in attractiveness for

potential buyers). The intention of the investor is to sell investment as soon as possible. Till the moment of sale the buildings will be rented. The villa and the hotel will be rented as a whole, while the apartments and office spaces in residential-commercial buildings could be rented separately.



Figure 2: Visualization of four solutions for investment project

Process of establishment of goal hierarchy structure begins with definition of main goal - "The best investment project or group of projects" and objectives identified by all experts/stakeholders. First level objectives are oriented to maximization of economic, civil-engineering, social & real estate market indicators. Second hierarchy level is consisted from objectives that support achievement of the first level objectives; objectives are divided into three groups. Each group supports only one first level objective. Second level objectives are measurable and cannot be further divided into supporting objectives. All stakeholders accepted these objectives as set of criteria for evaluation of possible solutions of analyzed investment project (alternative solutions). Figure 3 shows eleven criteria (C1, ..., C11). When hierarchy is established and criteria are defined than criteria weights must be determined. Determination of criteria weights is very important step because through them opinions of all stakeholders are introduced in comparison of alternative solutions. Criteria weights are determined by AHP method and their values are presented in circles of criteria on Figure 3. All stakeholders were involved in determination process and because of that obtained weights values represent compromised weights. Sum of all criteria weights always must be 100%.

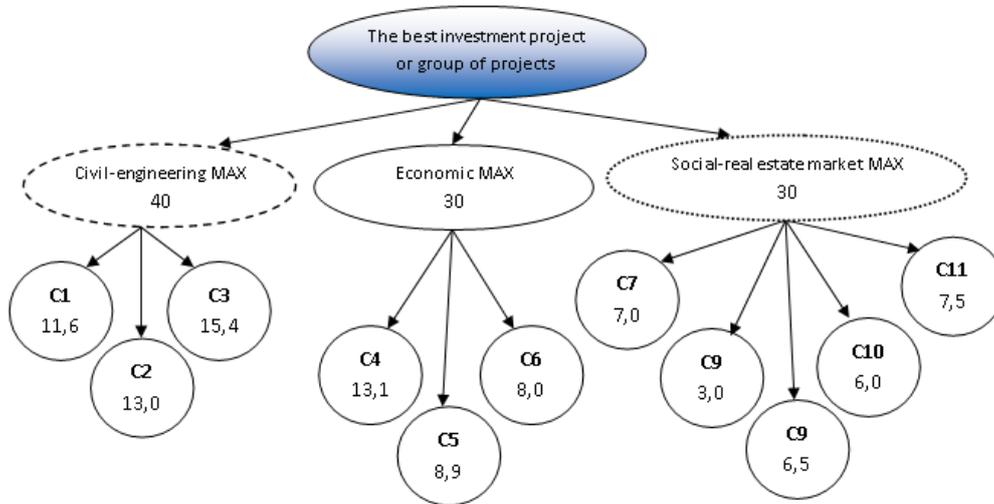


Figure 3: Goal hierarchy structure with compromised criteria weights

Due to visibility, in previous Figure 3 we showed only labels and compromised criteria weights while in following Table 1 we presented the full names of the criteria and their description. In Table 1 we described the way of evaluation of each alternative solution by each criterion. In addition Table 1 shows the way of forming preferences for each of criterion (fourth column – min or max; fifth column – preference functions). V-Shape function prevails. Linear-Shape function is used for two criteria and Usual-Shape functions for a single criterion.

Next step is the evaluation of all alternative solutions according to all criteria. All results of the evaluation together form the decision matrix which is shown in Table 2.

With usage of software Decision Lab 2000 (produced by the Visual Decision) all data were processed by multicriteria PROMETHEE methods I and II. These methods were used to establish a priority ranking (for inclusion in the investment plan) of four analyzed investment projects. PROMETHEE methods provided priority ranking by mutual comparison of all investment projects by all criteria with respect to opinions of all expert stakeholders. The results of application of the method PROMETHEE I (which gives a partial ranking) and PROMETHEE II (which gives a complete ranking) are shown by Figures 4 and 5.

Figure 4 presents complete ranking of all alternative investments according to priority for inclusion in investment plan for next investment cycle. Villa has best ranking (significantly better ranking than RCB Osijek and RCB Zagreb). Difference between rankings of RCB Osijek (2nd) and RCB Zagreb (3rd) is very low. The hotel has the worst rank.

Table 1: Criteria name and short description

Criteria label	Criteria name	Short description of criteria and of technique for evaluation of investment solutions	Preference	
			min/max	function
C1	Constructability	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	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 EUR	Min	V-Shape
C5	NPV	Net Present Value (for 5 years investment period starting from the completion of construction) - in EUR	Max	V-Shape
C6	IRR	Internal Rate of Return (for 5 years investment period starting from completion of construction) - %	Max	V-Shape
C7	Integration into spatial plans	It is determined whether the object is recorded into a spatial plans (eg city GUP) or not -grading as follows: if it is recorded – 1; if not recorded – 0	Max	Usual
C8	The quality of transport connections	Experts assessment that takes into account the use of the building – grading 1 (worst) -5 (best)	Max	V-shape
C9	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
C10	The attractiveness of the building/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
C11	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 (doubtless)	Max	V-Shape

Figure 5 presents partial ranking of investment solutions. Partial ranking better expresses relationships between analyzed investment solutions than complete ranking by PROMETHEE II and that is a reason why PROMETHEE I results are presented to investor. Stability intervals are presented to investor also. All of the above has been done to provide the investor better insight into the possibilities of its own impact on the final ranking while he is „Walking weights“ (conducting weights fine tuning).

Table 2: Decision matrix

Criteria ↓ Investment solutions	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Villa	10	10	18	1243500	771734	18	0.0	1	2	5	0.7
RCB Osijek	7	20	12	3762000	523420	13	1	5	8	4	0.6
RCB Zagreb	7	25	24	5767000	1032525	17	1	5	10	3	0.95
Hotel	5	18	18	2025600	473816	14	1	3	7	4	0.3

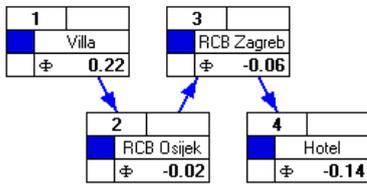


Figure 4: PROMETHEE II – complete ranking

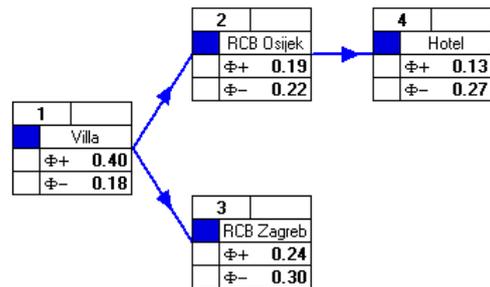


Figure 5: PROMETHEE I – partial ranking

The investor has decided to increase the weights of the following criteria C5 (NPV), C6 (IRR) and C7 (Integration into spatial plans) and to reduce the weights of the criteria C4 (Amount of investment) and C11 (The probability of selling the property). New weight values (the final weights) have led to a change in the ranking (now RCB Zagreb is on the second and RCB Osijek is on the third place). Figure 6 shows the final criteria weights and the final ranking of investment solutions is as follows: 1<sup>st</sup> is Villa, 2<sup>nd</sup> is RCB Zagreb, 3<sup>rd</sup> is RCB Osijek and 4<sup>th</sup> is Hotel.

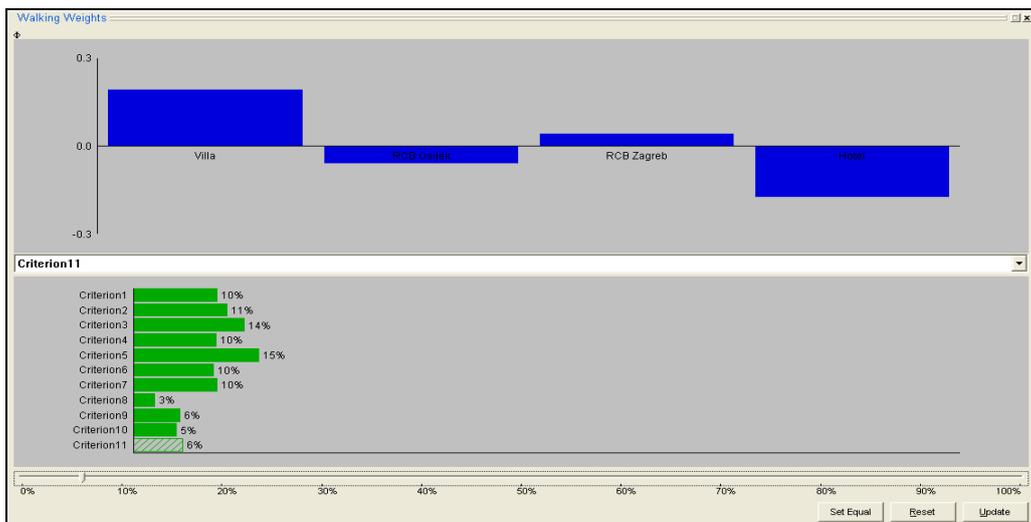


Figure 6: Final criteria weights and final ranking of investment solutions

Next step is constraints defining. All stakeholders are involved in it. These constraints are defined as a set of linear equations and/or inequalities. Only one constraint within this set is related to the available financial resources (7.500.000 EUR) for next investment cycle. All other constraints are related to functional and spatial aspects of analyzed problem. Three non-financial constraints are as follows: 1st - no more than one project in Adriatic region, 2nd - no more than one project in the inland and 3rd - at least one project must be included into the investment plan. PROMETHEE V method is used for introduction of these 4 constraints into investment planning process. The final goal function (obtained after walking weights by investor) and above specified constraints which are used are shown below:

$$\text{Max} \sum_{j=1}^{27} \Phi_j x_j, \quad j=1,2,3,4; \quad \text{Max}(0,18x_1 - 0,06x_2 + 0,04x_3 - 0,16x_4)$$

Non-financial constraints:  $x_1 + x_4 \leq 1$ ;  $x_2 + x_3 \leq 1$ ;  $x_1 + x_2 + x_3 + x_4 \geq 1$

Financial constraint:  $1243500x_1 + 3762000x_2 + 5767000x_3 + 2025600x_4 \leq 7500000$

According to the results of PROMETHEE V method two of four investment solutions (Villa and RCB Zagreb) should be included in the investment plan for the next investment cycle. The investor has decided to simultaneously implement both projects. His decision was based on availability of resources (within company) which are required for simultaneous construction of both projects and it represents an investment plan.

#### 4. CONCLUSION

By applying this approach it is possible to overcome most of the problems encountered when solving poorly structured problems such as planning of investment projects in the field of civil engineering (problems with a lot of different and usually conflicted criteria and with many required different stakeholders etc.). With the application of multicriterial approach to this problem we have identified a number of methodological and project managerial advantages of this approach for investment planning in the field of civil-engineering. The advantages are primarily manifested in relatively full capturing of all available information and data related to the all aspects of investment planning and in the way in which that data have been processed (by application of several adequate multicriteria methods). Next advantage of this approach is that it enables timely inclusion of all relevant stakeholders (experts and investors) which is required to ensure the quality of the planning process. It is particularly important that it allows us to include opinions of investors through all stages of planning (directly or indirectly) and that it is adaptable to changing conditions and to customizations required by investor. This

approach to the planning of investment projects is particularly valuable in the time of recession when other criteria that are different from financial ones can have a significant impact to the outcome of the investment project.

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