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Review paper

MULTI-CRITERIA ANALYSIS APPLICATION IN THE INVESTMENT PROJECTS ASSESSMENT

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Abstract. *The growth and development of each economic agent is inconceivable without investment or investment activity. In this sense, the investment decision plays a very important role in the realization of the development goals. Economically correct decision is based on the application of various methods of analysis of investment projects and the choice of the most acceptable one. Since a large number of factors affect the decision about the selection, the nature of the problem is multi-criteria. The evaluations of investment projects include an appraisal of their financial and market efficiency. For this purpose, the static and dynamic models of projects are rated as relevant criteria in the multi-criteria model and the ranking of projects is based on the method of multi-criteria analysis. In this paper, specific investment projects funded by the Development Fund of the Republic of Serbia were ranked using the methods of multi-criteria analysis.*

Key Words: *multi-criteria analysis, ELECTRE method, investment decisions, investment projects, efficiency evaluation of investment projects.*

1. INTRODUCTION

Investments are an instrument for the implementation of development policies. Investment decisions in firms are important for the realization of strategic development objectives. In addition, the decision maker often has to decide on the choice between more investments where only one or a few of them can be realized due to a lack of funds. The choice between several investment projects involves the use of different methods of analysis of investment projects and the choice of the most acceptable one. It is necessary to define clearly the targets of investment, criteria that will measure the achievement of

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these objectives, and then from available investment projects choose the one that best meets the set target of investment.

The advantage of using quantitative methods is particularly reflected in the solution of complex problems, where there are several possible solutions. The decision maker is often not able to assess a number of potential investment projects and on this basis to make a choice, so in these situations it is necessary to use a scientific approach and by using appropriate quantitative criteria make a choice of the best investment solutions. The classic approach to evaluation of investment projects is the analysis and measurement of results achieved after activation of the investment using the static and dynamic evaluation methods. On the other hand, contemporary works in this field show numerous disadvantages of this approach, resulting primarily from the fact that the classical approach ignores the risk and uncertainty (Zopounidis, 1999). First papers in the field of quantitative finance underline the fact that in addition to the basic principles of microeconomic theory which considers the enterprise profit maximization as the basic criterion for decision-making, there are a number of important and relevant criteria, dating back to the mid-twentieth century: the revenue maximizing model (Baumol, 1959), the manager's utility model (Williamson, 1964), the satisficing model (Simon, 1957) and the behavioural models (Cyert and March, 1963). Still in the research of Bhaskar's and McNamee's (1983), there is a question whether investment decisions can be made based on a single criterion, or these problems have multi-criteria nature. Also, this study raises the question of determining the importance of the criteria in the model for investment decisions, and which criteria should be given priority. In a similar study, Bhaskar (1979) points out three distinct critical reviews of the settling of the investment decision-making problems where only a single criterion is listed as relevant.

In this paper, an approach to investment decision-making with the help of exact scientific method is presented, which involves ranking of investment projects according to the aggregation of their financial and market efficiency. For this purpose, the static and dynamic models of evaluation of investment projects are used as relevant criteria in the multi-criteria model, and the multi-criteria analysis methods are used for the ranking of these investment projects.

2. Classical Approach to the Evaluation of Investment Projects

Justification of investment projects realization is evaluated through analysis and measurement of results obtained from investment. When a company has at its disposal several projects which can contribute to the achievement of development goals, priority will be given to those projects that show the best results in the economic and financial analysis of investment projects.

Measuring the overall effects from the realization of an investment project and their quantitative expression using various indicators can be helpful in order to assess whether the expected effects surpass the required investment. This procedure is called the rating of the efficiency of the implementation of the concrete investment project. The main purpose of the application of certain methods of evaluation and ranking of investment projects is reflected in the fact that they provide a more accurate evaluation of profitability of the investment project, which is expected in investing.

Profitability of the investment project can be:

- Financial evaluation – involves measuring the effects which the realization of the investment project brings to the investors,
- Social evaluation – comprises measuring the effects which the realization of an investment project brings to the whole country.

All methods for assessing the profitability of investments are categorized into two main groups:

(1) traditional or static methods, and (2) modern or dynamic methods.

Static methods for evaluation and ranking of investment projects ignore the time factor, since they are based on the effects of a single (representative) year. Therefore, these methods are usually applied to the so-called pre-investment studies to make a decision on the election of the program which will be the subject of further detailed analysis. However, as simplicity and ease of understandability are some of their main advantages, static methods are still widely used in practice to assess the effectiveness of investments.

The static methods of investment evaluation as a basis for analysis use the analysis of input and output, usually in a normal year of investment, which is a representative one. The representative year is the year in which the designed capacity is reached and in which the loans are repaid. Based on the available data it is possible to calculate the number of indicators that provide insight into the profitability of the project.

Commonly used static indicators are: (1) the accounting rate of return, (2) the payback period, (3) the unit cost, (4) indicators of productivity of investments, (5) indicators of efficiency of investments, and (6) indicators of investment profitability.

For the purposes of this study, the payback period, indicators of efficiency of investments and indicators of investment profitability will be further explained.

Dynamic methods or a dynamic approach to evaluation of investment projects, in contrast to the static approach which uses data from only one year of the economic life of a project, use data from the entire life of the project. With the help of the discounting techniques, investments and results from all the years of the investment and the operation period of the investment project are covered.

Dynamic indicators are complex indicators which in various ways include investments and investment results and also allow much more realistic analysis of the different aspects of one investment project and assess the reasonableness of its implementation.

Commonly used dynamic indicators are:

1 The payback period,

2. The net present value,

3. The internal rate of return,

4. The profitability Index.

For the purposes of this study indicators payback period on investment, the net present value and the internal rate of return will be explained in detail. Two of the most important criteria for choosing among investment projects are net present value (NPV) and internal rate of return (IRR). In many circumstances investment projects are ranked in the same order by both criteria. In some situations, however, the two criteria provide different rankings. This difference between rankings implies inconsistent recommendations about "the best project" (Osborne, 2010).

3. THE METHODOLOGICAL FRAMEWORK OF MULTI-CRITERIA ANALYSIS APPLICATION IN THE INVESTMENT PROJECTS

Once the decision maker chooses certain indicators which the evaluation of investment alternatives is going to be performed on, it is necessary to make a decision about running one of several projects. In the selection of the project, the decision maker faces a problem that is related to the existence of multiple criteria for the analysis of investment projects and that the choice among several investment projects has to be made. A particular problem is the possibility that there are more investment alternatives that meet all the criteria, so in this case it is necessary to rank investment alternatives and make the appropriate decision. The solution of this problem requires multi-criteria decision making, which is related to decision – making situations where there is a number of, usually conflicting, criteria which the decision maker has to evaluate in order to make an optimal decision. The reality and actuality of the area of decision – making have caused rapid and continuous development of methods which are used to solve the most complex problems. In fact, in most of the decision problems, the results achieved should be analyzed from different aspects and evaluated according to several criteria.

From the sixties onwards, a number of methods have been developed which are able to, more or less successfully, solve real-world problems of multi-criteria decision making. These are the methods of multi-criteria analysis.

The choice between a number of investment projects is part of the overall problem of investment management. The problem of the investment in the company is to determine the available investment projects which make the greatest effects with limited financial resources.

Multi-criteria analysis is an upgrade of single criteria optimization methods that are known in theory as linear and nonlinear programming, game theory, dynamic programming, optimization of reserves, queues, network planning, and others. These methods are applied in practice, but they are not applicable to most real business problems when we have a situation of choice between several alternatives described by several conflicting or partially conflicting criteria.

Real problems have some common features such as (Čupić, et al., 2001):

- A number of criteria, ie, the attributes that must be created by a decision-maker.
- Conflict among the criteria, as far the most common case for real problems.
- Not comparable units of measurement because, as a rule, each criterion or attribute has different units of measurement.
- Design or selection. Solutions of this kind of problems are designing the best action (alternative) or a selection of the best action from the final set of pre-defined actions.

Multi-criteria analysis methods are aimed at solving the problem of choosing one out of a series of m alternatives A_i ($i = 1, 2, ..., m$) based on the n criteria X_j ($j = 1, 2, ..., n$). Each of the alternatives is a vector $A_i = (x_{i1}, x_{i2}, ..., x_{ij}, ..., x_{im})$. The usual way of presenting the problem of multi-criteria analysis is the matrix form (Janković-Milić, Stanković, 2010).

Alternatives in a model form a set with a finite number of elements that should be examined, evaluated, prioritized and ultimately selected. The criteria in the model are presented with an appropriate functions, and their importance is shown by corresponding weights. Depending on the type of extreme values of the criterion function, there are two types of criteria. The first group consists of those where the decision maker's interest is to maximize the value of the criterion function. The second group includes criteria where the interest of decision-maker is to achieve the minimum value of the criterion function. The importance that the criteria will have in the model directly depends on the preferences of the decision maker, that is, on the weighting factor that the decision maker will assign to certain criteria. As far as the attributes are concerned, most authors agree that it is a particular feature, quality or characteristics of alternative by observed criteria. Attributes are the relevant characteristics of each of the alternatives that represent means of evaluating reached value of each of the criteria.

Depending on the relation between attribute and utility functions of decision-makers, attributes are divided into (Janković-Milić, Stanković, 2010):

- Revenue attributes, which are directly consistent with utility function of a decision maker,
- Expenditure attributes, which are inverse in relation to the decision maker's utility function,
- Non-monotonous attributes, which in one area directly agree, while in the second have inverse relation with the decision maker's utility function.

4. The Formation of Multi-Criteria Model and Selection of Method for Ranking Investment Projects

Multicriteria analysis models are suitable for solving a number of problems of financial decision making. Diverse nature of the factors that affect financial decisions (decision-making criteria, goals and objectives), the complexity of the financial business and economic environment, the subjective nature of many financial decisions are just some of the characteristics of the financial decisions that justify the application of multi-criteria analysis method (Zopounidis, Doumpos, 2002). Among these methods, one could mention the ELECTRE methods developed by Bernard Roy and his collaborators (Roy, Bouyssou, 1993; Roy, 1996), the PROMETHEE and GAIA methods (Brans, Vincke, 1985; Brans et al., 1986; Brans, Mareschal, 1994), the Analytic Hierarchy Process (AHP) method (Saaty, 1980), multiobjective/goal programming approaches (Lee, Chesser, 1980; Spronk, 1981), as well as preference disaggregation methods such as UTA method and UTADIS method (Jacquet-Lagreze, Siskos, 1982 and 1983; Zopounidis, Doumpos, 1999).

4.1. Selection of appropriate method

Examples of practical applications of these methods in the field of quantitative finance are given in Table 1-4. Categorization was done according to the data which Zopounidis (1999) introduced in his work "Multicriteria decision aid in financial management."

Table 1 Applications of MCDA approaches in bankruptcy and credit risk assessment

Approaches	*Methods*	*Studies*
Multiattribute utility theory	AHP	Srinivasan and Kim (1987)
		Srinivasan and Ruparel (1990)
		Jablonsky (1993)
Outranking relations	ELECTRE	Dimitras et al. (1995)
		Bergeron et al. (1996)
		Khalil et al. (2000)

Table 2 Applications of MCDA approaches in portfolio selection and management

Approaches	*Methods*	*Studies*
Multiattribute utility theory	AHP	Saaty et al. (1980)
Outranking relations	ELECTRE	Martel et al. (1988, 1991) Szala (1990) Khoury et al. (1993) Hurson and Zopounidis (1995, 1997) Hurson and Ricci (1998)
Outranking relations	PROMETHEE	Khoury and Martel (1990) Martel et al. (1991) Hababou and Martel (1998)

Table 3 Applications of MCDA approaches in the assessment of corporate performance

Approaches	*Methods*	*Studies*
Multiattribute utility theory	AHP	Lee et al. (1995) Babic and Plazibat (1998)
Outranking relations	ELECTRE	Colson and Mbangala (1998)
	PROMETHEE	Mareschal and Mertens (1990, 1992, 1993) Mareschal and Brans (1991) Pardalos et al. (1997) Babic and Plazibat (1998) Colson and Mbangala (1998) Zmitri et al. (1998) Baourakis et al. (2002)

Table 4 Applications of MCDA approaches in investment appraisal

Approaches	*Methods*	*Studies*
Multiattribute utility theory	AHP	Kivijarvi and Tuominen (1992)
Outranking relations	ELECTRE	Danila (1980) Buchanan et al. (1999)
Outranking relations	PROMETHEE	Ribarovic and Mladineo (1987) Vranes et al. (1996)

In fact, if there are more investment projects, which are simultaneously assessed by classic approach, that is by static and dynamic methods, which can be considered acceptable, it is necessary to rank them. It is in this segment, that ELECTRE, as a method of multi-criteria optimization, gives significant results. For the purpose of this study, the ELECTRE method will be discussed in detail.

4.2. Determination of the relevant criteria in the model

One of the most important segments of the formation of a multi-criteria model is the determination of the relevant criteria and the evaluation of their significance. It is assumed that all investment projects, whose ranking is required, are acceptable from the point of application of the classical approach to the evaluation of investment projects. In this context, a multi-criteria model should include all static and dynamic indicators as relevant criteria, because in this way the ranking of projects which at the same time respects the fulfillment of all these criteria is enabled. During the formation of the model, six criteria will be included in this paper:

(1) Payback Period, (2) Indicator of the Efficiency of Investment, (3) Indicator of the Profitability of Investment, (4) Discounted Payback Period (DPB), (5) Net Present Value Method (NVP) and (6) Internal Rate of Return.

The first criterion that will be considered as a relevant in the formation of the model is the Payback Period (PB) of investment, based on the criterion of minimizing the time of return of funds invested in a single investment. It is one of the most popular methods for the assessment of investment projects in commercial practice. The basic idea of the payback period criteria is determining the number of years needed for the initial investment to be returned from the net income earned in the economic life of the project. In order to calculate the time it takes to recover the invested capital, it is necessary to calculate the ratio of the total invested assets with an annual net income, and the payback period is calculated as the ratio of the initial capital expenditure and net cash inflows.

The second criterion in the model, efficiency, is one of the basic economic principles for operating businesses that provides maximum production or other performance and minimal wear of manufacturing components. It expresses the efficiency of spending or rationality of spending in the enterprise, through the requirement that the funds spent realize greater production output. Natural determining of efficiency (En) take as the basis the physical volume of production (Q) and its relation to the expenditures of the subjects of labour, resources and labour (U), so $E_n = \frac{Q}{U}$. Value expression of efficiency (E_V) comes down to the relation of the achieved production with the cost of production (T). It is important to choose a real expression of the value of production. In the measurement of efficiency, the market price (C), the average price, standard price, total revenue, etc can be used for the expression of the value of production. Hence, the value stated efficiency is calculated as $E_v = \frac{Q*C}{T}$.

The third criterion in a multi-criteria model is profitability as one of the most significant expressions of the quality of business of each company. Profitability indicates the economic principle of business whose implementation should provide higher gains with a smaller mass of used capital. Business of the company is more successful if the results are made with less spending and less usage of funds. Reducing spending and usage of capital is one of the lasting economic objectives and motives of business. Profitability is usually expressed as a ratio of any net effect and the total capital used to achieve this effect. As a criterion for evaluating, the profitability of investment projects is commonly expressed as a ratio of net profit and invested assets. The obtained results are compared with the average in a particular industry or group.

Discounted payback period (DPB) is the fourth relevant criterion and it represents the number of years necessary for capital expenditures in the period of the investment project to be repaid from the net cash inflows. Payback period criterion is based on the fact that for those who invest the time in which the investment will pay off needs to be as short as possible. Payback period as a dynamic indicator is calculated by discounting net profit of operating investments to the initial year of project launching and then the results are summed cumulatively. Some have argued that the PB method does not measure the profitability of projects at all but rather their time risk and their effects on liquidity (Yard, 2000). Even if PB is most often used as the first sieve or as a restriction (Jacquet-Lagreze, Siskos, 1983), the method is still quite often used as the single or at least primary method for investment evaluations. The two main deficiencies of the PB method are that it does not take into account cash flows after the project's payback period and that it ignores the time value of money, which is discussed in most textbooks on capital budgeting e.g. (Levy, Sarant, 1995). As a solution to the latter deficiency it has been suggested that the simple PB method could be modified by looking at a discounted payback period (DPB), thereby searching the payback period when the accumulated present value of the cash flows covers the initial investment outlay. The recommendations of which discount rate to use vary somewhat. Either a risk-free interest rate or a risk-adjusted discount rate, such as the company's weighted average cost of capital, can be used (Osborne, 2010). Others take it more or less for granted to use a cost of capital including a risk component (Roy, 1996). In the latter case the DPB method could be seen as a variation of the Net Present Value method.

Net Present Value Method, as the fifth criterion in the model takes into consideration the time value of money, and expresses the costs and benefits of an investment project through cash flows (giving and receiving cash). Net present value is the sum of the discounted net revenues generated during period of investments, if the net incomes per year are different net present value can be calculated as (Petrović, Denčić-Mihajlov, 2007):

$$\mathrm{NPV} = \frac{NP_1}{r} + \frac{NP_2}{r^2} + \frac{NP_3}{r^3} + \cdots + \frac{NP_n}{r^n} = \sum_{k=1}^{n} \frac{NP_k}{r^k}$$

Where: NPV - Net Present Value, NP_K - net income in year k, k - number of years.

Internal Rate of Return, as the sixth criteria in multi-criteria analysis model, is one of the modern methods for evaluating the profitability of investment projects because the benefits and costs of the project are expressed with cash flows, and it also takes into consideration the time value of money. It can be defined as the discount rate that equates the present value of net cash flow from operating the project with the present value of capital investment, and that is the discount rate at which the net present value is zero.

Internal rate of return can be calculated by using the formula for linear interpolation:

$$i_r = r_1 + (r_2 - r_1)\frac{NPV_1}{(NPV_1 - NPV_2)}$$

Where: r_1 – lower discount rate, r_2 – higher discount rate, NPV_1 – positive net present value at a discount rate r_1, NPV_2 – negative net present value at a discount rate r_2.

Complexity of calculating the internal rate of return is usually the biggest obstacle in the application of this investment criteria in practice, although the fact is that it has a number of positive characteristics in comparison to other investment methods.

5. Application of ELECTRE Method for The Ranking of Investment Projects

5.1. ELECTRE method

Different methods are available when it comes to solving the problem of multi-criteria decision-making so there is the issue of the choice and the usage of the best one. In the case of multiple projects to be evaluated according to different criteria, one of the methods that can be applied is the ELECTRE method. Method ELECTRE (Elimination Et Choix Trandusant la Realite) began to be developed in 1965 by a European consultant company, SEMA, which is still active. At that time, the research team at SEMA dealt with solving a specific, multi-criteria, real-world problem regarding decisions dealing with the development of new activities in firms. To solve this problem they created a general multicriteria method MARSAN (Methode d'Analyse, de Recherche, et de Selection d'Activites Nouvelles).

However, when this method was applied, numerous deficiencies have been noted. B. Roy therefore tried to find a new method to overcome the observed limitations. The ELECTRE method for selecting the best alternative from a set was designed in 1965. In the same year, this new method that can be used to solve the problem of multi-criteria decision-making was presented at a conference in Rome. However, the original idea of the ELECTRE methods was first published as a research report in 1966.

Shortly after its appearance, it turned out that the ELECTRE method can be applied to solve a wide range of problems, but this method became widely known in 1968 when it was published in the journal "Revue d'Informatique et de Recherche Operationnelle".

This article presents a comprehensive description of the ELECTRE method. It is a widely known method for evaluating alternatives that can be used to solve the problem of multi-criteria decision making where both qualitative and quantitative criteria can occur. It has four versions and in practical terms, the most commonly encountered methods are ELECTRE I, used for the determination of partial orders of alternatives and ELECTRE II, used for arranging full set of alternatives.

Application of the ELECTRE II method for solving the problems of the power supply can be found in "La promotion de l'electricite et l'utilisation de methodes multicriteres" (Charpentier, Jacquet-Lagreze, 1976). The application of ELECTRE I method for solving the problem of comparison of several alternatives for the development of water resources in Central Hungary is presented in the paper "Multi-criterion ranking of alternative long-range water resources systems" (David, Duckstein, 1976).

The ELECTRE method compares the actions in pairs and seeks correlation between weight of preferences and paired dominance relationships between individual actions, then examines the degree of disagreement, which is the difference in determined weight of certain actions. Because of this, the ELECTRE method is called analysis of compliance.

The original algorithm is contained in the version of ELECTRE I method and it is an integral part of all subsequent versions. The differences are in the degree of regulation of set of alternatives, the nature of the information used, way of looking at the criteria and their importance, etc.

Step 1: Determination of the normalized decision matrix

Since not all criteria need to have the equal measure scale values from decision matrix must be normalized. The most commonly used are relations for vector normalization

$$n_{ij}^{+} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}} \qquad n_{ij}^{-} = \frac{\frac{1}{x_{ij}}}{\sqrt{\sum_{i=1}^{m}\left(\frac{1}{x_{ij}}\right)^{2}}}$$

The feature takes values between 0 and 1, where the closer it is to zero, the value of the feature is lower. Normalized decision matrix is:

$$N = \begin{bmatrix} n_{11} & n_{12} & \cdots & n_{1n} \\ n_{21} & n_{22} & \cdots & n_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ n_{m1} & n_{m1} & \cdots & n_{mn} \end{bmatrix}$$

Step 2: Calculating the weighted normalized decision matrix

In this step, the decision maker has to express his preferences according to the attributes on which selection is done. Calculating the weighted normalized decision matrix is done by multiplying the normalized matrix with appropriate weights.

$$TN = \begin{bmatrix} n_{11} & n_{12} & \cdots & n_{1n} \\ n_{21} & n_{22} & \cdots & n_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ n_{m1} & n_{m1} & \cdots & n_{mn} \end{bmatrix} \begin{bmatrix} t_1 & \cdots & \cdots & 0 \\ \vdots & t_2 & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ 0 & \cdots & \cdots & t_n \end{bmatrix} = \begin{bmatrix} t_1 n_{11} & t_2 n_{12} & \cdots & t_n n_{1n} \\ t_1 n_{21} & t_2 n_{22} & \cdots & t_n n_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ t_1 n_{m1} & t_2 n_{m1} & \cdots & t_n n_{mn} \end{bmatrix} = \begin{bmatrix} t_{11} & t_{12} & \cdots & t_{1n} \\ t_{21} & t_{22} & \cdots & t_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ t_{m1} & t_{m1} & \cdots & t_{mn} \end{bmatrix}$$

Where $\sum_{j=1}^{m} t_j = 1$.

Step 3: Determination of the conference of agreement and disagreement

The essence of this step is the comparison of pairs of actions p and r (p,r=1, 2,… ,m i $p \neq r$). First you have to establish the so-called set of compliance S_{pr} for actions a_p and a_r which consists of all the criteria for which a_p is more preferred than a_r.

$$Spr = \{j \mid xpj \geq xrj\}$$

And then a complementary set of inconsistencies is formed, such that:

$$NSpr = \{j \mid xpj < xrj\}$$

Step 4: Calculation of matrix of compliance

The elements of the matrix of compliance are so-called indexes of consent. Their value is calculated as the sum of preferences, which correspond to the corresponding elements of the sets of compliance.

$$s_{pr} = \sum_{j \in S_{pr}} t_j$$

The value of index of consent is between 0 and 1, and higher value indicates a greater desirability of actions a_p in relation to a_r action. The calculated indexes of consent form the matrix of compliance.

$$S = \begin{bmatrix} 0 & s_{12} & \dots & s_{1n} \\ s_{21} & 0 & \dots & s_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ s_{m1} & s_{m1} & \dots & 0 \end{bmatrix}$$

Step 5: Determination of the matrix of disagreement

Elements of the matrix of disagreement are so-called indexes of inconsistent. The index of inconsistent is between 0 and 1, and it shows the extent to which the evaluation of action a_p is less desirable than the evaluation of action a_r.

$$ns_{pr} = \frac{\max_{j \in NS_{pr}} \left| t_{pj} - t_{rj} \right|}{\max_{j \in J} \left| t_{pj} - t_{rj} \right|}$$

Step 6: Determination of the matrix of consistent dominance (MCD)

Consistent dominance matrix is usually determined by the value of the so-called threshold index of consent which may be defined as the average index of consent:

$$PIS = \sum_{\substack{p=1 \\ p \neq r}}^{m} \sum_{\substack{r=1 \\ p \neq r}}^{m} \frac{s_{pr}}{m(m-1)}$$

Based on the value of average index of consent for action a_p can be said that there is likely to be preferable to action a_r only if its corresponding index of consent is higher than the average index of consent. Matrix of consistent dominance is based on criteria:

msdpr=1, for spr≥PIS
msdpr=0, for spr<PIS

Step 7: Determination of the matrix of incompatible domination

To determine the matrix of incompatible domination first the average index of disagreement must be calculated:

$$PINS = \sum_{\substack{p=1 \\ p \neq r}}^{m} \sum_{\substack{r=1 \\ p \neq r}}^{m} \frac{ns_{pr}}{m(m-1)}$$

And then, based on specific criteria, the matrix of incompatible dominance is established:

mnsdpr=1, for nspr≤PINS
mnsdpr=0, for nspr>PINS

Step 8: Determination of the matrix of aggregate dominance (MAD)

This matrix is formed by multiplying the matrix of consistent dominance and the matrix of incompatible dominance. Its elements are calculated as:

$$mad_{pr}=msd_{pr}*mnsd_{pr}$$

Step 9: The elimination of less desirable actions

If the value of mad_{pr} is 1 then action a_p dominates the action a_r on both criteria (agreement and disagreement). But that does not mean that there is no other action that does not dominate *p*. Therefore, the requirement that the action a_p is not dominated by any other action is:

$$mad_{pr}=1, \text{ for at least one } r, r=1, 2,\ldots, m \text{ and } p\neq r,$$
$$mad_{pr}=0, \text{ for every } i, i=1, 2,\ldots, m \text{ i } p\neq i \text{ i } i\neq r.$$

Action (line) with the highest number of elements $mad_{pr}=1$ dominate others, and in situations where the number of such elements is equal, it is not possible to establish the condition of dominance.

5.2. Computational results

Solving the problem of investment decision making should be based on a particular methodology:

1. In the first phase static and dynamic aspects of specific investment projects are calculated,
2. Then a decision matrix is formed,
3. Then weights for these indicators are determined,
4. At the end, rankings of investment projects on the basis of multi-criteria analysis are formed.

This paper analyzes three different investment projects.

The basic assumptions are that there are sources of funding from which funds can be provided for the three investments. The loan was approved by the Development Fund of the Republic of Serbia, for a period of 10 years at an interest rate of 4.5%. The indicators used in multi-criteria decision analysis are unit net present value (noting that investment cost is taken into account when calculating the net present value), internal rate of return and payback period as dynamic data, and profitability of investment, efficiency of investment and payback period as static data. The investment project 1 is related to the planning and equipping for the production of product X. Powered by the new plant, which would hire 12 employees in the first year, and in the other years 20 workers. The total economic life of the project is 10 years. Calculated static and dynamic aspects are given in Table 5.

Table 5 The value of dynamic and static indicators of investment project 1

Dynamic indicators	*Value*
Unit net present value	0.145
Internal rate of return	0.085
Payback period	9.15
Static data	
Efficiency of investment	1.1
Profitability of investment	0.15
Payback period	6.5

Investment Project 2 is related to the expansion and renovation of hotel rooms. Capacity expansion requires seven workers and economic life of the project is 10 years. The calculated data are presented in Table 6.

Table 6 The value of dynamic and static indicators of investment project 2

Dynamic indicators	*Value*
Unit net present value	0.215
Internal rate of return	0.095
Payback period	8.5
Static data	
Efficiency of investment	1.4
Profitability of investment	0.16
Payback period	6.00

The third investment project is related to building a plastics recycling plants. The reason for launching this investment is diversification of activities in order to withstand the financial crisis better. Seven employees will be staffed on the project, and economic life of the project is 10 years.

The calculated data are given in Table 7.

Table 7 The value of dynamic and static indicators of investment project 3

Unit net present value	0.195
Internal rate of return	0.102
Payback period	7.5
Static data	
Efficiency of investment	1.32
Profitability of investment	0.17
Payback period	5.90

The problem of multicriteria decision-making is characterized by decision-making matrix that has n alternative and m criteria for comparison of alternatives. The matrix has dimensions *NxM*, and the elements *xij* represent the value of *j*-th attribute of the *i*-th alternative. Each row in the matrix corresponds to an alternative and each column to one criterion. You should then determine to what type of criteria belong the selected data. The data have a revenue character when it is desirable that the value of the decision matrix is as much as possible, on the contrary they have the character of expenditure for which it is desirable that the value of the decision matrix is as small as possible. All criteria except payback period have revenue character. For a concrete example decision matrix can be represented as follows:

$$O = \begin{bmatrix} 0{,}145 & 0{,}085 & 9{,}15 & 1{,}1 & 0{,}15 & 6{,}5 \\ 0{,}215 & 0{,}095 & 8{,}5 & 1{,}4 & 0{,}16 & 6{,}0 \\ 0{,}195 & 0{,}102 & 7{,}5 & 1{,}32 & 0{,}17 & 5{,}9 \end{bmatrix}$$

To make an investment decision it is necessary to define the weights of each criterion. Weights are numbers that are subjectively chosen and the sum of these numbers equals 1. Current weights are shown in Table 8:

Table 8 Weight coefficients

Dynamic indicators			Static data		
Unit net present value	Internal Rate of Return	Payback period	Efficiency of investment	Profitability of investment	Payback period
0.2	0.1	0.3	0.1	0.2	0.1

To solve this problem of investment decision – making the ELECTRE method was used.

Step 1: Calculating the normalized decision matrix

Based on the formula for normalization, normalized decision matrix elements are calculated.

$$N = \begin{bmatrix} 0,447 & 0,521 & 0,524 & 0,496 & 0,542 & 0,543 \\ 0,663 & 0,583 & 0,564 & 0,632 & 0,578 & 0,589 \\ 0,601 & 0,626 & 0,639 & 0,596 & 0,614 & 0,599 \end{bmatrix}$$

Step 2: Calculating the weighted normalized decision matrix

By multiplying the normalized matrix and weight of each criterion weighted normalized decision matrix is obtained.

$$TN = \begin{bmatrix} 0,0894 & 0,0521 & 0,1572 & 0,0496 & 0,1084 & 0,0543 \\ 0,1326 & 0,0583 & 0,1692 & 0,0632 & 0,1156 & 0,0589 \\ 0,1202 & 0,0626 & 0,1917 & 0,0596 & 0,1228 & 0,0599 \end{bmatrix}$$

Step 3: Determination of the set of agreement and disagreement

Formation of sets is conducted according to the following criteria:

$$S_{pr}=\{j \mid x_{pj} \geq x_{rj}\} \text{ and } NS_{pr}=\{j \mid x_{pj} < x_{rj}\}.$$

Comparison of actions a_1 and a_2

j=1	$x_{11}<x_{21}$	$S_{12}=\emptyset$, $NS_{12}=\{1, 2, 3, 4, 5, 6\}$
j=2	$x_{12}<x_{22}$	
j=3	$x_{13}<x_{23}$	
j=4	$x_{14}<x_{24}$	
j=5	$x_{15}<x_{25}$	
j=6	$x_{16}<x_{26}$	

Comparison of actions a_1 and a_3

j=1	$x_{11}<x_{31}$	$S_{13}=\emptyset$, $NS_{13}=\{1, 2, 3, 4, 5, 6\}$
j=2	$x_{12}<x_{32}$	
j=3	$x_{13}<x_{33}$	
j=4	$x_{14}<x_{34}$	
j=5	$x_{15}<x_{35}$	
j=6	$x_{16}<x_{36}$	

Comparison of actions a_2 and a_3

j=1	$x_{21}>x_{31}$	$S_{23}=\{1, 4\}$, $NS_{23}=\{2, 3, 5, 6\}$
j=2	$x_{22}<x_{32}$	
j=3	$x_{23}<x_{33}$	
j=4	$x_{24}>x_{34}$	
j=5	$x_{25}<x_{35}$	
j=6	$x_{26}<x_{36}$	

Comparison of actions a_2 and a_1

j=1	$x_{21}>x_{11}$	$S_{21}=\{1, 2, 3, 4, 5, 6\}$, $NS_{21}=\emptyset$
j=2	$x_{22}>x_{12}$	
j=3	$x_{23}>x_{13}$	
j=4	$x_{24}>x_{14}$	
j=5	$x_{25}>x_{15}$	
j=6	$x_{26}>x_{16}$	

Comparison of actions a_3 and a_1

j=1	$x_{31}>x_{11}$	$S_{31}=\{1, 2, 3, 4, 5, 6\}$, $NS_{31}=\emptyset$
j=2	$x_{32}>x_{12}$	
j=3	$x_{33}>x_{13}$	
j=4	$x_{34}>x_{14}$	
j=5	$x_{35}>x_{15}$	
j=6	$x_{36}>x_{16}$	

Comparison of actions a_3 and a_2

j=1	$x_{31}<x_{21}$	$S_{32}=\{2, 3, 5, 6\}$, $NS_{32}=\{1, 4\}$
j=2	$x_{32}>x_{22}$	
j=3	$x_{33}>x_{23}$	
j=4	$x_{34}<x_{24}$	
j=5	$x_{35}>x_{25}$	
j=6	$x_{36}>x_{26}$	

Step 4: Calculation of matrix of compliance
First, calculate the index of compliance:

$s_{12}=0$
$s_{13}=0$
$s_{23}=t_1+t_4=0,2+0,1=0,3$
$s_{21}=t_1+t_2+t_3+t_4+t_5+t_6=0,2+0,1+0,3+0,1+0,2+0,1=1$
$s_{31}= t_1+t_2+t_3+t_4+t_5+t_6=0,2+0,1+0,3+0,1+0,2+0,1=1$
$s_{32}= t_2+t_3+t_5+t_6=0,1+0,3+0,2+0,1=0,7$

$$S=\begin{bmatrix} - & 0 & 0 \\ 1 & - & 0,3 \\ 1 & 0,7 & - \end{bmatrix}$$

Step 5: Determination of the matrix of disagreement
It is necessary to calculate the index of inconsistency:

$$ns_{12}=\frac{max[0,0432;0,0062;0,012;0,0136;0,0072;0,0046]}{max[0,0432;0,0062;0,012;0,0136;0,0072;0,0046]}=\frac{0,0432}{0,0432}=1$$
$$ns_{13}=\frac{max[0,0308;0,0105;0,0345;0,01;0,0144;0,0056]}{max[0,0308;0,0105;0,0345;0,01;0,0144;0,0056]}=\frac{0,0345}{0,0345}=1$$
$$ns_{23}=\frac{max[0,0043;0,0255;0,0072;0,001]}{max[0,0124;0,0043;0,0255;0,0036;0,0072;0,001]}=\frac{0,0255}{0,0255}=1$$
$ns_{21}=0$
$ns_{31}=0$
$$ns_{32}=\frac{max[0,0124;0,0036]}{max[0,0124;0,0043;0,0255;0,0036;0,0072;0,001]}=\frac{0,0124}{0,0255}=0,4863$$

$$NS=\begin{bmatrix} - & 1 & 1 \\ 0 & - & 1 \\ 0 & 0,4863 & - \end{bmatrix}$$

Step 6: Determination of the matrix of consistent dominance (MSD)

First, the average index of agreement has to be calculated:

$$PIS=\frac{1+1+0,7+0,3}{3(3-1)}=0,5$$

Based on the criteria:

$$msd_{pr}=1, \text{ when } s_{pr}\geq PIS$$
$$msd_{pr}=0, \text{ when } s_{pr}<PIS$$

the matrix of consistent dominance is formed:

$$MSD=\begin{bmatrix} - & 0 & 0 \\ 1 & - & 0 \\ 1 & 1 & - \end{bmatrix}$$

Step 7: Determination of the matrix of incompatible domination (MNSD)

First, the average index of inconsistency has to be determined:

$$PINS=\frac{1+1+1+0,4863}{3(3-1)}=0,58105$$

Based on the criteria:

$$mnsd_{pr}=1, \text{ when } ns_{pr}\leq PINS$$
$$mnsd_{pr}=0, \text{ when } ns_{pr}>PINS$$

the matrix of incompatible domination is formed:

$$MNSD=\begin{bmatrix} - & 0 & 0 \\ 1 & - & 0 \\ 1 & 1 & - \end{bmatrix}$$

Step 8: Determination of the aggregate dominance matrix (MAD)

This matrix is formed by multiplying the matrix of consistent dominance and the matrix of incompatible domination.

$$MAD=\begin{bmatrix} - & 0 & 0 \\ 1 & - & 0 \\ 1 & 1 & - \end{bmatrix}\begin{bmatrix} - & 0 & 0 \\ 1 & - & 0 \\ 1 & 1 & - \end{bmatrix}=\begin{bmatrix} - & 0 & 0 \\ 0 & - & 0 \\ 1 & 0 & - \end{bmatrix}$$

Step 9: The elimination of less desirable actions

On the basis that the value mad_{31} = 1, it can be concluded that the action a_3 dominates the other actions (A_2 and A_1). Therefore, the third investment project should be implemented, ie, investment funds should be allocated to the construction of facilities for recycling plastic.

6. CONCLUSION

When making investment decisions, the question is not usually whether an investment alternative should be implemented, the problem is the choice between several versions of investment. The decision maker will choose the investment project that contributes best to the development goals of the company. This can be done on the basis of intuition, based on a previous knowledge of the projects or precise scientific methods can be used. With the increasing number of investment projects, the ability of decision makers to solve the problem using intuition is reduced and therefore the exact scientific methods must be applied. This paper presents the investment decision–making on the basis of exact methods, where the solution of the problem boils down to an economic analysis of investment projects, which includes the calculation of various indicators and their comparison with each other using multi–criteria analysis methods. By applying the ELECTRE method, the solution of a given investment problem is obtained, the dominant investment alternative is determined and the decision–maker may decide on its implementation.

REFERENCES

1. Baumol, W.J. (1959) Economic Theory and Operations Analysis, Prentice-Hall, Englewood Cliffs, New Jersey.
2. Bhaskar, K. (1979) A multiple objective approach to capital budgeting, Accounting and Business Research, Winter, pp. 25-46.
3. Bhaskar, K., McNamee, P. (1983) Multiple objectives in accounting and finance, Journal of Business Finance and Accounting 10 (4), pp. 595-621.
4. Brans, J.P., Mareschal, B., (1994) The PROMCALC and GAIA decision support system for multicriteria decision aid, Decision Support Systems 12, 297-310.
5. Brans, J.P., Vincke, Ph., (1985) A preference ranking organization method, Management Science 31 (6), 647-656.
6. Brans, J.P., Vincke, Ph., Mareschal, B., (1986) How to rank and how to select projects: The PROMETHEE method, *European Journal of Operational Research* 24, 228-238.
7. Charpentier, A., Jacquet-Lagrèze, E., (1976) La promotion de l'électricité dans l'entreprise et l'utilisation des méthodes multicritères, In H.Thiriez and S.Zionts, editors, Multiple Criteria Decision Making, Vol. 130 of Lecture Notes in Economics and Mathematical Systems, pp 364-377.
8. Cyert, R.M., March, J.G. (1963) A Behavioral Theory of the Firm, Prentice-Hall, En. Cliffs, New Jersey.
9. Čupić, M., Rao Tummala, V.M., Suknović, M., (2001) Odlučivanje: Formalni pristup, Beograd, Fakultet organizacionih nauka.
10. David, L., Duckstein, L., (1976) Multi-criterion ranking of alternative long-range water resources systems, Water Resources Bulletin 12(4):731-754.
11. Jacquet-Lagreze, E., Siskos, J., (1982) Assessing a set of additive utility functions for multicriteria decision making: The UTA method, European Journal of Operational Research 10, 151-164.
12. Jacquet-Lagreze, E., Siskos, J., (1983) Methodes de Decision Multicritere, Editions Hommes et Techniques, Paris.
13. Janković-Milić, V., Stanković, J., (2010) Bajesijanski pristup višekriterijumskoj analizi u poslovnom odlučivanju, Vrnjačka banja.
14. Lee, S.M., Chesser, D.L., (1980) Goal programming for portfolio selection, The Journal of Portfolio Management, Spring, 22-26.
15. Levy, H., Sarnat, M., (1995) Capital Investment & Financial Decisions, 5th Edition, Prentice Hall, Englewood Cliffs, NJ, p. 158.
16. Osborne, M.J., (2010) A resolution to the NPV–IRR debate, The Quarterly Review of Economics and Finance 50 (2010), 234–239.
17. Petrović, E., Denčić-Mihajlov, K., (2007) Poslovne finansije: Dugoročni aspekt finansijskih ulaganja, Ekonomski fakultet, Niš.
18. Roy, B., (1996) Multicriteria Methodology for Decision Aiding, Kluwer Academic Publishers, Dordrecht.
19. Roy, B., Bouyssou, D., (1993) Aide Multicritere a la Decision: Methodes et Cas, Economica, Paris.
20. Saaty, T.L., (1980) The Analytic Hierarchy Process, McGraw- Hill, New York.
21. Saaty, T.L., Rogers, P.C., Pell, R., (1980) Portfolio selection through hierarchies, *The Journal of Portfolio Management, Spring*, 16-21.
22. Simon, H.A., (1957) Models of Man, Wiley, New York.
23. Spronk, J., (1981) Interactive Multiple Goal Programming Application to Financial Planning, Martinus Nijhoff Publishing, Boston.
24. Williamson, O.E., (1964) The Economics of Discretionary Behavior: Managerial Objectives in a Theory of the Firm, Prentice-Hall, Englewood Cliffs, New Jersey.
25. Zopounidis, C., (1999) Multicriteria decision aid in financial management, European Journal of Operational Research 119, 404-415.

26. Zopounidis, C., Doumpos, M., (1999) A multicriteria decision aid methodology for sorting decision problems: The case of financial distress, Computational Economics 14(3), 197-218.
27. Zopounidis, C., Doumpos, M., (2002) Multicriteria Decision Aid Classification Methods, Kluwer Academic Publishers, Dordrecht.
28. Yard, S., (2000) Developments of the payback method, International Journal of Production Economics 67, 155-167.

PRIMENA VIŠEKRITERIJUMSKE ANALIZE U PROCENI INVESTICIONIH PROJEKATA

Rast i razvoj svakog ekonomskog subjekta nezamisliv je bez investicija i investicionih aktivnosti. U tom smislu, za realizaciju razvojnih ciljeva veoma važnu ulogu ima investiciono odlučivanje. Ekonomski ispravna odluka zasnovana je na primeni različitih metoda analize investicionih projekata i izbora najprihvatljivijeg. Kako veliki broj faktora utiče na donošenje odluke o izboru priroda ovog problema je višekriterijumska. Evaluacija investicionih projekata podrazumeva ocenu njihove finansijske i tržišne efikasnosti. U tu svrhu koriste se statički i dinamički modeli ocene projekata kao relevantni kriterijumi u višekriterijumskom modelu, a rangiranje projekata vrši se na osnovu metode višekriterijumske analize. U ovom radu metodom višekriterijumske analize izvršeno je rangiranje konkretnih investicionih projekata koje finansira Fond za razvoj Republike Srbije.

Ključne reči: *višekriterijumska analiza, metod ELECTRE, investiciono odlučivanje, investicioni projekti, ocena efikasnost investicionih projekata.*