

# APPLICATION OF VIKOR METHOD IN RANKING THE INVESTMENT PROJECTS

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**Abstract:** *Investments represent one of the most significant activities in an enterprise. Investing in capital implies the immediate expense for an enterprise with the expected future benefits. These benefits usually last for more than one year. The examples, of such investments are investments in possessions like equipment, buildings and land, as well as introduction of new products, new distribution system or new research and development programme. Enterprises and other project implementers usually face the issue of choosing between different projects which can have various effects in the future. Future success and profitability of an enterprise depend on long-term decisions which are made instantly. This paper presents the way of evaluating the investment projects and comparing the alternative projects based on the dynamic indicators of financial evaluation, by using the compromise ranking method, i.e. multi criteria analysis. It is necessary to find the best and most efficient project by using the Vikor method, as most suitable for the presented issue.*

**Keywords:** *decision-making, project comparison, Vikor method, multi criteria ranking, compromise solution*

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## 1. INTRODUCTION

Decision-makers often have a possibility to choose between multiple projects which, for the enterprise, represent alternatives with various future outcomes. Most often, due to the lack of financial means, it is impossible to realize everything foreseen by the initial idea, so a decision has to be made on what the priorities are, i.e. what must be realized, and what can be prolonged. Investment projects should be evaluated according to whether it ensures income demanded by the investors. It is essential to make the right decision in situations when the means are limited, and it is necessary for the project to have as great as possible future financial benefits or other benefits for the subject realizing it.

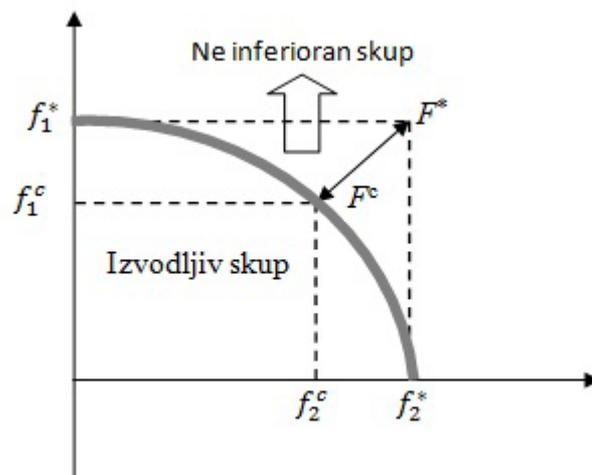
Multi criteria decision-making as modern scientific discipline has its broad application in all areas of human activities, as is also the case with issues of choosing between more investment projects. Any problem set in the business world is structured as problem of multi criteria optimization. If one business decision has no multiple alternatives, i.e. criteria according to which it is being observed, then there is no issue of selection.

Also in this model of investment decision-making there are several criteria for evaluation of every project, and there are several projects which represent alternatives. Each decision-maker gives different importance to certain criteria depending on the goals of investing. This paper firstly presents basic theoretical assumptions and the steps of conducting the VIKOR method, after which a specific example of ranking the projects by using this method is shown. Criteria, in this case, are dynamic indicators of financial evaluation of the projects.

## 2. VIKOR AS DECISION MAKING METHOD

VIKOR method is a method of multi-criteria analysis of decision-making for solving the issues where there are multiple conflicting criteria (Opricović, 1998). Compromise solution is viable solution which is close to the ideal goals, i.e. optimal solution. (Rahim Ramezaniyan, Kazemi, & Jafari, 2012). Idea of compromise solution was mentioned for the first time in papers of the author Yu (1973) and Zeleny (1982), and later in papers of Opricović and Tzeng (2002, 2003., 2004. and 2007.) (Alemi et al., 2013)

VIKOR (Multi-criteria optimization and compromise solution) was presented for the first time by Opricović (1998.) and Opricović and Tzeng (2002.) for finding the best possible solution of a certain problem through analysis of available alternatives (Dağ & Önder, 2013). In this method it is assumed that the decision maker is not biased towards one of the alternatives in decision-making process. The results obtained by this method are such that they make compromise between desires and possibilities, but also between various interests of decision makers.



**Picture 1.** Ideal and compromise solution

Compromise solution represents a compromise for mutually done favors between alternatives. It is based on determining the narrower collection of viable solutions which approach to the ideal point according to their values i.e. reference point in the space of criteria functions. (Puška, 2011). Furthermore, compromise means concordance based on the mutual concessions, as shown in the Picture 1:  $\Delta^+$  and  $\Delta^-$ . Under the assumption that each alternative is evaluated according to all criteria, ranking should be done by comparing the measures of closeness to the ideal solution. (Opricović, 2009) Here  $F^+$  is compromise solution, and  $F^*$  is ideal solution.

The criteria usually describe the maximization of profit and minimization of expenses. However, in practice, other dimensions can be evaluated like energy, services, influence on the environment etc. The criteria can be quantitative economic, quantitative technical and other quantitative criteria. Here we can have a problem of expressing the criteria functions in various measuring units, which makes comparison of alternatives more difficult. (Kovačić, 2004)

### 2.1. Application of VIKOR method

Application of VIKOR method is very simple because it contains the smaller number of steps for calculating the ranking order. Every method, including this one, has its advantages and disadvantages. The greatest disadvantage of the method is searching for the compromise ranking order, i.e. compromise between pessimistic and expected solution. By changing the weight of these solutions the ranking order is also changed, since it is the result of the solution. This disadvantage is characterized, by some authors, as an advantage of this method over the others. By changing the significance (weight) of pessimistic and expected solution, it is possible to determine in what way the influence of the weight coefficient influences the ranking order of the alternatives. By changing this significance it is possible to correct the initial weight coefficients and thus obtain the harmonized result which is a compromise of all criteria. Another deficiency is the usage of complex linear normalization in the formula for calculating  $d_{ij}$ , because usage of other normalizations is disabled. However, by correcting this can also be solved, so some other type of normalization can also be used. (Puška, 2011) Usage of the complex normalization is necessary in order for all the elements of the matrix, which usually have different metrics, to be obtained as dimensionless units (Mančev, 2013)

While using VIKOR method in literature the following signs are used (Mančev, 2013):

$A_i$  – alternative,  $i = 1, 2, \dots, m$ ;

$f_j$  – criterion,  $j = 1, 2, \dots, n$ ;

$f_{ij}$  – value of alternative for  $j$  criterion function;

$w_j$  – weight of  $j$  criterion function.

### 2.2. Steps in usage of Vikor method

There are several steps in application of Vikor method which can be presented in the following way:

1. Form the initial decision-making table.

2. Based on the initial decision-making table, the initial decision-making matrix is formed.

$$R = \begin{matrix} & \begin{matrix} f_1 & f_2 & f_3 & f_4 \\ w_1 & w_2 & w_3 & w_4 \end{matrix} \\ \begin{matrix} A_1 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} f_{11} & \cdots & f_{1n} \\ \vdots & \ddots & \vdots \\ f_{m1} & \cdots & f_{mn} \end{bmatrix} \end{matrix}$$

Every line in the matrix is adapted to one alternative, and each column to one criterion  $f_j$  ( $j=1, 2, 3, \dots, n$ ); values above the matrix represent criteria and their weight coefficient:

3. Determining the highest  $f_j^*$  and lowest  $f_j^-$  values of the given criterion (With criteria with demand for minimum, the best value is the lowest value, and the weakest value is the highest value)

4. Because of easier calculation units are introduced  $d_{ij}$  (necessary for calculation of the units  $S_i$  and  $R_i$ ):

$$d_{ij} = \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \quad (1)$$

5. Calculating the values of pessimistic solution and expected solution, i.e.:

$$S_i = \sum_{j=1}^n w_j \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} = \sum_{j=1}^n w_j d_{ij} \quad i = 1, 2, \dots, m \quad (2)$$

$$R_i = \max_j w_j d_{ij} \quad i = 1, 2, \dots, m \quad (3)$$

6. The decision-maker allocates the weight coefficients to those units, i.e. their weight is being determined  $v$ , and then the following units are determined:

$$S^* = \min_i S_i \quad R^* = \min_i R_i \quad (4)$$

$$S^- = \max_i S_i \quad R^- = \max_i R_i \quad (5)$$

7. Calculating the values for  $Q_i$ - compromise solution, as well as the values  $QS_i$  and  $QR_i$ , for every alternative, by which three independent ranking lists are being formed. These values are being calculated based on the following formulae:

$$QS_i = \frac{S_i - S^*}{S^- - S^*} \quad (6)$$

$$QR_i = \frac{R_i - R^*}{R^- - R^*} \quad (7)$$

$$Qi = \nu QS_i + (1-\nu) QR_i \quad (8)$$

Therefore  $\nu$  represents the weight of satisfying most criteria, and  $1-\nu$  is the weight of individual loss of opportunity;  $QS_i$  represents the measure of deviation which expresses the demand for maximum group benefit;  $QR_i$  represents the measure of deviation which expresses the demand for minimization of maximum distance between some alternative from the “ideal point”;  $Qi$  represents the establishing of compromise ranking list which unifies units  $QS_i$  and  $QR_i$ . (Mančev, 2013)

8. Ranking of the alternatives, i.e. sorting the alternatives according to the values of measures  $QR_i$ ,  $QS_i$  and  $Q_i$ . Alternative  $A_i$  is better than alternative  $A_k$  if  $Q_i < Q_k$ . (Puška, 2011)

To determine the compromise solution the alternatives should fulfill two conditions:

1. Acceptable (sufficient) advantage – Condition  $U_1$

First alternative  $A'$  on compromise list  $Q_i$  for  $\nu=0.5$  has sufficient advantage in relation to the next best ranked alternative  $A''$ , if:

$$Q(A'') - Q(A') \geq DQ, \quad (9)$$

where  $DQ$  is the threshold of “sufficient advantage” and is  $DQ = \min(0.25; \frac{1}{m})$ ,  $m$  is the number of alternatives, and 0.25 is the size of the threshold which limits it for the cases with small number of alternatives. (Mančev, 2013)

2. Acceptable stability in decision-making – Condition  $U_2$

Alternative  $A'$  also has to be ranked according to  $S_i$  and  $R_i$ . Firstly ranked alternative on the ranking list “sufficiently firm” keeps the first place if it satisfies at least one of the following conditions:

First-ranked on compromise ranking lists  $Q_i$  for  $\nu=0.25$  and  $\nu=0.75$ ;

First-ranked on the ranking list  $QS_i$ ;

First-ranked on the ranking list  $QR_i$ . (Kovačić, 2004)

If the first-ranked alternative does not fulfil at least one of the two conditions ( $U_1$ ) and ( $U_2$ ), then the compromise solution is determined in the following ways:

1. If the first-ranked alternative fulfills  $U_1$ , and does not fulfil  $U_2$ , a collection of compromise solutions is formed which includes first-ranked and second-ranked alternative;
2. If the first-ranked alternative fulfills  $U_2$ , and does not fulfil  $U_1$ , then a collection of compromise solutions includes first-ranked alternative and all alternatives from the compromise ranking list over which the first-ranked alternative has no “suf-

ficient advantage”.

3. If the first-ranked alternative does not fulfill  $U_1$  nor  $U_2$ , then it is not “sufficiently” better than the second ranked, then a collection of compromise solutions includes all alternatives. (Opricović, 2009)

### 3. APPLICATION OF VIKOR METHOD IN RANKING OF INVESTMENT PROJECTS

Choosing between more investment projects represents the part of the overall problem of managing investments. The problem of investments in an enterprise consists of determining the available investment projects which bring the greatest effects with limited financial means. Methods for multi-criteria analysis are usually used in this form of investment decision-making, and are more flexible than the strictly mathematical techniques of pure optimization.

This paper deals with the issue of selection of the best project from five offered alternatives, which are being graded by four criteria which are actually dynamic indicators of financial evaluation of projects through the period of project duration. In this decision-making process, we will use the method of multi-criteria optimization VIKOR, as most suitable one.

The following table shows the indicators of financial efficiency of the projects which are used as criteria for ranking of investment projects. These are the most important indicators of financial evaluation based on which a decision is made on the justification of project realization, so they can be used as criteria which will show which project brings greatest economic benefits in the future. During the calculation of indicators of financial evaluation the discount rate of 5% is used, and the foreseen incomes are the same in all years of project duration.

**Table 1.** Indicators of financial evaluation of the projects (criteria for project ranking)

Projects	Duration of the project	Return period	NPV	IRR	PI
Project 1	30	13.33333	305867.7	0.063005	1.152934
Project 2	25	12.71676	238252.4	0.070891	1.108297
Project 3	25	11.39241	426843.2	0.061038	1.237135
Project 4	25	12.90323	221473.7	0.079151	1.092281
Project 5	26	12.72727	271905.6	0.067346	1.129479

**Table 2.** Marks per criteria and their weight coefficients

Criterion	Mark	Weight coefficient
Return period	$f_1$	0.3
NPV	$f_2$	0.4

IRR	$f_3$	0.1
PI	$f_4$	0.2

**Table 3.** Initial decision table

Project $P_i$	Criteria with weights			
	$f_1$ $w_1=0,3$	$f_2$ $w_2=0,4$	$f_3$ $w_3=0,1$	$f_4$ $w_4=0,2$
$P_1$	13.33	305867.70	0.06	1.15
$P_2$	12.72	238252.40	0.07	1.11
$P_3$	11.39	426843.20	0.06	1.24
$P_4$	12.90	221473.70	0.08	1.09
$P_5$	12.73	271905.60	0.07	1.13

Based on initial decision table, the initial decision matrix is made  $R$ .

$$R = \begin{matrix} & f_1 & f_2 & f_3 & f_4 \\ & w_1=0.3 & w_2=0.4 & w_3=0.1 & w_4=0.2 \\ \begin{matrix} P_1 \\ P_2 \\ P_3 \\ P_4 \\ P_5 \end{matrix} & \left[ \begin{array}{cccc} 13.33 & 305867.70 & 0.06 & 1.15 \\ 12.72 & 238252.40 & 0.07 & 1.11 \\ 11.39 & 426843.20 & 0.06 & 1.24 \\ 12.90 & 221473.70 & 0.08 & 1.09 \\ 12.73 & 271905.60 & 0.07 & 1.13 \end{array} \right] \end{matrix}$$

In this matrix column it is necessary to determine the lowest and the highest value, shown in the table 4. One should have in mind that with criteria with demand for the minimum, the best is the minimum value, and the worst the highest value (here it is the first criterion  $f_1$  which refers to the period of *return of the means* – the sooner the invested means are returned, the better the investment).

**Table 4.** Best and weakest values of the projects per given criteria

	$f_1$	$f_2$	$f_3$	$f_4$
$f_1^*$	11.39	426843.2	0.08	1.24
$f_1^-$	13.33	221473.7	0.06	1.09

The following table gives the calculated values for  $d_{ij}$  and  $w_j d_{ij}$ , in order to calculate more easily the other values.

**Table 5.** Calculated values for  $d_{ij}$  and  $w_j d_{ij}$  for all projects per all criteria

Project	$d_{ij}$				$w_j d_{ij}$			
	$f_1$	$f_2$	$f_3$	$f_4$	$f_1$	$f_2$	$f_3$	$f_4$
$P_1$	1	0.5891	0.8914	0.4187	0.3	0.2356	0.0891	0.0837
$P_2$	0.6823	0.9183	0.4560	0.1106	0.2047	0.3673	0.0456	0.0221
$P_3$	0	0	1	1	0	0	0.1	0.2
$P_4$	0.7784	1	0	0	0.2336	0.4	0	0
$P_5$	0.6877	0.7544	0.6517	0.2568	0.2063	0.3018	0.0652	0.0514

Based on the calculated values for  $d_{ij}$  and  $w_j d_{ij}$  are calculated per formulae the following values  $S_i$  i  $R_i$ , which are often showed in the form of matrix. However, here they are shown per projects in order for them to be more clearly shown.

**Table 6.** Calculated values  $S_i$  and  $R_i$  for each project

Project	$S_i$	$R_i$
$P_1$	0.70851	0.3
$P_2$	0.639737	0.36732
$P_3$	0.3	0.2
$P_4$	0.63352	0.4
$P_5$	0.624627	0.301773

From the previous table with values for  $S_i$  and  $R_i$  we can read the values for the following units:

$$S^* = \min_i S_i = 0.3$$

$$R^* = \min_i R_i = 0.2$$

$$S^- = \max_i S_i = 0.70851$$

$$R^- = \max_i R_i = 0.4$$

These values are necessary for further calculation of matrices  $QS_i$ ,  $QR_i$  and  $Q_i$  ( $\nu=0.5$ ), which are obtained based on the formulae (6), (7), (8).

Due to the later ranking, i.e. check of the fulfillment of conditions  $U_1$  and  $U_2$  it is necessary to form the matrices  $Q_i$  ( $\nu=0.25$ ) and  $Q(\nu=0.75)$ . Due to the clearer overview all values are given in the following table, instead as individual matrices with values.

**Table 7.** Calculated values  $QS_i$ ,  $QR_i$ ,  $Q_i$  (for  $v=0.5$ ;  $v=0.25$ ;  $v=0.75$ ) for each subproject

Project	$QS_i$	$QR_i$	$Q_i(v=0.5)$	$Q_i(v=0.25)$	$Q_i(v=0.75)$
$P_1$	1	0.5	0.75	0.625	0.875
$P_2$	0.831649	0.8366	0.8341246	0.835362	0.832887
$P_3$	0	0	0	0	0
$P_4$	0.81643	1	0.9082152	0.954108	0.862323
$P_5$	0.794661	0.508865	0.651763	0.580314	0.723212

According to the obtained values for  $QS_i$ ,  $QR_i$  and  $Q_i$  three independent ranking lists can be formed for each project, which are shown in the following table (Table 8.).

**Table 8.** Ranking of all projects according to the criteria  $QS_i$ ,  $QR_i$  and  $Q_i(v=0.5)$ 

Project	$QS_i$	$QR_i$	$Q_i(v=0.5)$
$P_1$	5	2	3
$P_2$	4	4	4
$P_3$	1	1	1
$P_4$	3	5	5
$P_5$	2	3	2

Based on this table we can see the best ranked project  $P_3$ .

The check of fulfillment of condition  $U_1$ :

In case of  $v=0.5$  the following, i.e. second best ranked alternative after the project  $P_3$  is project  $P_5$ . It must be checked whether the following condition is valid:

$$Q_5 - Q_3 \geq \frac{1}{n-1}, \text{ i.e. } 0.65173 \geq \frac{1}{5-1} = \frac{1}{4} = 0.25$$

The first condition is fulfilled, which means that there is no need for including the following ranked alternative in the collection of compromise solutions. There is no need for checking of this condition for the lower ranked projects as well, because it certainly does not apply.

The check of fulfillment of condition  $U_2$ :

Project  $P_3$  is at the first position on the ranking lists  $QS_i$  and  $QR_i$ , as well as on ranking lists for  $Q_i$ , for values  $v=0.25$  and  $v=0.75$ , which shows the fulfillment of conditions  $U_2$  (it is necessary to have only one condition fulfilled, and in this case both are fulfilled).

Final and only solution, in this case, is the third alternative, i.e. project  $P_3$ , so the decision maker will choose third project as the best solution.

## 4 CONCLUSION

Multi-criteria decision making is the process with various changes in all areas of human activity. In every selection connected to the decision making there are several alternatives, as well as several criteria by which those alternatives are ranked. VIKOR method is one of the methods which solves this issue very successfully.

This paper shows in which way VIKOR method can be used in traditional evaluation of the investment projects by using the dynamic indicators, and in ranking those projects based on the indicators. Therefore, on the practical example of selection of investment projects, a scientific method of decision making is represented, which realizes the development goals of an enterprise, in the best possible way, by using the multi-criteria analysis.

Method showed the simplicity in its application in issues during selection of investment projects and as such it can be used in other decision making processes in an enterprise especially when it is necessary to determine the order of alternatives in that decision-making. Application of VIKOR method is very simple because it contains smaller number of steps for calculating of ranking order. Every method, as well as VIKOR, has its advantages and disadvantages, but the convenience and simplicity of usage, which this method has in the process of decision-making, are increasing its significance.

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