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# THE POSSIBILITY OF USING METHOD OF MULTI-CRITERIA OPTIMIZATION IN FINANCIAL ALLOCATION IN THE DEFENSE SYSTEM

**Abstract**

*The research performed in this paper refers to the model that would be used to analyze the effects of the implementation of Planning, Programming, Budgeting and Execution Process (PPBE) on the budget of the Republic of Serbia defence system. The aim of this model is to overcome certain shortcomings of budgeting of the Ministry of Defence by using multicriteria optimization methods during allocation of financial resourcestoprogrammes, projects and activities. The purpose of the model is to facilitate the decision- making process, solving a certain problem – in this case the problem of optimal allocation of financial resources approved by the budget of the Ministry of Defence, with the best possible effects.*

*It enablesstudy, analysis and evaluation of certain situations which would otherwise be difficult or impossible to investigate. In a specifically defined environment, while recognizing international experiences in implementation of PPBE, the model is actually a methodology for solving the abovementioned problem. It may be defined as a process for creating a model of an actual system and conducting experiments, which enables understanding of the system behavior and/or evaluation of different strategies for system functioning.*

***Key words**: allocation of financial resources, budgeting, PPBE, multicriteria optimization.*

**JEL Classification:** O21,022.

# MOGUĆNOSTI KORIŠĆENJA METODA VIŠEKRITERIJUMSKE OPTIMIZACIJE PRILIKOM RASPODELE FINANSIJSKIH SREDSTAVA U SISTEMU ODBRANE

**Apstrakt**

*Istraživanje sprovedeno u ovom radu odnosi se na model kako bio se izvršila analiza efekata primene principa PPBI na budžet sistema odbrane Republike Srbije. Cilj ove analize je da prevaziđe određene nedostatke formiranja budžeta Ministarstva odbrane, koristeći metode višekriterijumske optimizacije prilikom raspodele finansijskih sredstava na programe, projekte i aktivnosti. Svrha modela je da pomogne u procesu donošenja odluka kojima se određeni problem rešava*

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*– u ovom slučaju problem optimalne raspodele finansijskih sredstava odobrenih budžetom Ministarstva odbrane sa što boljim efektima.*

*Zahvaljujući njoj moguće je proučavati, analizirati i evaluirati određene situacije koje bi bilo teško ili se ne bi mogle ispitivati na drugi način. U konkretno definisanom okruženju, uz uvažavanje inostranih iskustava u primeni PPBI, model je zapravo metodologija za rešavanje navedenog problema. Ona se može definisati kao proces kreiranja modela realnog sistema i izvođenja eksperimenata pomoću njega, koji omogućavaju razumevanje ponašanja sistema i/ili evaluaciju različitih strategija za funkcionisanje sistema.*

***Ključne reči:*** *raspodela finansijskih sredstava, budžet, PPBI, višekriterijumska optimizacija*

## Introduction

Making a right decision for a certain problem, especially when financial resources are involved imposes great responsibility on the decision makers. If that problem is viewed within a defencesystem frameworka question which project to finance, that is, why not some other, arises? One of the ways to find an answer to this question is by implementing multicriteria optimization, which provides a range of representative methods for making a right decision. Analytic Hierarchy Process (AHP) is one of the best known and most frequently applied methods for multi-criteria decision making and therefore will be used in this paper for determination of relative weights of criteria and optimal solution to a problem, that is, determination of significance of a project to which resources are to be allocated in the budgeting process.

Implementation of multicriteria optimization during allocation of financial resources, approved by the budget, is the main objective of this paper. The primary contribution of the paper is its applicative aspect, that should result from an elaborated example. Multicriteria decision-making plays a key role in many real life problems. This is confirmed in practice, whether it be state authorities, company managers or any other occupation, since they all face a situation to select the best among a number of alternatives, on the basis of the existing criteria. This paper provides empirical analysis of multicriteria problem, that the defencesystem leaders encounter, and a recommendation for creating and implementing a model that would improve the very process of decision-making.

## The concept of planning, programing, budgeting and execution in the Republic of Serbia defence system

The process of planning, programing, budgeting and execution (PPBE) represents the basic tool for strategic management of resources in a defence system, that ensures efficient and rational distribution of resources and control of their expenditure. It's primary purpose is to support and provide responsible decision-making on distribution of resources intended for the defence system in order to meet the safety challenges and risks threatening the defence system.

The entire PPBE system consists of four phases.[2] Planning involves the initial phase of this process in which interests and goals of national security and defence are determined, and the connection between the possibilities for their realization in conditions of limited resources is established. This phase also includes determination of strategic responses to security challenges, priorities among strategic goals and activities that need to be carried out for the purpose of development and maintenance of abilities necessary for implementation of established policies and strategies.

Programing phase involves preparation of programme proposal, showing forces with adequate abilities necessary for realization of missions and goals which have been set in plans. This phase also includes programme proposal analysis in order to determine both to what extent the set goals may be achieved, as well as the effectiveness of resource usage in developing and sustaining the necessary abilities.

Budgeting phase of PPBE includes financial dimensioning of necessary resources on the basis of information obtained after programing. Budgeting is the process of preparation of financial plan and it involves calculation of human and material resources, expressed through economic classification accounts necessary for programme realization. Budgeting process comprises formulation-preparation of drafts and proposals, approval, execution and budget control.[3] Budgeting also includes harmonization with existing fiscal limitations and political decisions brought after the previous PPBE cycle. Programme budgeting represents a more transparent mechanism for monitoring budget expenses and expenditure, and allows more efficient planning of resources according to the priorities of the authorities and enables decision makers to understand the connection between the required/approved resources, strategies, programmes and results. Budget users and users of budget resources use the budgeting programme model to plan activities within their competence, with the task to achieve set strategic goals within a certain period of time.

Final phase in this process is execution, which implies realization of defined plans, programmes and budget, all with the aim to create defined abilities of the defence system.

By observing the PPBE process it may be concluded that the basic condition for realization of programmes resulting from the programming phase, is formation of financial base, that is, enforcement of the budgeting phase. Defence system budget is an important segment of the state budget and public finances in general, and as such attracts attention of the public. This budget should be based on actual needs, depending on the level of security situation and actual threats to the security of the state. However, according to the facts the total amount of this budget is limited, and depends primarily on the available financial resources of the state, that is,on the achieved GDP.[4]

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[2] Guidelines for medium-term planning and programming of the defence system, for the period from 2014 to 2019, pp. 2

[3] Milojević I., Mihajlović M., Cvijanović M., *Impact of organiyational failure of relevance consolidated budget*, Ekonomika poljoprivrede, Vol. LIX, N°1 (1-176), 2012, str. 63-71.

[4] Curčić N., Jovanović Z., Muhović A., *Using decision analisys when solving management problems*, Ekonomika, Niš, Vol. LIX, I-III, broj 1, 2013, str. 197-204

## The concept of Analytic hierarchy process (AHP) method

There are numerous methods for solving the model of multicriteria decision-making which can be categorized on the basis of several criteria, and the following currently stand out as the best:

- ELECTRE method;
- PROMETHEE method;
- AHP (Analytic Hierarchy Process) method;
- TOPSIS method, etc.

From the perspective of methodology, AHP is a multi-criteria technique that is based on breaking down a complex problem into hierarchy. The goal is at the top of hierarchy, while criteria, subcriteria and alternatives are to be found at lower levels. AHP holds all hierarchy parts connected, making it is easy to see how changing one criterion effects other criteria.

## Project selection model - alternative for allocation of financial resources in defence system

The basic challenge the Ministry of Defence faces, during distribution of the budget of the Republic of Serbia allocated for defence purposes, is how to make a right decision for optimal distribution of resources. By using an established hypothetical model, an attempt will be made to establish a conceptual and mathematical supposition with the help of analytic hierarchy process method (AHP), used to make a decision on the basis of numerous criteria and in multiple time periods, in order to help decision-makers in solving complex problems of decision-making.

The goal of the established model is to show how application of AHP method can help in project selection, that is selection of an alternative for achieving the goals of the Defence System with most favourablecommitment of approved financial resources. Bearing in mind the fact that the currently predominant model of distribution of approved financial resources of the Ministry of Defence, is based on experiences, this model should point out possibilities for scientifically based distribution of financial resources,by using multicriteria decision- making method.

## Terms of decision-making problem

The problem observed in this model, selection of an alternative of a project to be financed for the purpose of achieving set goals of defence system, includes several terms that need to be defined. Based on the definition of decision-making, namely, that it represents selection of one alternative out of a set of possible alternatives, while the set has to include at least two alternatives, it may be concluded that the implementation of decision-making theory is possible in this procedure.

A criterion as a term refers to attributes related to alternatives among which selection is made. They may be divided into qualitative and quantitative criteria

depending on the degree of measurability. Quantitative criteria are the ones that may be measured precisely and expressed in different units of measurement. Qualitative criteria cannot be numerically expressed. They are classified in two sub-groups: attributes whose values cannot be measured precisely, but they can still be ranked by "intensity" and attributes based on which no quantitative comparison of alternatives can be carried out. There are numerous ways of expressing qualitative criteria values through quantitative.[5] Most frequently used scales are: ordinal scale, interval scale and ratio scale. Another criterion, also used for division of decision making criteria is correlation direction of their values and benefits they provide. According to direction of agreement, the following classification is made:[6]

- Revenue criteria
- Expenditure criteria
- Nonmonotonic criteria.

Initially, the criteria have to be precisely defined, and in the presented model those are: total amount of financial resources necessary for realization of the alternative[7] and other 5 criteria are short- term priorities of the defence system, determined on the basis of medium-term and short-termgoals and medium-term and short-term priorities of the defence system.[8] The model will also consider 6 criteria altogether, in relation to which alternatives, i.e. projects will be observed.

Alternatives are solutions which appear as a choice and among which a project,meeting the set criteria best, is selected. In the decision making process, a minimum of three alternatives will be assumed. The alternatives represent projects which will be programmed and budgeted in advance, providing information on how much a certain alternative "costs". They possess characteristics which correspond to the predefined criteria and among them an alternative with the highest value of priorities will be determined in the model.

## Implementation of AHP method for multi-criteria optimization of project selection

Assumption in this problem is to perform distribution of financial resources among several projects in the defence system, among four potential solutions – alternatives. The model will be presented in several steps through which weighting coefficients of criteria will be determined, defining their relative value in relation to the set goal (criteria) and performing project ranking.

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[5] Borović S, Milić M., *Zbirka zadataka iz odabranih oblasti operacionalnih istraživanja*, Military Academy, Belgrade, 2001, pp. 172.

[6] Pavlicic, D., (2010) *Teorija odlučivanja,* Faculty of Economics, Belgrade, pp. 176.

[7] Assumption that financial resources are highly significant for alternatives will be realized through high significance of this criterion and its quantification in Saaty's scale.

[8] Medium-term and short-term goals and medium-.term and short-term priorities of defence system are given and explained in detail in Guidelines for medium-term planning and programming of defence system.

**1. step:**

Define the criteria at the beginning, draft the decision making matrix and determine relative value of the criteria for selection of the best project alternative. Each of those alternatives has to meet certain criteria that were met in previously performed programming and budgeting.

The following criteria will be used as a basis for evaluation of the alternatives in this model:

**$C_1$ –** Total amount of financial resources necessary for realization of the alternative is one of the most important criteria, which represents total financial resources necessary for realization of that alternative, and which are distributed to accounts of economic classification.

Other criteria represent significance of certain project alternatives for realization of the defined short-term defence system priorities:

**$C_2$ –** Realization of activities, that is missions and tasks, in accordance with the law and other regulations.

**$C_3$ –** Supply and maintenance of armament and military equipment.

**$C_4$** – Achieving planned level of interoperability and abilities of declared units of the Serbian Armed Forces for their deployment in international operations and activities of the Partnership for Peace.

**$C_5$**–Investment maintenance of facilities.

**$C_6$** – Improvement of Ministry Of Defence and Serbian Armed Forces member's standard.

A decision making matrix is then formed with input data, and in this particular model it would have the following form:

Table No. 1: Input data

| Criteria / Solution | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| Alternative 1 | 720,000 | Completely realized | Completely realized | Realized | Realized | Realized |
| Alternative 2 | 790,000 | Completely realized | Realized | Realized | Realized | Completely realized |
| Alternative 3 | 885,000 | Completely realized | Realized | Realized | Completely realized | Realized |
| Alternative 4 | 915,000 | Completely realized | Realized | Completely realized | Completely realized | Realized |

**2. step:**

By quantifying the previous matrix and using Saaty's nine point scale for assigning weights, the following matrix is obtained:

Table No. 2: Quantified input data

| Criteria / Solution | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| Alternative 1 | 720,000 | 9 | 9 | 5 | 5 | 7 |
| Alternative 2 | 790,000 | 9 | 7 | 6 | 5 | 9 |
| Alternative 3 | 885,000 | 9 | 5 | 8 | 9 | 6 |
| Alternative 4 | 915,000 | 9 | 6 | 9 | 7 | 5 |

**3. step:**

At the beginning of problem processing, criteria relative weights should be determined, i.e. criteria significance. The following is the matrix of criteria comparison in relation to a goal:

Table No.3: Assessment of criteria relative weights

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| $C_1$ | 1 | 7 | 6 | 7 | 8 | 9 |
| $C_2$ | (7) | 1 | 5 | 7 | 6 | 5 |
| $C_3$ | (6) | (5) | 1 | 4 | 2 | 6 |
| $C_4$ | (7) | (7) | (4) | 1 | 2 | 5 |
| $C_5$ | (8) | (6) | (2) | (2) | 1 | 7 |
| $C_6$ | (9) | (5) | (6) | (5) | (7) | 1 |

Table No. 4: Determination of criteria relative weights

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| $C_1$ | 1 | 7 | 6 | 7 | 8 | 9 |
| $C_2$ | 0.143 | 1 | 5 | 7 | 6 | 5 |
| $C_3$ | 0.167 | 0.200 | 1 | 4 | 2 | 6 |
| $C_4$ | 0.143 | 0.143 | 0.250 | 1 | 2 | 5 |
| $C_5$ | 0.125 | 0.167 | 0.500 | 0.500 | 1 | 7 |
| $C_6$ | 0.111 | 0.200 | 0.167 | 0.200 | 0.143 | 1 |
| $\sum$ | 1.688 | 8.710 | 12.917 | 19.700 | 19.143 | 33 |

**4. step:**

The next step is to calculate eigenvector of corresponding matrix eigenvalues. There is a simple method for calculation of matrix eigenvalues. First, summarize all its elements in each column, and then divide each of the matrix elements by the sum obtained for the column that element is in.

Table No. 5: Calculation of eigenvector of corresponding values

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $\sum$ | W ($\sum$/6) |
|---|---|---|---|---|---|---|---|---|
| $C_1$ | 0.592 | 0.804 | 0.465 | 0.355 | 0.418 | 0.273 | 2.906 | 0.484 |
| $C_2$ | 0.085 | 0.115 | 0.387 | 0.355 | 0.313 | 0.152 | 1.407 | 0.234 |
| $C_3$ | 0.099 | 0.023 | 0.077 | 0.203 | 0.104 | 0.182 | 0.688 | 0.115 |
| $C_4$ | 0.085 | 0.016 | 0.019 | 0.051 | 0.104 | 0.152 | 0.427 | 0.071 |
| $C_5$ | 0.074 | 0.019 | 0.039 | 0.025 | 0.052 | 0.212 | 0.422 | 0.070 |
| $C_6$ | 0.066 | 0.023 | 0.013 | 0.010 | 0.007 | 0.030 | 0.150 | 0.025 |
| Check sum | 1 | 1 | 1 | 1 | 1 | 1 | 6 | 1 |

Criteria weight values are calculated in this way, on the basis of calculated eigenvalue vector. Each criterion is given an adequate weighting coefficient, defining its relative value in relation to the previously defined goal.

**5. step:**

Based on the data provided by evaluation of criteria relative weights, the same procedure should be used for reviewing available alternatives, i.e. projects. Saaty's scale is used again for comparison of the alternatives. After the tables showing pairwise comparison of weights for each alternative have been created, calculation of eigenvector is performed. That is presented in the following tables:

Table No. 6: Calculation of eigenvector of correspondingeigenvalues (Total amount of financial resources necessary for realization of alternative)

| | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 | ∑ | W (∑/4) |
|---|---|---|---|---|---|---|
| Alternative 1 | 1 | 2 | 3 | 4 | 1.745 | 0.436 |
| Alternative 2 | (2) | 1 | 2 | (2) | 0.794 | 0.199 |
| Alternative 3 | (3) | (2) | 1 | 4 | 0.832 | 0.208 |
| Alternative 4 | (4) | 2 | (4) | 1 | 0.629 | 0.157 |

Table No. 7: Calculation of eigenvector of correspondingeigenvalues (Realization of activities, that is missions and tasks)

| | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 | ∑ | W (∑/4) |
|---|---|---|---|---|---|---|
| Alternative 1 | 1 | 4 | 2 | 4 | 1.670 | 0.418 |
| Alternative 2 | (4) | 1 | 3 | (4) | 0.738 | 0.185 |
| Alternative 3 | (2) | (3) | 1 | 4 | 0.867 | 0.217 |
| Alternative 4 | (4) | 4 | (4) | 1 | 0.699 | 0.175 |

Table No. 8: Calculation of eigenvector of corresponding eigenvalues (Supply and maintenance of armament and military equipment )

| | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 | ∑ | W (∑/4) |
|---|---|---|---|---|---|---|
| Alternative 1 | 1 | 3 | 2 | (4) | 0.959 | 0.240 |
| Alternative 2 | (3) | 1 | 2 | (4) | 0.610 | 0.153 |
| Alternative 3 | (2) | (2) | 1 | 2 | 0.898 | 0.225 |
| Alternative 4 | 4 | 4 | (2) | 1 | 1.533 | 0.383 |

Table No. 9: Calculation of eigenvector of corresponding eigenvalues (Ability to perform multinational operations)

| | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 | ∑ | W (∑/4) |
|---|---|---|---|---|---|---|
| Alternative 1 | 1 | (4) | 5 | (4) | 0.789 | 0.197 |
| Alternative 2 | 4 | 1 | 2 | 3 | 1.177 | 0.294 |
| Alternative 3 | (5) | (2) | 1 | 5 | 0.771 | 0.193 |
| Alternative 4 | 4 | 4 | (5) | 1 | 1.263 | 0.316 |

Table No. 10:Calculation of eigenvector of corresponding eigenvalues (Investment maintenance of facilities)

| | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 | ∑ | W (∑/4) |
|---|---|---|---|---|---|---|
| Alternative 1 | 1 | 5 | 2 | (4) | 1.161 | 0.290 |
| Alternative 2 | (5) | 1 | 3 | 5 | 1.236 | 0.309 |
| Alternative 3 | (2) | (3) | 1 | (5) | 0.261 | 0.065 |
| Alternative 4 | 0 | (5) | 5 | 1.000 | 1.342 | 0.336 |

Table No. 11: Calculation of eigenvector of corresponding eigenvalues (Improvement of Ministry OfDefence and Serbian Armed Forces member's standard)

| | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 | ∑ | W (∑/4) |
|---|---|---|---|---|---|---|
| Alternative 1 | 1 | 2 | 2 | 3 | 1.545 | 0.386 |
| Alternative 2 | (2) | 1 | 4 | (4) | 0.742 | 0.186 |
| Alternative 3 | (2) | (4) | 1 | (5) | 0.377 | 0.094 |
| Alternative 4 | (2) | 4 | 5 | 1 | 1.336 | 0.334 |

**6. step:**

Final step is determination of problem solution, that is, selection of one of four alternatives or selection of a project. After the assessment of the alternatives relative weights has been performed in relation to each criterion individually, the most favourable alternative is selected in accordance with predefined criteria. Project selection is carried out on the basis of the obtained alternative eigenvectors and previously obtained criteria eigenvectors. Overall priorities of the alternatives are obtained by multiplying the weight of each alternative, within observed criterion, one after the other, and finally adding up the results.

TableNo. 12: Determination of the most favourable alternative – project

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | Overall priorities of alternatives |
|---|---|---|---|---|---|---|---|
| | 0.484 | 0.234 | 0.115 | 0.071 | 0.070 | 0.025 | |
| Alternative 1 | 0.436 | 0.418 | 0.240 | 0.267 | 0.290 | 0.386 | 0.385 |
| Alternative 2 | 0.199 | 0.185 | 0.153 | 0.246 | 0.309 | 0.186 | 0.201 |
| Alternative 3 | 0.208 | 0.217 | 0.225 | 0.146 | 0.065 | 0.094 | 0.195 |
| Alternative 4 | 0.157 | 0.175 | 0.383 | 0.341 | 0.336 | 0.334 | 0.217 |

Table 12 shows that after implementation of AHP method, for a given model, order of alternatives – projects is as follows: Alternative 1 – 38,50%, Alternative 2 – 20,10%, Alternative 3 – 19,50% and Alternative 4 – 21,70%. The obtained results indicate that in respect of priority level, Alternative 1 is in the first and Alternative 3 in the second place, and that selection of Alternative – project 1 would be the best decision. The ranking should affect allocation of available resources to those projects (human, material, infrastructure and time), including financial means, in the given order.

## Conclusion

By implementing modern methods of multicriteria decision-making and adequate software, an optimal solution for distribution of financial resources in a defence system may be reached in a scientifically reliable way.

The paper presents implementation of Analytic Hierarchy Process (AHP) within the Ministry of Defence and for the purpose of planning and selection of projects to which financial resources will be allocated. The problem is presented as a two level hierarchy, at the top of which is the goal – selection of an optimal alternative – project. At the second hierarchy level are six criteria. Logarithm method of least squares has been used to determine the weighting coefficients of criteria. Evaluation of alternatives has identified one alternative as the best project, which best meets the set criteria, with previously programmed and budgeted financial resources.

On a hypothetical example, by investigating the possibilities of implementation of AHP method in the decision making process the objective of which is selection of particular projects of the Ministry of Defence, which will be financed and to which financial resources will be allocated,from the budget of the Republic of Serbia, its practical applicability has been determined. Benefits of implementation of this method arein simple and fast decision-making, but primarily in the ability to reasonably justify acceptability of an offer at any given moment.

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