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Selection of the Optimal Maintenance Organization for Specific Purpose Devices

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Abstract: This paper is a result of a broader study, oriented to optimization of maintenance process for special purpose devices and presents the selection of optimal maintenance variant for selected specific purposes device, using the method of analytic hierarchy process, with assumed model of device usage. This paper formalizes the decision process, decision-makers subjectivism boils down to an acceptable level, impruves optimization approach for solving the problems in hierarchical systems, and encourages training in the improvement of decision makers in solving problems of multi character.

Keywords: Multi-criteria analysis, the method of analytic hierarchy process, organization of maintenance

1 Introduction

Application of modern logistic concepts requires that for each technical device that is inserted into the Serbian Army is develop: the concept of maintenance, maintenance organization and maintenance technology. Decisions are maded by respecting the characteristics and properties of the resources, technical and tactical demands of the holder, the designer and the device user. All the factors that should be taken into consideration can be divided into several groups: tactical, technical and logistics factors. One of the major problems in the logistical support in the Army of Serbia is the development and selection of the adequate maintenance process for special purposes devices [1, 2]. Observing the problem from the point of decision-making, can be seen that this is a multi-criteria problem. Good decisions on the selection of the appropriate maintenance can be taken only if the decision-making process is formalized and implemented based on scientific method, with consideration of

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several variants of the maintenance and multiple criteria of different complexity and different levels of significance.

Knowledge from practice shows that the decisions on the selection of appropriate maintenance organization are made with a lot of subjectivity, intuitive and experience, without the use of available modern methods, techniques, software and equipment.

In order to increase the objectivity of the decision-maker in process of choosing the optimal organization of maintenance, this work presents the application of the method of analytic hierarchy process and the use of „*Expert Choice*" software for optimal variant selection of the special purpose devices maintenance. In developing and defining the variants of maintenance are taken into account all elements of the system (resources, personnel, equipment maintenance and diagnostics, space and facilities), maintenance and their characteristics, maintenance procedures, maintenance methods, methods of repair and maintenance of well-known organizational forms.

2 AHP Method

The method of analytic hierarchy process (AHP) has developed by Thomas Saaty. This method is a tool that assists decision makers in solving complex multicriteria decision problems. Method of the AHP is based on a hierarchical decomposition the complex problems in a real system. The aim is at the top of the hierarchy, while the criteria, sub-criteria and alternatives are at lower levels. Application of the method proceeds in four phases:

- structuring the problems,
- collecting the data,
- evaluation of relevant weight and
- finding the solutions.

Structuring the problems consists of a problem decomposition into a series of hierarchies, defining objectives, criteria, sub-criteria and alternatives.

With collecting the data and their measurement begins the second phase of the AHP method. The decision maker assigns a relative evaluation criteria by comparing them in pairs of one hierarchical level and so for all levels of the entire hierarchy. For this purpose it is used nine-point scale [3]. Upon completion of the second phase, is obtained matrix of comparing the respective couples, or matrix of estimation criteria.

Evaluation of relevant weight is the phase in which the matrix of pairs comparisons ”translates” into the problem of determining eigenvalues and normalized in order to obtain their own unique vector weight for all criteria.

Finding the solutions is the last phase of the AHP method, and she involves finding the composite normalized vectors. After determination of the sequence vector for model ordering activity criteria, for this criteria starts the process of determination for order of importance model activity. The overall synthesis of the problem is performed in the following manner: involvement of each alternative is multiplied by the weight of the monitored criteria, and then these values are summed separately for each alternative. The resulting information is the weight of the observed model alternative. By comparing the weight of each alternatives, we determine their order in the model. AHP method has the ability to identify the consistency of decision-makers in the process of comparing elements from hierarchy. Since the comparison of alternatives is based on a subjective assessment from decision maker, it is necessary its constant monitoring in order to ensure the required accuracy [4, 5]. AHP method enables monitoring of consistency in such a way that is by using consistent index, calculate the ratio of consistency. If for matrix of comparisons is relationship between consistency $C.R. \leq 0.10$, evaluation of relevant significance criteria are counted as **acceptable**.

3 Solving the Problems of Optimal Device Maintenance Organization using the Software "Expert Choice"

The special purpose device is used within the radio-relay system of the Army. Variants of system maintenance are assumed according to technological maintenance programs that include the necessary technological operations and should be implemented in each of the proposed levels of maintenance (**Table 1**).

Table 1

Assumed variants maintenance organization with technological tasks.

Maintenance variants ----------→ **Maintenance levels with a technological tasks**	**I**	**II**	**III**	**IV**
I level of maintenance – technical inspection which is realized by II level of maintenance units	**X**		**X**	
I level of maintenance – basic maintenance and technical inspection which is realized by immediate device users		**X**		**X**
II level of maintenance – corrective maintenance at the module level, which is realized by II level of maintenance units	**X**	**X**		
II level of maintenance – corrective maintenance at the module level, which is realized by II level of maintenance units with a mobile workshop which contains equipment for level II maintenance and spare modules			**X**	**X**
III level of maintenance – corrective maintenance at the components level, which is realized by III level of maintenance units	**X**	**X**	**X**	**X**

Assumed technology programs creates conditions that presume hierarchical organization of maintenance at three levels, in terms of technology, clearly separated powers, responsibilities and duties of each level of maintenance [6, 7]. The objective function is defined *by selecting the optimal variant* of the maintenance special purposes devices.

The decision maker is in a position to choose between 4 different versions of the maintenance of appropriate technological applications which are shown in **Table 1**.

Selection is based on 7 criteria that can be seen in Fig. 1. Structured problem of choosing the optimal maintenance organization is represented in Fig. 1.

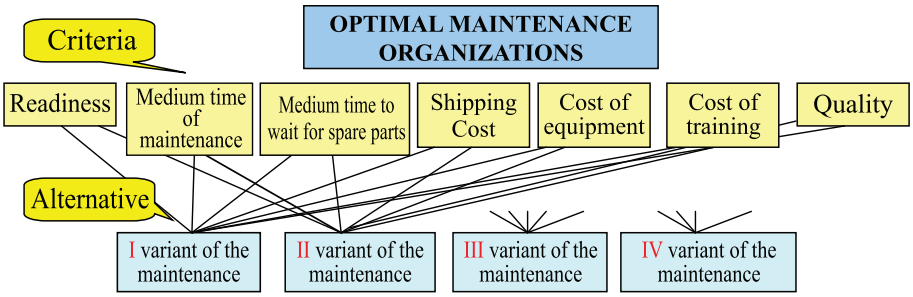

Fig. 1 – *The structure of the optimal choice problem for special purpose devices maintenance.*

In further studies of optimal maintenance organization by the method of AHP, we used the results obtained by using the software solutions "Expert Choice" [8]. Fig. 2 shows the ranking criteria defined in the model. From the picture you can see that the criteria "Readiness" and "Quality" have the highest values of their own vector. Consistency coefficient is $C.R. = 0.04 < 0.10$.

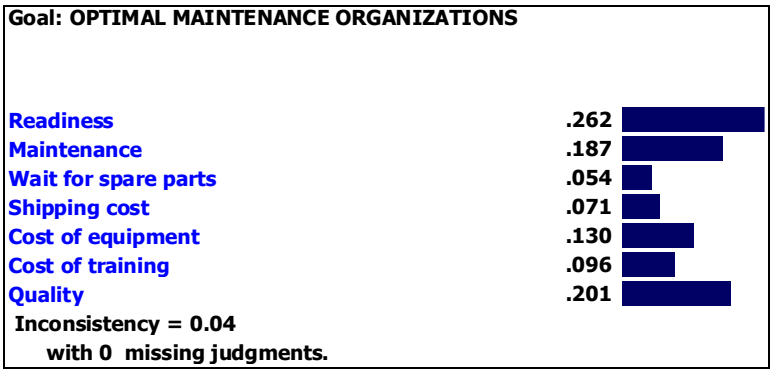

Fig. 2 – *Displaying important criterion in the model.*

In the same way are determined the eigenvectors of alternatives in relation to each criterion individually Fig. 3 shows comparison of alternatives weights of alternatives and presented order of alternatives in relation to criterion *K1* (readiness).

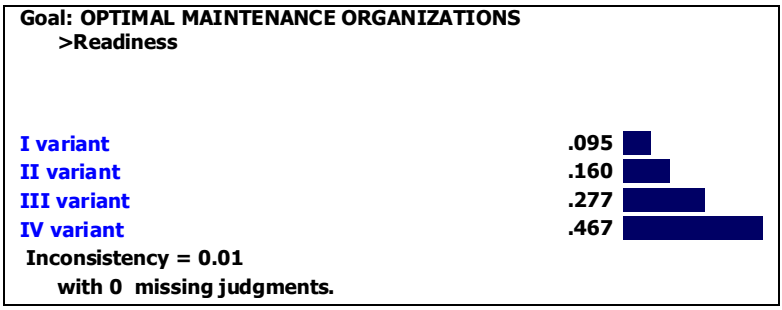

Fig. 3 – *Importance of alternatives in relation to criterion K1 (readiness).*

By using a software application "Expert Choice" were calculated eigenvectors alternatives (variants maintenance) in relation to other 6, and the criteria are shown in the following figures.

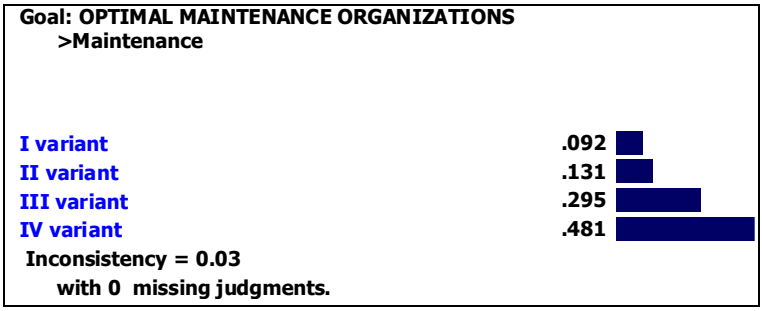

Fig. 4 – *Importance of alternatives with respect to criterion K2 (mean time of maintenance).*

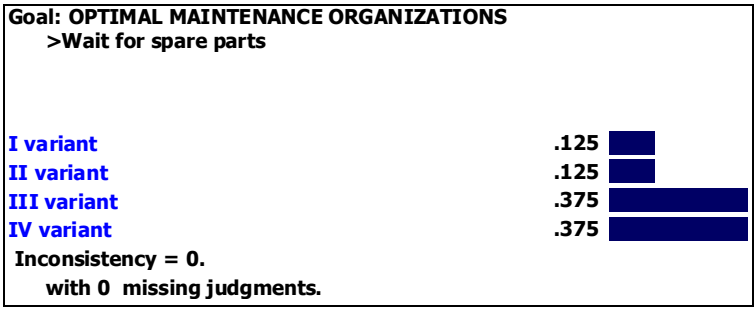

Fig. 5 – *The importance of alternatives to criterion K3 (mean waiting time for spare parts).*

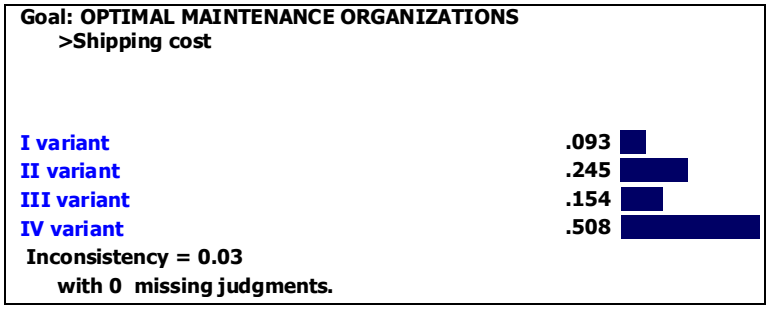

Fig. 6 – *The importance of of alternatives against the criteria K4 (transport costs due to maintenance of the devices).*

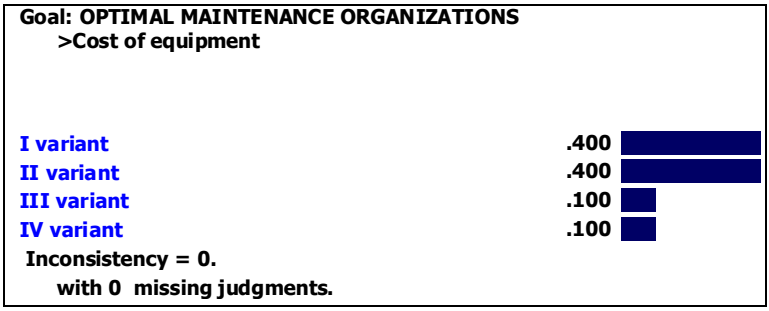

Fig. 7 – *The importance of of alternatives against the criteria K5 (equipment costs).*

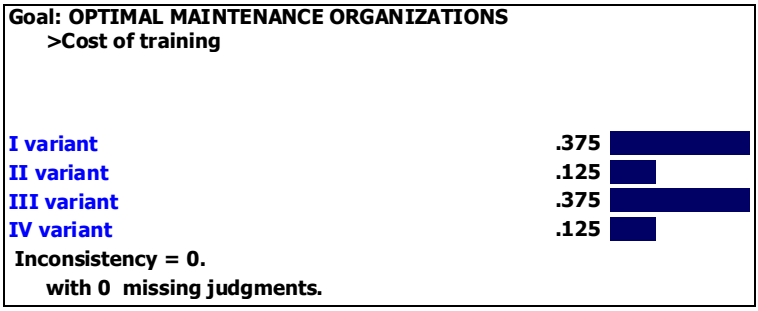

Fig. 8 – *The importance of of alternatives against the criteria K6 (training costs).*

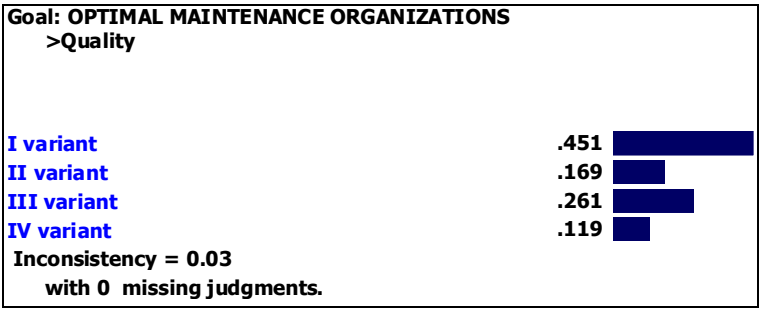

Fig. 9 – *The importance of of alternatives against the criteria K7 (quality).*

A comprehensive synthesis of *optimal choice problem for the special purposes devices* maintenance is obtained by adding the products of its own vector of each alternative, and participation (weight) within the observed criteria. **Table 2** below presents final table of the obtained results, and these results are shown graphically in Fig. 13.

Maintenance of devices for special purposes, organized by the presumed IV variants of maintenance organization is the optimal choice for the defined criteria, which directly attaches importance to the criterion of readiness and indirectly to maintenance costs (Fig. 11). Other presumed variants have worse performance in relation to these criteria

Table 2

The final table of the results (L – the criteria weight ratio).

Alternative	Total Rang	Readiness (L: .236)	Maintenance (L: .193)	Waiting for spare parts (L: 055)	Transport (L: .082)	Equipment (L: .145)	Training (L: .093)	Quality (L: .196)
I variant	0.236	0.204	0.192	0.333	0.182	1	1	1
II variant	0.193	0.343	0.272	0.333	0.482	1	0.333	0.374
III variant	0.256	0.593	0.614	1	0.304	0.25	1	0.578
IV variant	0.315	1	1	1	1	0.25	0.333	0.264

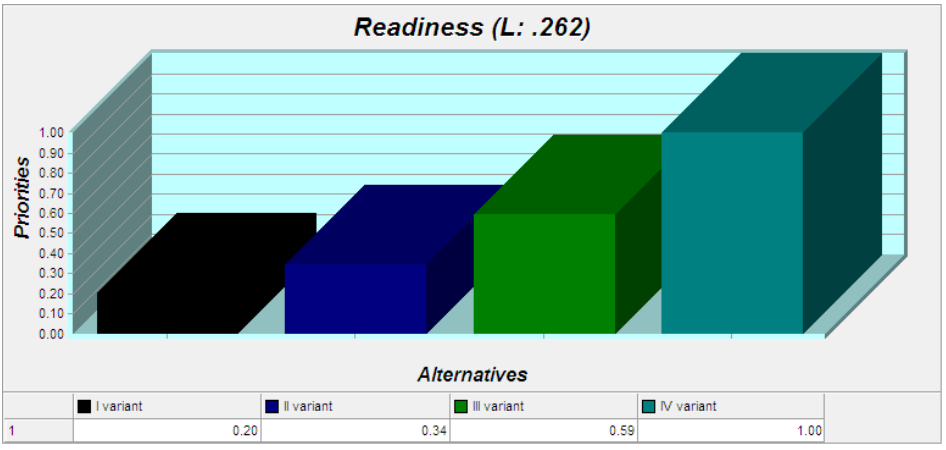

Fig. 11 – *Comparison of variants in relation to dominant maintenance readiness criteria.*

Suppose that the decision maker have to give the dominant importance of the criteria of "quality" in relation to a criterion of readiness and other criteria (Fig. 12). In this case, by increasing criteria of quality for 15% **I variant** of maintenance of special purpose devices becomes the optimal choice, until II i III variant of maintenance organization remains unchanged, and rank IV variants of the maintenance decreases.

Also, **I variant** of maintenance organization has the highest value when ranking is the dominant criteria for selecting the initial investment in equipment and training of employees.

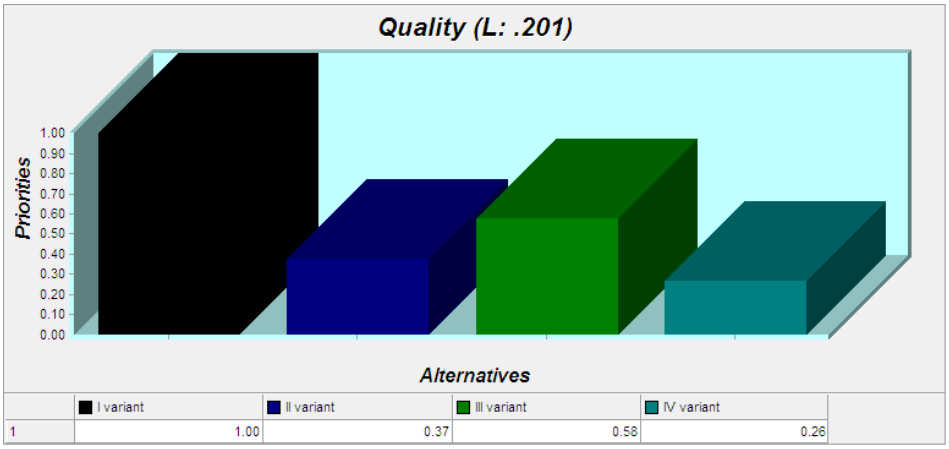

Fig. 12 – *Comparison of variants in relation to dominant maintenance quality criteria.*

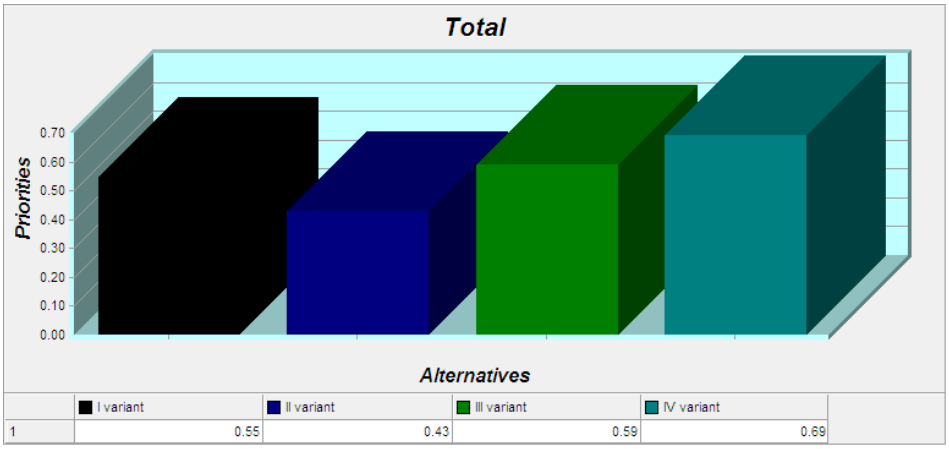

Fig. 13 – *Final Ranking of presumed maintenance variants.*

From the aspect of the transporting cost, it is preferable to implement **IV variant** maintenance as optimal choice of the maintenance organization.

Fig. 13 shows ranking of superiors maintenance variants, and final rank, and Fig. 14 shows the final solution for the problem of optimal supervisor of maintenance of special purposes devices, for the considered criteria and alternatives.

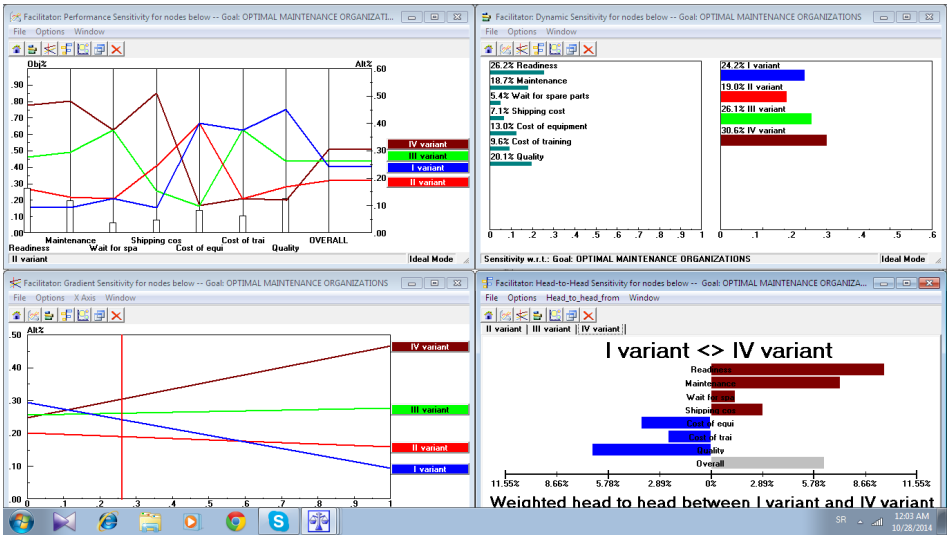

Fig. 14 – *View of the final decision choice of optimal maintenance organization in different graphs sensitivity.*

4 Conclusion

In solving the problem of optimal maintenance organization for special purposes devices, in order to increase the objectivity of the decision makers and to optimize decision-making process, we applied the method of analytic hierarchy process. In addition to defining problems, criteria and alternatives of the maintenance organization, is described the process of application methods, and the problem is solved using the software Expert Choice. It can be concluded that for a given problem, directly prefere two criteria: the quality and readiness of the indirect costs of transportation to maintain the product. Criteria for readiness and quality are mutually opposed, so that although the lead IV variant for the maintenance organization, if the decision maker decides that the quality has a dominant importance, the solution will also be a **I variant** of maintenance for special purposes devices. The used software package is a very powerful tool for decision makers which well knows the concept and logic multi-criteria decision making, usage of the considered devices and realistic system

maintenance. Used tool allows also improving the training of decision-makers in real logistical and other organizational systems in solving problems of multi character (most in the environment). The tool provides a number decision maker analysis: a sensitivity analysis, the analysis of reaching the goal and what if analysis, in accordance with their preferences and aversions.

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