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# APPLICATION OF DIFFERENT QUANTITATIVE TECHNIQUES TO INVENTORY CLASSIFICATION

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Subject review

In this paper, through example, a comparison between the traditional ABC inventory classification and advanced multiple criteria inventory classification method has been given. Inventory control or management, which is one of the important techniques of operational research field, plays an important role in the company management. Application of different inventory control methods and models has a great influence on improving the company competitiveness. The traditional ABC method of inventory classification is based only on one criterion. This criterion, very often, is not the most important one, so different multiple criteria decision making methods have been developed. Some of them are described in this paper and applied for the classification of parts for the assembly of agricultural machine. The parts are classified using the traditional ABC classification based only on one criterion and analytical hierarchy process (AHP) methodology.

**Keywords:** *inventory control, multiple criteria decision making, ABC inventory classification, analytical hierarchy process*

### Primjena različitih kvantitativnih tehnika pri klasifikaciji zaliha

Pregledni članak

U radu je, na jednom primjeru, prikazana usporedba klasifikacije zaliha primjenom tradicionalne ABC analize i primjenom metode višekriterijskog odlučivanja. Upravljanje zalihama, kao jedna od značajnih tehnika operacijskih istraživanja, igra važnu ulogu u upravljanju cijelim poduzećem. Primjena različitih metoda i modela upravljanja zalihama, utječe na poboljšanje konkurentnosti poduzeća. Pomoću tradicionalne ABC analize, zalihe se klasificiraju na osnovi samo jednog kriterija. Taj kriterij, vrlo često, nije najznačajniji, te se koriste i metode višekriterijskog odlučivanja. Neke od tih metoda su opisane u radu i primijenjene pri klasifikaciji dijelova za montažu poljoprivrednog stroja. Korištena je tradicionalna ABC analiza, te klasifikacija pomoću AHP (analitički hijerarhijski proces) metodologije.

**Ključne riječi:** *upravljanje zalihama, višekriterijsko odlučivanje, ABC analiza, analitički hijerarhijski proces*

## 1 Introduction
Uvod

Inventory control (also stock control, inventory management), which is one of the important techniques of operational research discipline, plays an important role in the company management. A systematic approach to inventory control may have a significant influence on the company competitiveness. Application of optimization and multiple criteria decision making methods helps to achieve this goal. Because of the huge number of inventory items in many companies, great attention is directed to the inventory classification into different groups. Different groups require the application of different management tools and policies. ABC analysis or ABC inventory classification which is based on the Pareto principle, takes into account only one criterion. Very often, it is annual cost usage, obtained by the multiplication of annual demand and average unit price. Sometimes, only one criterion is not a very efficient measure for decision making. Therefore, multiple criteria decision making methods are used. Consequently, the term multiple criteria inventory classification is used. Other criteria, except for the annual cost usage, are as follows: lead time of supply, part criticality, availability, average unit price, stock out penalty costs, etc.

Flores et al. [1, 2] have transformed the traditional ABC analysis for the inventory classification, taking into consideration another relevant i.e. significant criterion. This method, so called bi-criteria inventory classification, uses the traditional ABC analysis to classify inventory by the first criterion, and then by the second criterion. The main disadvantage of this method is that the weights of the two criteria are assumed to be equal. Ramanathan [3] developed a weighted linear optimization model, which is based on the concept of data envelopment analysis (DEA). The weighted additive function (score) is used, which includes all the performances in terms of different criteria for an item. Optimization linear model is defined for each item. By solving this model, the optimal inventory score for each item, as well as weighted factor values (weights) for all the criteria are generated. For a large number of items, this method is time consuming, but it provides the objective way of determining the weights. Wan Lu Ng [4] proposes very similar, but simplified model to Ramanathan's model. This approach does not require a liner optimizer to solve the model. All the criteria data for each alternative are transformed and normalised to the scale from 0 to 1. The partial averages of the transformed criteria values are calculated then for all items. The next step is to choose the maximal partial average value for each item and rank the items by these values. The traditional ABC analysis is then applied. The authors [5] presented an extended version of the Ramanathan's model with the main aim of avoiding the classification of the items with the high value of an unimportant criterion, to the group A. Chen et al. [6] suggested a model based on the ranking by the distances from the positive and negative ideal solution. It seems to be a TOPSIS method. The first step of this method is to present the whole population (all of the items) by the three representative case sets for groups A, B and C. Further, quadratic distances of the case sets criteria data from the minimal and maximal value of the whole population should be calculated. These values are the basis for the formulation of quadratic nonlinear model with the quadratic objective function to be minimised, subjected to the constraints of distances $R_A$, $R_B$ and $R_C$. Items with the distance smaller than $R_A$, are sorted to the group A. Items with the distance greater than $R_A$, and smaller than $R_B$, are classified to the group B.

Finally, items with the distance greater than $R_B$, are classified into the group C. Bhattacharya et al. [7] have also used a TOPSIS method to classify inventories into the groups. Partovi et al. [8] have used an analytical hierarchy process (AHP further) methodology to classify inventory. Both quantitative and qualitative criteria can be taken into consideration. This methodology is based on the pair wise comparisons of alternatives and pair wise comparisons of criteria, by means of Saatys scale [9, 10]. Calculated criteria weights and alternative priorities (preferences) are used to rank the alternatives (inventory items or stock keeping units).

Artificial intelligence methods like neural networks and genetic algorithms are also applied to the inventory classification. Partovi et al. [11] uses neural networks to classify inventory. Unit price, ordering cost, demand range and lead time present input neurons. A, B and C groups present the output layer. Guvenir et al. [12] applied genetic algorithms technique to the problem of multiple criteria inventory classification. Their proposed method is called Genetic Algorithm for Multicriteria Inventory Classification and it uses genetic algorithm to learn the weights of criteria. After the weights are obtained by the genetic algorithm, the total score for each item is calculated similarly to AHP methodology.

The main objective of this paper is to apply and compare the traditional ABC inventory classification based on one criterion and inventory classification based on multiple criteria decision making. The four criteria are considered.

## 2 Description of the used methods
### Opis korištenih metoda

ABC analysis is very popular and most widely used analytical method for the inventory classification. The classification is based only on one criterion. Very often, this criterion is annual cost usage. There are some other criteria like average unit price, the number of orders, purchasing conditions and some other.

By the ABC analysis, items are classified into three groups: A, B and C. Group A presents the group of the most important items, while group C is the group with the lowest importance, according to the predefined criterion. Group A involves about 10 to 20 % of all items, but it has the highest proportion (about 70 to 80 %) of the total annual cost usage. Group B involves items which amount to 15 to 20 % of total annual cost usage. Into group C (less important, but with the largest number of items), about 60 to 70 % of all items with the smallest proportion (5 to 10 %) of total annual cost usage, are classified. Figure 1 shows an example of ABC analysis. By the application of the computer, this method is easy to use, even for a very large number of items. Also, the method is included into many informational systems (inventory modules).

Figure 1 shows that 20 % of items (6 items of 30), amounts approximately to 80 % of total annual cost usage. These items are classified into the group A, and a great attention of inventory managers must be paid to this group. Another 6 items of 30 (20 %) amount approximately to 15 % of total annual cost usage. These items are classified into the group B. The largest quantity of items (18 items out of 30), which presents 60 % of all, amounts approximately to 5 % of total annual cost usage. These items belong to group C

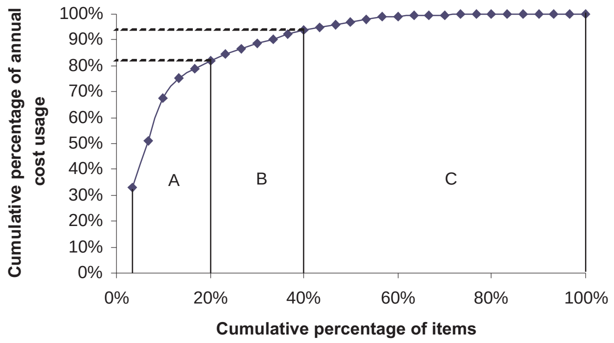


***Figure 1*** *Graphical presentation of ABC analysis*
***Slika 1*** *Grafički prikaz ABC analize*

which requires the least attention of inventory managers. Suggested borders between the A, B and C groups should not be so rigid. The borders can depend on every defined problem.

ABC classification is based just on one criterion, which is the main disadvantage of this classification method. Therefore, more than one criterion should be considered at the same time. Consequently, multiple criteria decision making methods have to be applied.

Multiple criteria decision making methods are divided into the two basic groups, as follows: multiple *attribute* decision making methods and multiple *objective* decision making methods [13]. The first mentioned methods deal with the selection of the best alternative among many feasible alternatives. Each alternative is defined by some quantitative and/or qualitative criteria or attributes. There are a lot of multiple attribute decision methods: analytical hierarchy process (AHP), ELECTRE method, PROMETHEE method, LINMAP method, domination method, maximin method, maximax method, TOPSIS method and some other.

Multiple objective decision making methods deal with the problems of two or more objective functions subjected to some constraints. Some of the most usable methods are as follows: utility function method, goal programming, STEP method (STEM) and some others.

Analytical hierarchy process methodology is widely applied in almost every field of human activity, for example economy [14], traffic [15], agriculture [16], information technologies [17] and many others. AHP methodology is developed by Thomas Saaty [9, 10]. This methodology is based on the decomposition of the defined decision problem to the hierarchy structure. The hierarchy structure is a tree-like structure which consists of the main goal at the top of the hierarchy (the first level), followed by the criteria and sub-criteria (also sub-sub-criteria) and finally by the alternatives at the bottom of the hierarchy (the last level), Figure 2.

The goal presents the optimum solution of the decision problem. It can be the selection of the best alternative among many feasible alternatives. Also, the ranking of all alternatives can be performed, by obtaining the priorities. Criteria (sometimes called objectives or attributes) are the quantitative or qualitative data (judgements) for evaluating the alternatives. The weights of the criteria present the relative importance of each criterion compared to the goal. Finally, alternatives present the group of feasible solutions of the decision problem. Alternatives are evaluated against the set of criteria.

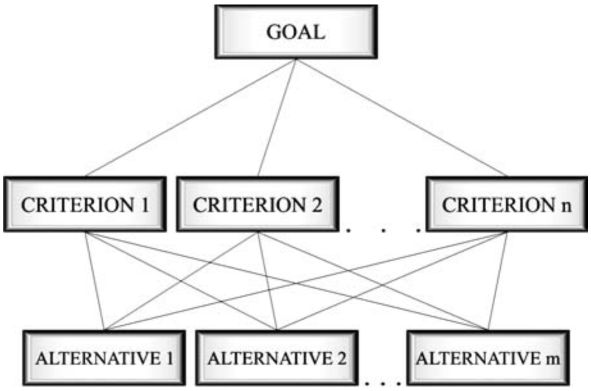


*Figure 2* AHP model with "n" criteria and "m" alternatives
*Slika 2* AHP model s "n" kriterija i "m" alternativa

AHP methodology has three basic steps:

- Decomposition of the defined decision problem to the hierarchic structure - building an AHP model with the overall goal, the evaluation criteria (sub-criteria) and alternatives.
- Pair wise comparisons of the criteria and alternatives based on the Saatys scale of numbers from 1 to 9, Table 1. The value 1 means equal importance of two criteria (alternatives), while the value 9 stands for extreme importance of one criterion (alternative) to another. Pair wise comparisons of the criteria are performed with respect to the goal or criteria at higher level. The weights of the criteria present the ratio of how much more important is one criterion than another, with respect to the goal or criterion at higher level. Pair wise comparisons of the alternatives are performed against each criterion and present the ratio of how much more important is one alternative than another, taking into account each criterion. The local priorities of alternatives are derived. Testing the consistency of subjective judgements is also performed.
- Synthesising the results by the calculation of the total priorities of alternatives. The total priority of each alternative is calculated by the multiplication of the local priority of alternative by the weight of corresponding criterion and then summing all the products for each criterion. Sensitivity analysis can be also performed and it gives the response of the alternative priorities to the change of the input data.

***Table 1*** *Saaty's scale for pair wise comparisons*
***Tablica 1*** *Saaty-eva skala za usporedbu u parovima*

| Scale | Description of the importance |
|---|---|
| 1 | equal |
| 3 | moderate |
| 5 | strong |
| 7 | very strong |
| 9 | extreme |
| 2,4,6,8 | intermediate values |

In AHP methodology, for a very large number of alternatives, making pair wise comparisons of alternatives, with respect to each criterion, can be time consuming and confusing, because the total number of comparisons is very big, too (see the expression (1)).

$$NK = \frac{m \cdot (m-1)}{2} \tag{1}$$

where:
$NK$ - the total number of comparisons
$m$ - the number of alternatives.

Therefore, instead of pair wise comparisons, alternatives' relative priorities can be obtained by the scaling (normalizing, transforming) the alternative data for each criterion. The data (qualitative or quantitative) can be transformed in different ways. It can be explained in the following text, starting with the decision matrix, Table 2.

***Table 2*** *Decision matrix m × n*
***Tablica 2*** *Matrica odluke m × n*

| | Criterion 1 | Criterion 2 | … | Criterion n |
|---|---|---|---|---|
| Alternative 1 | $x_{11}$ | $x_{12}$ | | $x_{1n}$ |
| Alternative 2 | $x_{21}$ | $x_{22}$ | | $x_{2n}$ |
| … | | | $x_{ij}$ | |
| Alternative m | $x_{m1}$ | $x_{m2}$ | | $x_{mn}$ |

where:
$x_{ij}$ - the $j$-th criteria data for the $i$-th alternative

The decision matrix can be transformed to the following matrix, Table 3.

***Table 3*** *Transformed decision matrix m × n*
***Tablica 3*** *Transformirana matrica odluke m × n*

| | Criterion 1 | Criterion 2 | … | Criterion n |
|---|---|---|---|---|
| Alternative 1 | $x_{11}$* | $x_{12}$* | | $x_{1n}$* |
| Alternative 2 | $x_{21}$* | $x_{22}$* | | $x_{2n}$* |
| … | | | $x_{ij}$* | |
| Alternative m | $x_{m1}$* | $x_{m2}$* | | $x_{mn}$* |

where:
$x_{ij}$* - the transformed $j$-th criteria value for the $i$-th alternative.

Transformations of criteria data on the alternatives can be performed according to different formulas (see expressions 2, 3, 4, 5 and 6).

The vector normalization is one of the transformation techniques where each $j$-th criteria data is divided with its norm and consequently, the following transformed $j$-th criteria value of the $i$-th alternative is obtained [13]:

$$x^*_{ij} = \frac{x_{ij}}{\left[\sum_{i=1}^{m} x_{ij}^2\right]^{1/2}} \tag{2}$$

In linear transformation each positively related $j$-th criteria data is divided with the maximum data of the $j$-th column of decision matrix and consequently, the following transformed *j-th* criteria value of the *i-th* alternative is obtained [13]:

$$x^*_{ij} = \frac{x_{ij}}{\max_i x_{ij}} \tag{3}$$

In linear transformation, for negatively related criteria, each $j$-th criteria data is put into relation with the minimum data of the $j$-th column of decision matrix and consequently, the following transformed $j$-th criteria value of the $i$-th alternative is obtained [13]:

***Table 4*** *Criteria and criteria data for the alternative items*
***Tablica 4*** *Kriteriji i vrijednosti kriterija za dijelove*

| Item No. | Annual demand, items/year | Average unit price, €/item | Annual cost usage, €/year | Criticality | Lead time 1, working days | Lead time 2, working days |
|---|---|---|---|---|---|---|
| 1 | 4200 | 1,22 | 5124 | 1 | 15 | 5 |
| 2 | 1400 | 0,38 | 532 | 1 | 15 | 5 |
| 3 | 700 | 0,26 | 182,28 | 1 | 30 | 20 |
| 4 | 2100 | 0,05 | 105 | 1 | 5 | 5 |
| 5 | 1400 | 0,91 | 1274 | 3 | 45 | 30 |
| 6 | 1400 | 1,08 | 1507,94 | 4 | 30 | 20 |
| 7 | 700 | 1,48 | 1034,6 | 4 | 30 | 20 |
| 8 | 1050 | 0,06 | 63 | 1 | 15 | 5 |
| 9 | 700 | 0,43 | 301 | 1 | 15 | 5 |
| 10 | 700 | 0,43 | 301 | 1 | 15 | 5 |
| 11 | 700 | 0,46 | 322 | 1 | 15 | 5 |
| 12 | 700 | 2,67 | 1869 | 4 | 60 | 45 |
| 13 | 350 | 12,45 | 4357,5 | 2 | 25 | 15 |
| 14 | 350 | 4,80 | 1680 | 1 | 15 | 10 |
| 15 | 700 | 10,03 | 7021 | 3 | 15 | 5 |
| 16 | 700 | 10,35 | 7245 | 3 | 15 | 5 |
| 17 | 350 | 58,39 | 20436,33 | 2 | 30 | 20 |
| 18 | 700 | 5,51 | 3857 | 3 | 15 | 5 |
| 19 | 350 | 7,93 | 2775,5 | 2 | 25 | 15 |
| 20 | 1400 | 0,56 | 784 | 3 | 30 | 20 |
| 21 | 700 | 8,15 | 5705 | 3 | 30 | 20 |
| 22 | 700 | 6,60 | 4620 | 3 | 30 | 20 |
| 23 | 700 | 3,35 | 2345 | 3 | 30 | 20 |
| 24 | 1400 | 6,95 | 9730 | 4 | 30 | 20 |
| 25 | 700 | 1,08 | 756 | 2 | 20 | 15 |
| 26 | 350 | 118,60 | 41510 | 5 | 15 | 5 |
| 27 | 700 | 0,17 | 119 | 2 | 15 | 5 |
| 28 | 700 | 0,23 | 161 | 2 | 15 | 5 |
| 29 | 700 | 0,05 | 35 | 2 | 15 | 5 |
| 30 | 700 | 0,12 | 84 | 2 | 15 | 5 |
| 31 | 350 | 0,15 | 52,5 | 2 | 15 | 5 |
| 32 | 700 | 0,02 | 14 | 1 | 15 | 5 |
| 33 | 700 | 0,04 | 28 | 1 | 15 | 5 |
| 34 | 350 | 0,02 | 7 | 1 | 15 | 5 |
| 35 | 700 | 0,01 | 7 | 1 | 15 | 5 |
| 36 | 700 | 0,00 | 2,66 | 1 | 20 | 15 |
| 37 | 700 | 0,01 | 9,87 | 1 | 20 | 15 |
| 38 | 2100 | 0,03 | 63 | 1 | 15 | 5 |
| 39 | 1050 | 0,20 | 210 | 1 | 15 | 5 |
| 40 | 1400 | 0,01 | 14 | 1 | 15 | 5 |
| 41 | 700 | 5,88 | 4116 | 4 | 35 | 15 |
| 42 | 700 | 0,09 | 63 | 1 | 15 | 5 |
| 43 | 700 | 0,16 | 112 | 2 | 15 | 5 |
| 44 | 140 | 25,30 | 3542 | 1 | 10 | 5 |
| 45 | 700 | 22,26 | 15582 | 4 | 35 | 15 |
| 46 | 700 | 5,70 | 3990 | 2 | 15 | 5 |
| 47 | 700 | 1,91 | 1337 | 1 | 15 | 5 |
| 48 | 4200 | 5,70 | 23940 | 4 | 15 | 5 |
| 49 | 700 | 3,52 | 2464 | 1 | 30 | 20 |
| 50 | 700 | 22,18 | 15526 | 3 | 30 | 20 |
| 51 | 700 | 17,97 | 12579 | 3 | 30 | 20 |
| 52 | 700 | 61,90 | 43330 | 4 | 40 | 30 |
| 53 | 700 | 7,90 | 5530 | 2 | 25 | 15 |
| 54 | 700 | 3,74 | 2618 | 3 | 30 | 25 |
| 55 | 700 | 56,00 | 39200 | 4 | 20 | 15 |
| 56 | 350 | 128,90 | 45115 | 5 | 35 | 20 |
| 57 | 350 | 128,90 | 45115 | 5 | 35 | 20 |

$$x^*_{ij} = \frac{\min_i x_{ij}}{x_{ij}} \quad (4)$$

For the positively related criteria, the greater value of criteria means the more importance. On the other hand, for the negatively related criteria, the smaller value of criteria means more importance.

The modification of linear transformation gives, for the positive criteria, the following expression [13]:

$$x^*_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \quad (5)$$

while, for the negative criteria, the following expression is given [13]:

$$x^*_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \quad (6)$$

All the criteria data are transformed to the 0 - 1 scale.

Very often scales consist of intensities such as: low, moderate, high or bad, good, excellent.

Scaled value of the *j*-th criterion ($S_{Vij}$) for the *i*-th alternative is multiplied by the weighting factor (or simply weight) of the *j*-th criterion ($B_j$). The sum of multiplied scaled values and weighting factors across all of the criteria (so called weighted sum) presents the overall score for the alternative item (see the expression (7)). The alternative with the maximum score is on the top, while the alternative with the minimum score is on the bottom of the ranking

$$V_{ri} = \sum_{j=1}^{n} B_j \cdot S_{Vij} \to \max. \quad (7)$$

where:
$V_{ri}$ - the overall score for the *i*-th alternative ($i = 1, \ldots, m$)
$B_j$ - weighting factor for the *j*-th criterion ($j = 1, \ldots, n$)
$S_{Vij}$ - scaled *j*-th criterion value for the *i*-th alternative
*n* - number of criteria

Weighting factor or simply the weight presents the relative importance of the criterion according to the defined objective. This factor can be determined by using the experience, the digital-logic method applied in weighted properties method [18, 19], using the Saaty scale. The digital-logic method is based on the pair wise comparison of criteria, where more important criterion has mark 1, and less important criterion has mark 0. After that, for every criterion the number of positive decisions is determined. Weighting factor for the criterion is the ratio of the number of positive decisions and the total number of decisions. Pair wise comparisons of the criteria by using the Saaty scale (Table 1) are previously described in Step 2 of the AHP methodology.

## 3 Inventory classification
## Klasifikacija zaliha

This part of the paper illustrates the application and comparison of AHP methodology and traditional ABC analysis for ranking and classifying the items into the groups. 57 items for the assembly of the part of agricultural machine have been quantitatively analyzed. Evaluation criterion for the traditional ABC analysis was annual cost usage, while for the multi attribute decision making, four criteria were included. All the criteria are positively related to the importance level. Criteria data on the alternatives are given in Table 4. The criteria are as follows:

- Annual cost usage (calculated by multiplying the annual demand and the average unit price),
- Criticality factor (rated from 1 – noncritical to 5 – extremely critical),
- Lead time 1 – this is an interval from the ordering till the receiving of items for the development of a new product and start up of batch production.
- Lead time 2 – this is an interval from the ordering till the receiving of items for the batch production when the new product is already developed. The lead time 2 is shorter than lead time 1, because the development phase is missing.

Multiple criteria inventory classification is carried out by using the modified AHP methodology, which includes pair wise comparisons of criteria, but not the pair wise comparisons of alternatives. Except from the annual cost usage, the above mentioned criteria are included. The AHP model is shown in Figure 3.

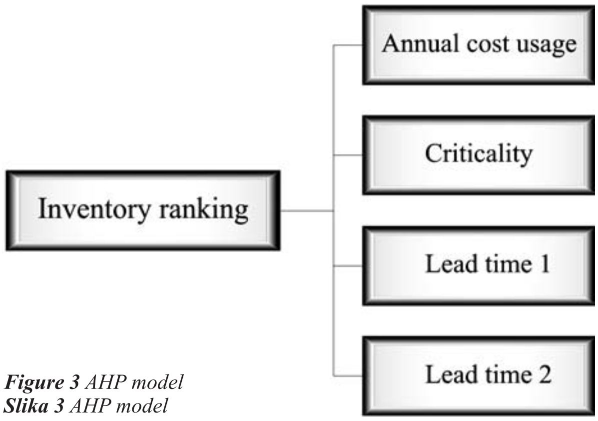


***Figure 3*** *AHP model*
***Slika 3*** *AHP model*

Criteria weights are derived from the pair wise comparisons according to the Saaty scale (Table 5). The following considerations about the criteria given by the experts in this field are significant. The criterion criticality is very important because of considerable consequence of not having a part when it is needed for the assembly. Lead time 2 is more important than lead time 1, because of planning and scheduling batch production. From the technical and manufacturing point of view, annual cost usage criterion is less important, but for the purchasing unit it is more important.

***Table 5*** *Pair wise comparisons of criteria*
***Tablica 5*** *Uspoređivanje kriterija u parovima*

| | Criticality | Lead time 1 | Lead time 2 |
|---|---|---|---|
| Annual cost usage | 1/2 | 2 | 1 |
| Criticality | - | 2 | 3 |
| Lead time 1 | - | - | 1/2 |

Because of large number of alternatives (57), pair wise comparisons of the alternatives are not performed (according to the expression 1, there will be 1596 pair wise comparisons with respect to each criterion). Instead of that, transformation of the criteria data of alternatives is made by using the expression (3). Overall score for each alternative (item) across all four criteria is calculated using the expression (7).

***Table 6*** *Multiple criteria inventory classification and traditional ABC analysis*
***Tablica 6*** *Višekriterijska klasifikacija zaliha i tradicionalna ABC analiza*

| Item No. | Annual cost (transformed) | Criticality (transformed) | Lead time 1 (transformed) | Lead time 2 (transformed) | Overall score | Group | Group |
|---|---|---|---|---|---|---|---|
| | $B_1 = 0{,}224$ | $B_2 = 0{,}431$ | $B_3 = 0{,}138$ | $B_4 = 0{,}207$ | | AHP methodology | Traditional ABC analysis |
| 56 | 1 | 1 | 0,583333 | 0,444444 | 0,8275 | A | A |
| 57 | 1 | 1 | 0,583333 | 0,444444 | 0,8275 | A | A |
| 52 | 0,960434 | 0,8 | 0,666667 | 0,666667 | 0,789937 | A | A |
| 12 | 0,041427 | 0,8 | 1 | 1 | 0,69908 | A | C |
| 26 | 0,920093 | 1 | 0,25 | 0,111111 | 0,694601 | A | A |
| 55 | 0,868891 | 0,8 | 0,333333 | 0,333333 | 0,654431 | A | A |
| 45 | 0,345384 | 0,8 | 0,583333 | 0,333333 | 0,571666 | A | A |
| 24 | 0,215671 | 0,8 | 0,5 | 0,444444 | 0,55411 | A | A |
| 48 | 0,530644 | 0,8 | 0,25 | 0,111111 | 0,521164 | A | A |
| 41 | 0,091234 | 0,8 | 0,583333 | 0,333333 | 0,514736 | A | B |
| 6 | 0,033424 | 0,8 | 0,5 | 0,444444 | 0,513287 | A | C |
| 7 | 0,022933 | 0,8 | 0,5 | 0,444444 | 0,510937 | B | C |
| 5 | 0,028239 | 0,6 | 0,75 | 0,666667 | 0,506426 | B | C |
| 50 | 0,344143 | 0,6 | 0,5 | 0,444444 | 0,496688 | B | A |
| 51 | 0,278821 | 0,6 | 0,5 | 0,444444 | 0,482056 | B | A |
| 54 | 0,058029 | 0,6 | 0,5 | 0,555556 | 0,455599 | B | C |
| 21 | 0,126455 | 0,6 | 0,5 | 0,444444 | 0,447926 | B | B |
| 22 | 0,102405 | 0,6 | 0,5 | 0,444444 | 0,442539 | B | B |
| 17 | 0,452983 | 0,4 | 0,5 | 0,444444 | 0,434868 | B | A |
| 23 | 0,051978 | 0,6 | 0,5 | 0,444444 | 0,431243 | B | C |
| 20 | 0,017378 | 0,6 | 0,5 | 0,444444 | 0,423493 | B | C |
| 16 | 0,16059 | 0,6 | 0,25 | 0,111111 | 0,352072 | B | B |
| 15 | 0,155625 | 0,6 | 0,25 | 0,111111 | 0,35096 | B | B |
| 18 | 0,085493 | 0,6 | 0,25 | 0,111111 | 0,33525 | C | B |
| 53 | 0,122576 | 0,4 | 0,416667 | 0,333333 | 0,326357 | C | B |
| 13 | 0,096587 | 0,4 | 0,416667 | 0,333333 | 0,320535 | C | B |
| 19 | 0,061521 | 0,4 | 0,416667 | 0,333333 | 0,312681 | C | B |
| 25 | 0,016757 | 0,4 | 0,333333 | 0,333333 | 0,291154 | C | C |
| 49 | 0,054616 | 0,2 | 0,5 | 0,444444 | 0,259434 | C | C |
| 46 | 0,088441 | 0,4 | 0,25 | 0,111111 | 0,249711 | C | B |
| 3 | 0,00404 | 0,2 | 0,5 | 0,444444 | 0,248105 | C | C |
| 28 | 0,003569 | 0,4 | 0,25 | 0,111111 | 0,230699 | C | C |
| 27 | 0,002638 | 0,4 | 0,25 | 0,111111 | 0,230491 | C | C |
| 43 | 0,002483 | 0,4 | 0,25 | 0,111111 | 0,230456 | C | C |
| 30 | 0,001862 | 0,4 | 0,25 | 0,111111 | 0,230317 | C | C |
| 31 | 0,001164 | 0,4 | 0,25 | 0,111111 | 0,230161 | C | C |
| 29 | 0,000776 | 0,4 | 0,25 | 0,111111 | 0,230074 | C | C |
| 37 | 0,000219 | 0,2 | 0,333333 | 0,333333 | 0,201249 | C | C |
| 36 | 5,9E-05 | 0,2 | 0,333333 | 0,333333 | 0,201213 | C | C |
| 14 | 0,037238 | 0,2 | 0,25 | 0,222222 | 0,175041 | C | C |
| 1 | 0,113576 | 0,2 | 0,25 | 0,111111 | 0,169141 | C | B |
| 47 | 0,029635 | 0,2 | 0,25 | 0,111111 | 0,150338 | C | C |
| 44 | 0,07851 | 0,2 | 0,166667 | 0,111111 | 0,149786 | C | B |
| 2 | 0,011792 | 0,2 | 0,25 | 0,111111 | 0,146341 | C | C |
| 11 | 0,007137 | 0,2 | 0,25 | 0,111111 | 0,145299 | C | C |
| 9 | 0,006672 | 0,2 | 0,25 | 0,111111 | 0,145194 | C | C |
| 10 | 0,006672 | 0,2 | 0,25 | 0,111111 | 0,145194 | C | C |
| 39 | 0,004655 | 0,2 | 0,25 | 0,111111 | 0,144743 | C | C |
| 8 | 0,001396 | 0,2 | 0,25 | 0,111111 | 0,144013 | C | C |
| 38 | 0,001396 | 0,2 | 0,25 | 0,111111 | 0,144013 | C | C |
| 42 | 0,001396 | 0,2 | 0,25 | 0,111111 | 0,144013 | C | C |
| 33 | 0,000621 | 0,2 | 0,25 | 0,111111 | 0,143839 | C | C |
| 32 | 0,00031 | 0,2 | 0,25 | 0,111111 | 0,14377 | C | C |
| 40 | 0,00031 | 0,2 | 0,25 | 0,111111 | 0,14377 | C | C |
| 34 | 0,000155 | 0,2 | 0,25 | 0,111111 | 0,143735 | C | C |
| 35 | 0,000155 | 0,2 | 0,25 | 0,111111 | 0,143735 | C | C |
| 4 | 0,002327 | 0,2 | 0,083333 | 0,111111 | 0,121221 | C | C |

Table 6 presents the calculated transformed criteria values, weighting factors and overall scores for each item. Items are ranked according to overall scores. The last column presents the classification of the parts carried out by the application of the traditional ABC analysis, where annual cost usage was the criterion. The limits for the groups are derived on the following basis. Group A involves 20 % of the total amount of items. It is taking about 80 % of the total annual cost usage. Group B involves another 20 % of the total amount of items with 15 % of the total annual cost usage, while 60 % of items belong into the group C. These items are taking only 5 % of the total annual cost usage.

## 4 Conclusion
Zaključak

On the basis of the above calculated results obtained by the application of traditional ABC analysis and AHP methodology, the following conclusions can be made. Traditional ABC classification of parts considering just one criterion (annual cost usage) gives different results when compared to the multiple criteria inventory classification. The use of more than one criterion has a considerable influence on the classification. Parts No. 12, 6, 7, 5 and 54, with relatively low price (Table 4) belong to group C (Table 6), if traditionally classified. On the other hand, by the application of the multiple criteria approach, where the criteria criticality and lead times are taken into account, these parts are reclassified into groups A and B. This is just opposite to the traditional ABC analysis conclusion. Those are the parts with the relatively high criticality factor and long lead times. Therefore, great attention must be paid and appropriate inventory strategy should be suggested to control the parts in group A. In this case, multiple criteria classification is useful to avoid the stock outs of inventory items with long lead times. On the other hand, penalty costs and delay in production can occur.

Some researchers have criticised the determination of weighting factors by the Saaty scale because it is quite subjective. However, the optimum solution obtained by the application of quantitative techniques must be subjected to further analysis and estimation of an experienced inventory decision maker.

The AHP model can be effectively implemented to inventory module of ERP systems with the main goal of automated selection of A group of inventory items. For those very important items calculation of economic order quantity, safety stock and reorder point can be performed. In addition, selection of the reliable supplier can be performed. Further research will be directed to the application of artificial intelligence methods like neural networks and expert systems to the inventory classification and the selection of the reliable supplier.

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