

## TRANSPORTATION PROCESS OPTIMIZATION – SELECTED EXAMPLE

AGNIESZKA WANIEWSKA,<sup>1</sup> PAULINA KRAWCZYSZYN,<sup>2</sup>  
MAGDALENA KOWACKA<sup>3</sup>

Wyższa Szkoła Oficerska Wojsk Lądowych imienia generała Tadeusza Kościuszki we Wrocławiu, Wydział Zarządzania, POLAND

<sup>1</sup> e-mail: a.waniewska@wso.wroc.pl

<sup>2</sup> e-mail: p.krawczynszyn@wso.wroc.pl

<sup>3</sup> e-mail: m.kowacka@wso.wroc.pl

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ABSTRACT

Due to the dynamic world growth, people more often need to choose the optimal mean of transport. To do it properly, experts correlate many transport offers and compare such features as: time of transit, costs, capacity. But it should be mentioned, that process of collecting, comparing and studying the data is a time consuming process. The article presents how the AHP method could be used as an aid to choose the optimal mean of transport. The method is widely used not only because of high effectiveness of resolving complex problems, but also because it is simple and the results are transparent and easy to interpret. Several significant parameters were chosen to conduct the analysis.

### Introduction

The AHP method was developed and described by Saaty. It is mainly used as an aid tool during complex decision making process. During that process, the user can select physical objects and states that represent the project or other variants, that could lead to the certain states (quality, risk). What is more, diagnostic and comparative evaluation of examined objects is possible by using the AHP method (Downarowicz, Krause, Sikorski,

Stachowski, 2000, p. 7). The assumption is, that the AHP method would make it easier to choose optimum variant in the multicriterial optimizing, especially because of its reduction to the series of comparison in pairs (Emrouznejad, Marra, 2017, p. 6653). The method has many advantages, but the fact that both measurable and nonmeasurable features can be used in the analysis should be considered as the most crucial issue (Mu, Pereyra-Rojas, 2017). The aim of the article is to show possible usage of the AHP method in transportation problem.

## Literature review

Because of the comparison in pairs of all elements with each other, standard evaluation scales are insufficient. To make the analysis more complete, the 9-point grade scale was introduced. Comparing two elements with each other will show which is more significant and how much (Przybyło, Krężolek, 2017).

When we want to compare the elements that are nonmeasurable, the linguistic approach should be applied. In that approach, the linguistic variable takes as its value the verbal definition. In order to evaluate the elements on different levels in the analyzed structure, the comparison matrix was created (Cabała, 2010, pp. 5–23), and its degree is equal to the number of compared elements (Mu, Pereyra-Rojas, 2017).

$$A = \begin{bmatrix} a_{11} = 1 & a_{12} & \dots & a_{1n} \\ a_{21} = \frac{1}{a_{12}} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} = \frac{1}{a_{1n}} & 1 & \dots & a_{nn} \end{bmatrix} \quad (1)$$

where:  $A$  – square matrix where  $a_{ij}$  denote the elements of the matrix ( $i, j = 1, 2, \dots, n$ ); the matrix is called square if:<sup>1</sup>

- $a_{ij} = z$ , then  $a_{ji} = \frac{1}{z}$ ,  $z \neq 0$
- criteria  $C_i$  is equiponderant to  $C_j$ , then  $a_{ij} = 1$  and  $a_{ji} = 1$ , and  $a_{ij} = 1$  for  $i = j$ .

Where with matrix  $A$  also fulfill the following property:  $a_{ij} > 0$ ,  $a_{ij} = \frac{1}{a_{ji}} \forall i, j = 1, 2, \dots, n$ .

All the elements of the model are ordered according to validity of the priority vectors  $W = w_1, \dots, w_n$ . Firstly, to calculate the priority vector  $W$ , it is necessary to perform a matrix  $A$  normalization (the matrix  $B$  is created), by dividing each element of the matrix by the sum of the elements in column, in which it is located (Mu, Pereyra-Rojas, 2017):

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}} \quad (2)$$

Next, average value in every row of the new matrix should be defined. That value is the element  $w_i$  priority vector  $W$ :

<sup>1</sup> [http://www.dii.unisi.it/~mocenni/Note\\_AHP.pdf](http://www.dii.unisi.it/~mocenni/Note_AHP.pdf).

$$w_i = \frac{\sum_{j=1}^n b_{ij}}{n} \quad (3)$$

where  $i, j = 1, \dots, n$  wherein  $\sum_{i=1}^n w_i = 1$ . In case of priority vectors analyzed criteria we use  $k_i$ , while for the priority vector of the  $i$ th element according to the  $j$ th criteria, we use  $o_{ij}$ .

Value of the AHP rate, denoted as  $h_i$ , is determined based on the dependence:

$$h_i = \sum_{j=1}^n (k_i o_{ij}) \quad (4)$$

where  $k_i$  is the value of the priority vector element for the  $i$ th criteria (weight of the  $i$ th criterion), where as  $o_{ij}$  is a value of the priority vector element for the  $j$ th object in terms of the  $i$ th criterion, wherein  $\sum_{i=1}^n h_i = 1$ .

Therefore, the criteria and the variants comparison is made by defining superiority of one element over the other. The experts usually make that observation and because of that it is rather subjective opinion. Even an experienced expert could make a mistake while studying data, what is most often caused by the lack of consequences during the evaluation (Mu, Pereyra-Rojas, 2017).

According to E. Mu and M. Pereyra-Rojas, checking the credibility of results in the AHP method should be made by calculating the consistency ratio from the under mentioned formula:

$$CR = \frac{CI}{RI} 100\% \quad (5)$$

where:

$RI$  – Random Consistency Index, gaining values from 0 to 1.57 (Table 1),

$CI$  – Consistency Index, we define from dependence:

$$CI = \frac{(\lambda_{\max} - n)}{(n - 1)} \quad (6)$$

where  $\lambda_{\max}$  is maximum value from the matrix, always higher or equal to rank of the matrix  $n$ .

**Table 1.** Random Consistency Index  $RI$

Matrix order number	$n$	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RI	$RI$	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.54	1.56	1.57

Source: Mu, Pereyra-Rojas (2017).

Maximum estimated value of the matrix  $\lambda_{\max}$  can be calculated as the amount of sums of the products averaged in row normalized values of wages and sum of columns referring each criteria, what can be written as (Ginda, 2007):

$$\lambda_{\max} = \sum_{i=1}^n \left( w_i \sum_{j=1}^n a_{ij} \right) \quad (6)$$

The value of the consistency ratio  $CR$  should not exceed 10%, because it will mean that the evaluation process must be repeated (Mu, Pereyra-Rojas, 2017).

## Method

Using above information, the authors decided to use the AHP method to conduct the simulation of the decision making process, where the optimal mean of transport has to be chosen. There are five criteria in analysis: speed, transport availability, capacity, transport costs, exploitation reliability. What is more, there are 6 different means of transport taken into account: heavy-loaded truck, truck, train, ship, ferry, airplane.

First part of the analysis is to make the criteria ranking, what is shown in Table 2. Secondly, it is necessary to normalize the criteria ranking, what is presented in 3th Table.

**Table 2.** Criteria ranking

	Speed	Transport availability	Capacity	Transport costs	Exploitation reliability
Speed	1.00	0.33	0.14	5.00	0.11
Transport availability	3.00	1.00	0.20	5.00	0.11
Capacity	7.00	5.00	1.00	7.00	0.11
Transport costs	0.20	0.20	0.14	1.00	0.11
Exploitation reliability	9.00	9.00	9.00	9.00	1.00
Sum	20.20	15.53	10.49	27.00	1.44

Source: own work.

**Table 3.** Normalized criteria ranking

	Speed	Transport availability	Capacity	Transport costs	Exploitation reliability
Speed	0.05	0.02	0.01	0.19	0.08
Transport availability	0.15	0.06	0.02	0.19	0.08
Capacity	0.35	0.32	0.10	0.26	0.08
Transport costs	0.01	0.01	0.01	0.04	0.08
Exploitation reliability	0.45	0.58	0.86	0.33	0.69
Sum	1.00	1.00	1.00	1.00	1.00

Source: own work.

Calculations in that method are rather complex but repetitive and because of that the authors decided to omit some of it in further part of the article. Next part of the analysis is the alternative ranking of all the alternatives in all the criteria. Table 4. shows example of the alternatives ranking according to the exploitation reliability criteria.

In that case,  $CR = 0.04$ . In other criteria, the  $CR$  is:

- speed – 0.09,
- transport availability – 0.05,

- capacity – 0.08,
- transport costs – 0.06.

That values show, that the CR is optimum in every case. After building the pairwise comparison matrices, the decision maker could point out the score vectors, that are shown in Table 5.

**Table 4.** Ranking of the alternatives according to the exploitation reliability criteria

Exploitation reliability	Truck	Heavy-loaded truck	Train	Ship	Ferry	Airplane
Truck	1	0.33	0.11	0.20	0.20	0.14
Heavy-loaded truck	3	1.00	0.14	0.33	0.33	0.20
Train	9	7.00	1.00	5.00	5.00	3.00
Ship	5	3.00	0.20	1.00	1.00	0.33
Ferry	5	3.00	0.20	1.00	1.00	0.33
Airplane	7	5.00	0.33	3.00	3.00	1.00
Sum	30	19.33	1.99	10.53	10.53	5.01

Source: own work.

**Table 5.** Score vectors in each criteria

	Speed	Transport availability	Capacity	Transport costs	Exploitation reliability
Truck	0.11	0.32	0.03	0.05	0.03
Heavy-loaded truck	0.11	0.32	0.05	0.05	0.05
Train	0.18	0.20	0.09	0.03	0.45
Ship	0.03	0.06	0.35	0.18	0.11
Ferry	0.03	0.06	0.35	0.18	0.11
Airplane	0.53	0.03	0.14	0.51	0.24

Source: own work.

Next, the score vectors should be multiply by the priority vector and the sum in rows. The results are shown in Table 6.

**Table 6.** Overall priority for variants

	Priority vectors
Truck	0.06
Heavy-loaded truck	0.08
Train	0.31
Ship	0.16
Ferry	0.16
Airplane	0.23

Source: own work.

According to the calculations and the initial assumptions, optimal mean of transport in that case is train.

## Conclusions

Taking everything into consideration, the AHP method is one of the mathematical method that support the decision-making process in complex and multicriterial problems (Lu, Qin, Jin, 2017). That method is an aid, especially for those who are not enough experienced in some fields. The AHP method grant an optimum solution to be chosen from the different alternatives. Among many advantages, the most valuable is that during the decision-making process the problem can be seen from different perspectives and complex problem could be reduced to the simple mathematical equations. Thanks to that, taken decision is not biased or influenced by the one issue.

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