ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1138619

ANALYSIS OF SIGNIFICANCE OF CRITERIA FOR TRANSPORTATION SYSTEM OPERATION QUALITY ASSESSMENT

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Abstract

Selection and determination of assessment criteria is of great importance for evaluation of the system operation quality. The analysis was made within the research on operation quality of a selected transportation system. This was a real system, operating purposefully, providing passengers with transport tasks, over an assigned urban area and suburbs, according to an established schedule. Such a system of operation is affected by the behaviour of people, functioning of transport means and the environmental impact. On the basis of performed tests, a set of criteria, whose fulfilment degree is crucial for functioning of the analyzed system, has been determined. It must be remembered, though those particular criteria are diversified in terms of their significance for the transportation system assessment. Therefore, the analytic hierarchy process AHP has been applied in this work, in order to establish significance of particular criteria, from the point of view of the set quality requirements for the studied transportation system. The analytic hierarchy process has been used in the papers concerning the problems of quality control and assessment of transportation systems. It is one of several tools supporting the process of selection of the most significant criteria aiming at reduction of the considered vector dimensionality and establishing a set of features, accepted for an assessment of the research object operation quality, while building the resultant model.

Keywords: *transport, transportation system assessment, assessment criteria, system operation quality, resultant model*

1. Introduction

The presented study concerns the problems of transportation systems operation quality. On the basis of the developed method [4, 7] it has been established that specification of the most significant qualitative criteria and determination of their significance is the point of reference for performance of the assessment process.

Having done initial research with the use of principal component method (PCA), it was found that the distinguished set of 16 criteria is oversized. Therefore, the authors of this study have made use of Analytic Hierarchy Process AHP, in order to decrease the number of the considered set of criteria and establish their significance in terms of their influence on the analyzed transportation system operation quality.

On the basis of the authors' own research, there was distinguished a set of sixteen criteria which were assessed by respondents. These criteria included (1-16): safety, availability, ergonomics, information, punctuality, time of the service performance, external factors, damageability, reliability, cost effectiveness (price). The respondents were divided into three groups (3x50) from the point of view of the role they play in the system and their different requirements as for the quality of its functioning. The first group was drivers of buses used in the considered system, the second group consisted of its users- passengers and the third group included workers of the subsystem providing the system with continuity of operation.

The obtained set of 150 opinions were subjected to the Analytic Hierarchy Process, first in subgroups, in order to reveal preferences of particular respondents, and then totally for an overall analysis of results.

Application of Analytic Hierarchy Process (AHP) in all the works connected with the problems of assessment and qualitative control of transportation systems is a tool supporting the process of specifying the most significant criteria and aims at reducing a 16 dimensional vector of the criteria accepted for an assessment of the research object operation quality.

2. Research object

The research object is a real, complex, purposefully operating transportation system, performing passenger transport tasks in an urban agglomeration and suburban territories. This is a socio-technical system of the type <H–M–E> (Human – Machine – Environment) in which the operation quality assessment is carried out in dependence on changes of values of features describing behaviour of operators, controlled by them technical objects and the environmental impact [5].

The main goal of such a system operation is safe and cost efficient transport over a given territory, in a defined quantity and time, by technical objects used in the system. Its subsystems have a direct influence on its operation quality as well as the environment impact. The subsystem performing the main function of the system – passenger transports is the executive one. It consists of elementary subsystems (driver-bus).

A general scheme of the operation and maintenance system of the transport means is presented in Fig. 1.

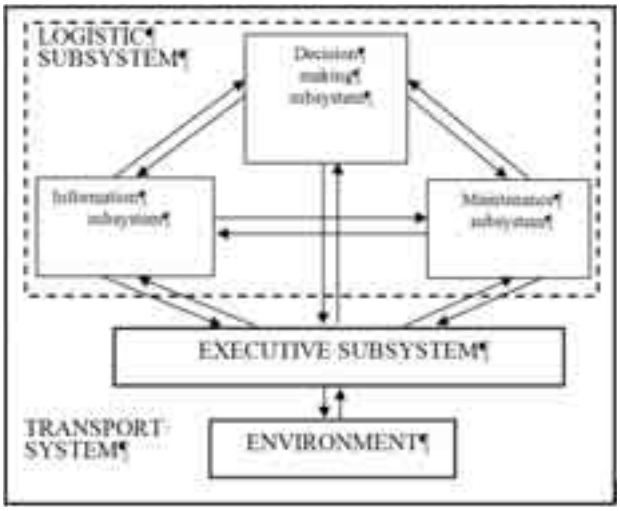

Fig. 1. A general scheme of the operation and maintenance system of the transport means

3. Testing significance of criteria

Input data of the analysis are weights of a transportation system operation quality assessment criteria, determined with the use of a survey, carried out on the group of 150 experts divided into three groups (drivers, users and maintenance workers in the system) to find out about their opinions on the subject of the studied system- from the point of view of its operation quality.

Weights of the criteria were defined in a scale from 0–10 where grade 10 referred to the most significant criterion.

In order to determine the resultant weight of a particular criterion, a table with comparison of criteria in pairs (each with each), has been elaborated, according to AHP method [1]. The number of the verse and column of each element denotes the number of the compared criteria, whereas, a comparison between criterion i and j is, according to the survey, a difference in significance degree between criterion i and j, in the element of verse i and column j.

$$a_{ij} = si_i - si_j \,, \tag{1}$$

where:

a_{ij} – denotes value in element i and column j of the comparison table,
si_j – significance degree defined in the surveys for criterion j,
si_i – significance degree defined in the surveys for criterion i.

The calculated values change in the range from –10 to 10, and according to the used method, they should change within the range from 6 to 6 [2]. Thus, normalization was carried out on elements of the tables, according to dependence (2), and the results were rounded off to integral values.

$$an_{ij} = round\,(0.6 \cdot a_{ij}) \,, \tag{2}$$

where:

an_{ij} – denotes the value in element of verse i and column j after normalization.

In this way 150 such tables have been obtained, divided into three groups of data.

Comparisons of criteria with each other were not accounted for in further calculations. With such an assumption, a matrix of coefficients and absolute terms describing the system of normal equations was created for the comparison tables. These matrixes are of the following form:

$$X = \begin{bmatrix} il_1 & -il_{12} & \cdots & -il_{1n} \\ -il_{21} & il_2 & \cdots & -il_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ -il_{n1} & -il_{n2} & \cdots & il_{nn} \end{bmatrix}, \tag{3}$$

$$Y = \begin{bmatrix} \sum_{j=1}^{n} an_{1j} \\ \sum_{j=1}^{n} an_{2j} \\ \vdots \\ \sum_{j=1}^{n} an_{nj} \end{bmatrix}, \tag{4}$$

where:
il_{ij} – denotes the number of grades in an element of verse i and column j for all the tables,
il_i – denotes the number of grades in elements of verse I for all the tables.

According to AHP, the obtained systems are undetermined. In order to solve them the weight of one of the criteria with value is assumed to be 0, and its corresponding verse is removed. Acceptance of a zero value results also in removing the appropriate column. For the purpose of calculation, the weight value of criterion 1 was accepted to be zero (also analogical operations were performed with acceptance of the last criterion weight to be zero, obtaining an equivalent solution).

The reduced systems of equations were solved with the use of 'scilab' program. In this way, these solutions have been received.

The obtained solutions can be normalized, by adding to them value 10. Receiving assessments of the criteria significance according to SMART method. These assessments can be interpreted in consistence with the table.

Tab. 1. Interpretation of criterion assessment

Criterion assessment	Interpretation
10	Extremely significant
9	Very significant
8	Significant
7	Medium significant
6	Little significant
5	Very little significant
4	Insignificant

For calculations of a transportation system operation quality it is better to use the weight of criteria established for AHP method as their values approach to 1, which reflects relative degrees of the criteria significance in relation to each other. For this purpose there was made a transformation, according to the dependence described in work [6, 8]:

$$c_j = \frac{2^{w_j}}{\sum_{i=1}^{n} 2^{w_i}}, \tag{5}$$

where:
c_i – denotes AHP assessment of criterion j,
w_i – denotes solution of a normal equation system for criterion j,
n – number of criteria.

The obtained AHP weights have been presented in Tab. 1–4, being ordered from the most to the least significant one. Weights of criteria, according to particular groups of respondents and for the whole population of experts, are presented in the form of chart.

Results of calculations for particular groups and for all experts' method SMART are presented in Fig. 1.

In order to analyze the results obtained for particular groups of results, a relative weight drop was calculated for each criterion, according to the dependence:

$$wz_{j,j+1} = \frac{c_{j+1} - c_j}{c_{j+1}}, \tag{6}$$

where:
c_i – denotes AHP assessment of criterion j,
$wz_{j,j+1}$ – denotes a relative drop in weight of criterion j, in relations to j+l.

In Tab. 2–5, the first criterion, for which a bigger than 25% drop in weight was noted, is marked in bold. It is the first significance threshold for the considered criteria.

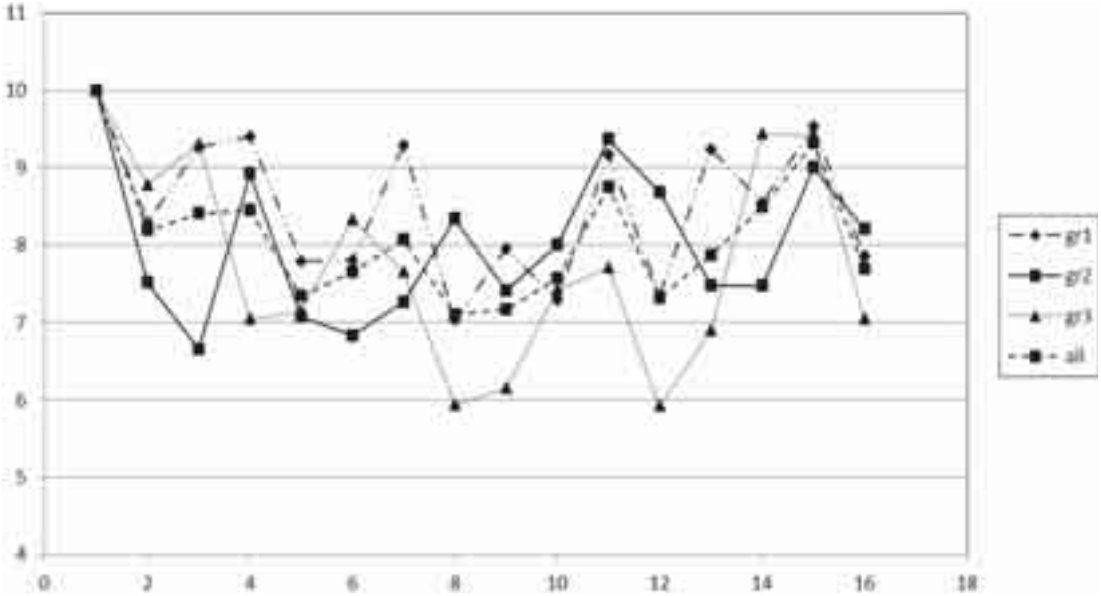

Fig. 1. Results of calculations for particular groups and for all experts

Whereas, it seems that a better criterion for reduction of the number of criteria is taking into consideration only three criteria whose weight is larger than the half of weight of the most significant criterion. The considered criteria presented in the tables in italics.

Tab. 2. Results of studies from the analysis of quality criteria significance assessment for the considered transportation system, provided by the drivers

Number of criterion	AHP weight	Relative drop in weight
1	0.14789167	
15	0.10677255	0.278035
4	0.097572114	0.086169
7	0.090801674	0.069389
3	0.088779026	0.022275
13	0.087405186	0.015475
11	0.083193389	0.048187
14	0.054037798	0.350456
2	0.045165428	0.164188
9	0.035868537	0.205841
16	0.033350743	0.070195
6	0.032270566	0.032388
5	0.032019902	0.007768
12	0.02343994	0.267957
10	0.022621881	0.0349
8	0.018809596	0.168522

Having analyzed results from the first set (Tab. 2) it can be said that the considered set of criteria can be reduced by criteria: 9, 16, 6, 5, 12, 10, 8 treating them as little insignificant from the point of view of this research.

Criteria: 2, 13, 14, 9, 7, 6, 3 concerning requirements of the analyzed system users (Tab. 3), can be regarded to be of little significance according to the obtained survey results.

As for the third set of notes, given by workers of the subsystem providing the system with operating continuity (Tab. 4), the criteria based quality vector dimensionality can be reduced to 6 criteria: 1, 2, 3, 6, 14, 15.

Tab. 3. Results of surveys obtained from the analysis of the transportation systems users' requirements

Number of criterion	AHP weight	Relative drop in weight
1	0.197825674	
11	0.127498447	0.355501
15	0.098998575	0.223531
4	0.093415229	0.056398
12	0.079442321	0.149578
8	0.062491405	0.213374
16	0.05685975	0.090119
10	0.049456418	0.130203
2	0.035214211	0.287975
13	0.034459643	0.021428
14	0.034310681	0.004323
9	0.032941535	0.039904
7	0.029637171	0.10031
5	0.02607031	0.120351
6	0.021960452	0.157645
3	0.019418177	0.115766

Tab. 4. Results of surveys obtained from the analysis of requirements of the transportation system maintenance workers

Number of criterion	AHP weight	Relative drop in weight
1	0.201156126	
14	0.136326466	0.322285
15	0.133868421	0.018031
3	0.124471519	0.070195
2	0.086128683	0.308045
6	0.06326878	0.265416
11	0.041167156	0.349329
7	0.03935355	0.044055
10	0.033612405	0.145886
5	0.027803062	0.172833
4	0.025806666	0.071805
16	0.025784316	0.000866
13	0.023440344	0.090907
9	0.013889491	0.407454
8	0.012039235	0.133213
12	0.01188378	0.012912

On the basis of the summary assessment of a particular criterion significance for a transportation system operation quality (Tab. 5) it can be said that criteria: 5, 12, 9, 8 were found to be of least importance, according to the respondents.

5. Conclusions

Having analyzed preferences of each group of the respondents it can be concluded that dimensionality if the considered set can be reduced to a seven-dimensional, criteria based quality vector, made up of criteria: 1, 2, 3, 4, 11, 14, 15.
In further research on the subject of a given transportation system operation quality, the determined criteria will provide basis for its assessment, whereas, their fulfilment degree will be crucial for the analyzed transportation system operation quality.

Tab. 5. Results of surveys concerning qualitative criteria, according to requirements of drivers, users of the system, and its maintenance workers

Number of criterion	AHP weight	Relative drop in weight
1	0.19938931	
15	0.123985496	0.378173804
11	0.08378447	0.324239748
14	0.069826088	0.166598674
4	0.068172168	0.023686287
3	0.066116766	0.03015016
2	0.056929754	0.138951325
7	0.052250066	0.082201089
13	0.045644241	0.126427104
16	0.040383506	0.115255189
6	0.039233865	0.028468081
10	0.036999766	0.056943116
5	0.031501769	0.148595453
12	0.031005328	0.01575915
9	0.028064885	0.094836698
8	0.026712521	0.048187042

It must be noted that the fulfilment degree of a particular criterion is affected by drivers who perform the transport tasks, users, that is, passengers of the studied system and workers of the system particular subsystems.

In connection with the above, for further research on the analyzed transportation system operation quality, the following criteria have been assumed: safety, efficiency, availability, ergonomics, punctuality, damageability, reliability.

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