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THE CRITERIA FOR IDENTIFYING THE QUALITY OF PASSENGERS' TRANSPORTATION BY RAILWAY AND THEIR RANKING USING AHP METHOD

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Abstract. Passengers' transportation by rail involving various interested groups, such as managers, service staff and passengers, is a complicated process. Decision-making persons, organizing railway trips should take into account the interests, needs and possibilities of these particular groups. The solution to some problems associated with passengers' transportation by rail depends on the experience and qualification of decision-makers, people who are responsible for the effectiveness of this work. To increase the quality of railway trips, the interested parties, groups of people mentioned above, should coordinate their actions, cooperate with each other in solving the problems and exchange relevant information. Therefore, the increasing quality of passenger transportation is a complicated issue, requiring good professional skills based on knowledge, practical experience, high intellect and new ideas of all the people involved in this process. The current paper presents a diagram showing passenger's transportation quality with a number of criterion groups A, B, C, D matching the structure and numbers of the questions included in the questionnaires to survey respondents (passengers) and experts (service and administration staff of the train). What is more, the *Analytic Hierarchy Process* (AHP) methodology based on the pair wise comparison ~~of~~ criteria is used to determine their weights (significances) considering the data obtained from the respondents and experts of each ~~of~~ three categories. Only these questionnaires which have no contradictory estimates are used. Also, the calculation methods demonstrating the results of the survey are provided in this work. One more point such as the data elicited from the respondents who took part in the survey (i.e. passengers from the train running on the international route Vilnius–Moscow) and experts (i.e. service staff of the already mentioned train and representatives of the administration staff from the Joint-Stock Company 'Lithuanian Railways' (AB „Lietuvos geležinkeliai")) is analyzed. Finally, the conclusions for improving the quality for passenger transportation by Lithuanian railways are given.

Keywords: passenger transportation, railway, quality, expert evaluation, AHP approach, consistency of estimates.

1. Introduction

The priorities of rail transport development in Lithuania are traffic safety, energy efficiency, competitiveness and provision of quality services to customers. It is also required that rail transport development should be environmentally friendly.

Transport sector is the key economic driver in any state, and Lithuania is not an exception in this respect. According to some analysts there is a great influence on economic development which definitely will remain in the future in the transition countries such as the Baltic States. However, the growth of transport sector, especially, road transport, causes the growth of jams and pollution, and the decrease of the traffic safety as well (Mačiulis *et al.* 2009). Therefore, the developed transport systems should be standardized, the control of transport sector performance should be more effective and the environment and noise pollution (particularly, the acoustic noise caused by rolling stocks) should be decreased or eliminated (Akgüngör and Demirel 2008; Bazaras 2006; Paslawski 2009; Tanczos and Torok 2007).

In recent years, the solution to transport problems has been based on various scientists' researches and their recommendations. To begin with, various investigations and the interaction problem among different rail transport systems in the EU member-states were discussed by Bureika and Mikaliūnas (2008), different high-speed transport systems were compared and the methods of their stochastic evaluation were considered by Schach and Naumann (2007). What is more, theoretical and technical aspects of electrodynamic braking of rolling stocks, which are of particular importance for high-speed rail transport,

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were analysed (Liudvinavičius and Lingaitis 2007). In addition, the methods of evaluating the locomotives' quality were studied (Juršėnas and Vaičiūnas 2007), the application of the assessing method of pre-design costs in the railway systems based on parametric modelling was described (Sonmez and Ontepeli 2009), and the model of urban railway to be used for increasing the performance of a complex railway system of transportation was constructed (Koutsopoulos and Wang 2007). In other works, the analysis of automatic clutch durability (Daunys *et al.* 2009) and the methods of improving traffic safety (Strang *et al.* 2007) and fire protection system in rail transport were described (Щеглов *и др.* 2007). Also, it is very important to control complicated processes, the analysis of activities, aims and tasks, as well as methods of their fulfilment, in order to be performed. The influence of various factors on work efficiency and quality should be also evaluated. To make effective decisions in technological and management areas as well as in the processes of automation in construction, etc., expert systems (Česnauskis 2007; Podvezko *et al.* 2010; Zavadskas *et al.* 2005; Wu *et al.* 2008; Abdelrahman *et al.* 2008; Chua and Li 2000; Liu *et al.* 2009; Brauers *et al.* 2008; Мальцев, Захаренков 2007), multicriteria evaluation methods (Ginevičius and Podvezko 2008; Žvirblis and Zinkevičiūtė 2008; Sivilevičius *et al.* 2008; Turskis *et al.* 2009), decision support systems *TOPSIS* and *SAW* (Jakimavičius and Burinskienė 2007; Liu 2009; Liaudanskienė *et al.* 2009; Zavadskas *et al.* 2010), games theory (Wang *et al.* 2007) and AHP (Ginevičius *et al.* 2004; Skibniewski and Chao 1992; Lin *et al.* 2008; Lai *et al.* 2008; Pan 2008; Podvezko 2009; Ustinovichius *et al.* 2007; Vainiūnas *et al.* 2009) method are commonly used. The procedures of ranking based on statistical hypotheses and their verification are also applied (Weed *et al.* 2007).

The growing construction of high-speed rail lines in Europe and in other world countries has sparked serious controversy about the possibility of introducing bimodal services to this type of track (Guirao *et al.* 2005). Korean trains express (KTX) of South Korea high-speed commercial rail service was introduced on 1/4/2004. It currently has two lines covering 661.1 km, and its trains achieve speeds of 300 km/h. KTX actually reduced rail travel time between major cities by half (Suh and Yang 2005). In Russia, high-speed trains are also expected to appear soon. The design speed on recently modernized railroad Moscow–Sankt-Petersburg is 250 km/h, and a completely new railway section is going to be built in this direction, allowing trains to develop the speed of 300–350 km/h.

In Lithuania, rail transport is not very attractive: trains do not attract passengers because their speed as well as the level of comfort is not high, while railways and the dynamic characteristics of the locomotives are far from being perfect (Bureika 2008; Dailydka *et al.* 2008). When rolling stocks are getting older, the maintenance costs are growing (Vaičiūnas and Lingaitis 2008).

Now, when Lithuania is the EU member-state, there is an urgent need for providing comfortable trips by train to the inhabitants of Lithuania and other EU member-states. Lithuania should provide direct passenger transportation by rail to Poland, which would allow Lithuanian citizens to travel to the other European countries by rail transport (Butkevičius 2007). To attract more passengers, transport services should be greatly improved, implying that not only high quality locomotives (Lata 2008), but well-trained personnel should be available too. This explains why the problems to increase the knowledge and skills for service people in the rail transport have been in such a focus for some researchers in various fields for several decades.

In the present paper, a model for evaluating knowledge potential, which is adapted to transport sector and takes into account the specific nature of the criteria describing it is offered. The following criteria are included in the model: education, professional experience, level of responsibility, scope of decision-making, independence in work, and work culture. Moreover, the use of technologies in the work, its complexity, motivation as well as the influence of the worker on realization of the organization's tasks and objectives (Morkvėnas *et al.* 2008) are considered. It is also important to identify the problems associated with the country's passenger transportation by rail, including the decrease of passenger flows, growth of transportation cost, lack of financing of unprofitable transportation routes, unfair competition conditions with road transport, lack of relevant laws, etc. (Butkevičius 2009). It is necessary to identify the needs and aims of passengers as well as methods of evaluating and improving the quality of passenger transportation by rail (Маскелюнайте, Сивилявичюс 2008). For this purpose, a questionnaire survey of passengers should be conducted and the weights of quantitative criteria should be determined (Maskeliūnaitė *et al.* 2009; Маскелюнайте, Сивилявичюс 2009; Пастухов 2008a, 2008b; Огинская, Толкачева 2006; Мирошниченко, Пастухов 2006). Surveys are often conducted for carrying out research, designing transport systems and collecting the required data. For example, a questionnaire survey on maintaining the corridor for freight and passenger transportation by rail transport was conducted in USA (Preserving Freight and Passengers… 2007).

Effective railway operation largely depends on the performance of railway terminals (Adamko and Klima 2008; Baublys 2009), optimization of traction vehicles' parameters (Jonaitis 2006), minimization of losses due to train delays and excessive power consumption (Mišauskaitė and Bagdonas 2006), as well as planning of the required rolling stock for transportation (Jonaitis 2007), cost reduction of railway passenger trips (Ziari *et al.* 2007), and incentives. For example, in Sweden, incentives resulted in train delay decrease of about 10% and the decrease of the number of technical errors about 20% (Stenbeck 2008).

2. Respondents, experts and questionnaires

Trips by train should be safe and comfortable. Only then railways can attract passengers and be competitive on the market. To attract more passengers, transport services should be improved, implying not only the availability of high-quality trains, but the identification of the needs

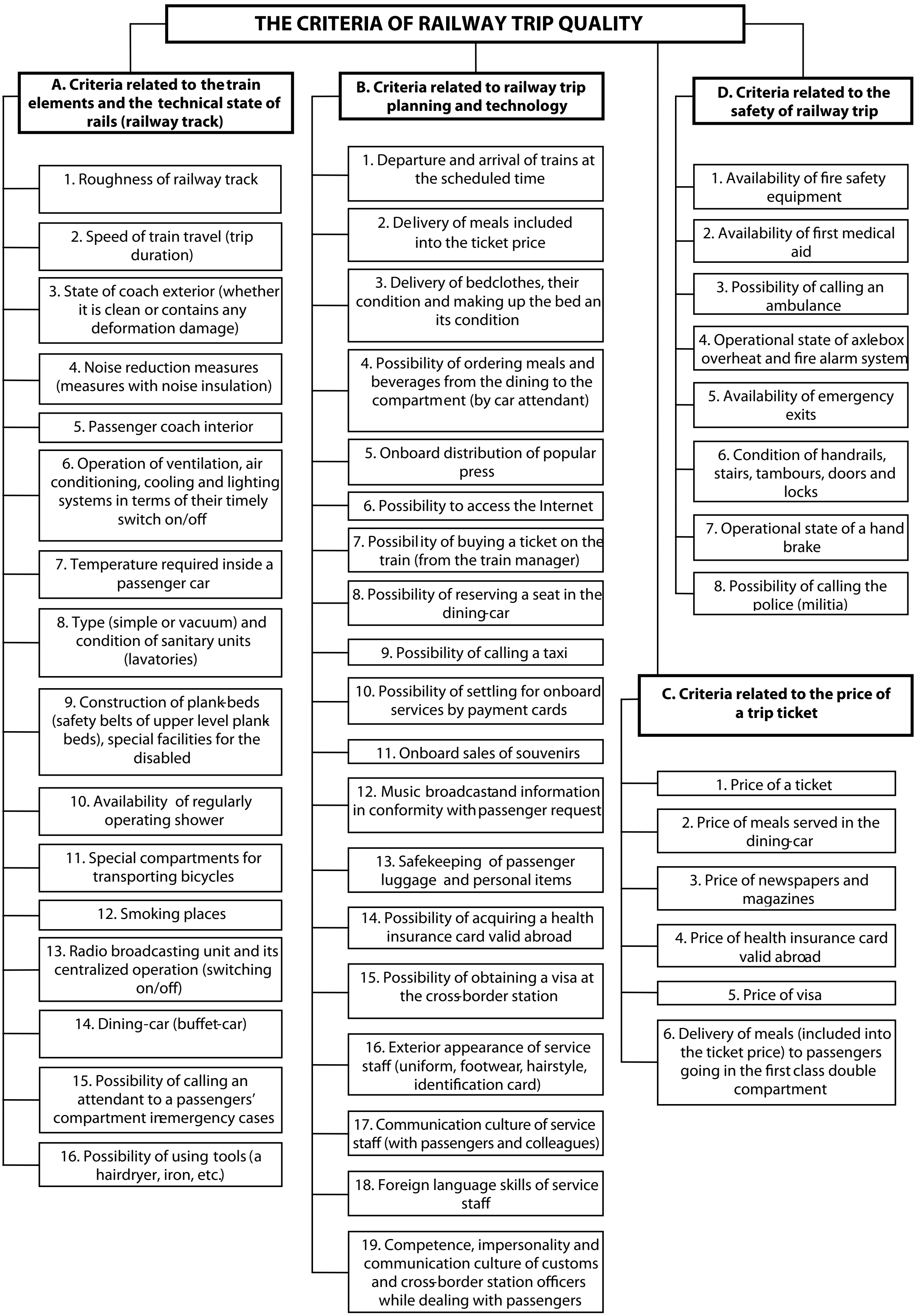

Fig. 1. A diagram of railway trip quality criteria groups A, B, C, D

for passengers as well. For this purpose, the profound analysis of passenger transportation quality should be performed.

The analysis was based on the application of the AHP method. The criteria describing railway trip quality were collected, the appropriate survey questionnaires were prepared and later distributed among the respondents (passengers) and experts (service staff and representatives of the Passenger Transportation Board of the Joint-Stock Company 'Lithuanian Railways' (AB „Lietuvos geležinkeliai")). The diagram of the railway trip quality criterion groups A, B, C, D (questionnaire's structure) is given in Fig. 1. A survey during the period from 3/9/2007 to 16/1/2008 was conducted. The questionnaire was translated into the English and Russian languages. Thirty two questionnaires were distributed among the passengers, represented by eighteen citizens of Lithuania, nine of Russia, one of the USA, one of Spain, one of Italy, one of Germany and one of Great Britain. However, only the data on 10 questionnaires completed by passengers (whereof 3 came from Lithuania, 4 from Russia, 1 from the USA, 1 from Germany and 1 from Italy) were actually used in the survey as the remaining 22 questionnaires were found to be inconsistent and, therefore, rejected.

17 questionnaires were given to the experts (i.e. service staff) too. Only 11 questionnaires were used in the survey.

Four questionnaires were handed over to the managers of Passenger Transportation Board of the Joint-Stock Company 'Lithuanian Railways' (AB „Lietuvos geležinkeliai"). Only three of them were used in the survey. Meanwhile, the evaluation of one questionnaire was rejected for the reason described above.

Table 1 shows, a number of questionnaires, distributed among the respondents and experts, which were completed, analyzed and used in the survey.

The inertia of the service staff of the train (e.g. train master, car attendant) and passengers (preferring to read a book or visit a dining car) did not allow us to conduct surveys in the trains operating on other routes and thereby to increase the number of respondents.

The questionnaires filled in by all respondents were collected, processed and analyzed.

Table 1. The number of questionnaires, distributed among the respondents and experts

Category of respondents or experts*	Submitted (used) questionnaires			
	Groups of criteria			
	A	B	C	D
K	32 (10)	32 (10)	32 (10)	32 (10)
P	17 (11)	17 (11)	17 (11)	17 (11)
A	4 (3)	4 (3)	4 (3)	4 (3)

* Categories of respondents and experts: K – passengers, P – service staff of the train, A – administration staff

3. Determining the significance of the criteria to describe the railway trip quality using AHP–approach

3.1. Determining the estimates of the criteria weight elicited from one expert

It is important to determine the significance of the obtained criteria by applying a decision support system. A method of pair wise comparison ~~of~~ criteria developed by T. Saaty was chosen for indicating the railway trip quality.

Methods of determining the weights of the criteria to describe the railway trip quality are considered to be subjective if they are evaluated by respondents or experts. In that case, experts' qualification should be high because the agreement of their estimates depends on it. For this purpose, the method of pairwise comparison of criteria suggested by Saaty (1980) and widely known as AHP (*Analytic Hierarchy Process*) is well suited. This approach allows the researchers to determine the weights of the criteria of the same hierarchical level with respect to higher level criteria or to determine hierarchically unstructured criteria weights. Experts compare all the evaluated criteria R_i and R_j $(i, j = 1,...,n)$, where n is the number of the compared criteria.

The application of AHP requires highly developed logical thinking, in particular, the estimate of one highly qualified expert may be more important than the estimates made by a number of inexperienced (not logically thinking) specialists. Therefore, researchers usually interview a number of highly qualified experts, for e. g. 5 experts (Farhan and Fwa 2009).

The method described above is easy to use because it is easier to compare pairs of criteria than all of them at a time. In this case, it is much more important a particular criterion which is compared to another. It is also possible to transform qualitative criteria estimates elicited from experts into the quantitative ones.

The matrix of the comparison of evaluation criteria ($a_{ji} = 1/a_{ij}$) is as follows:

$$\boldsymbol{A} = \begin{bmatrix} 1 & a_{12} & a_{13} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & a_{23} & \cdots & a_{2n} \\ \frac{1}{a_{13}} & \frac{1}{a_{23}} & 1 & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \frac{1}{a_{3n}} & \cdots & 1 \end{bmatrix}. \quad (1)$$

Let us find the eigenvector which may (1) be calculated in four ways (Шикин, Чхартишвили 2000). We will use the 4-th method:

1. The elements of each row are multiplied together and the results obtained are written as follows:

$$\omega_i'' = \prod_{j=1}^{n} a_{ij}. \quad (2)$$

2. *n-th* root is extracted from the element of each row (since the number of the criteria compared is $n = 6$,

the 6-*th* root is extracted). The results obtained are written as follows:

$$\omega_i' = \sqrt[n]{\prod_{j=1}^{n} a_{ij}}. \quad (3)$$

3. Let us add together the elements of this row:

$$\sum_{i=1}^{n} \omega_i' = \sum_{i=1}^{n} \sqrt[n]{\prod_{j=1}^{n} a_{ij}}. \quad (4)$$

4. Let us divide each element of this row by the sum obtained, i.e. the evaluations normalization:

$$\omega_i = \frac{\sqrt[n]{\prod_{j=1}^{n} a_{ij}}}{\sum_{i=1}^{n} \sqrt[n]{\prod_{j=1}^{n} a_{ij}}}. \quad (5)$$

Thus, the eigenvector $\boldsymbol{\omega}$ is found (step 4). The sum of its elements is equal to unity:

$$\sum_{i=1}^{n} \omega_i = 1. \quad (6)$$

3.2. The numerical example of processing the questionnaire's data

Let us calculate a pairwise comparison questionnaire completed by a respondent to illustrate the used technique.

To evaluate the quality of a railway trip, the weights of 6 criteria, describing the trip cost (the criteria of group C) (Fig. 1) were determined. The respondents (passengers) were given questionnaires of pairwise comparison of criteria. The completed comparison matrix is given in Table 2 as an illustration.

Table 2. An example of the 4th respondent's pairwise comparison of the criteria, describing ticket price

Indicator No.	1	2	3	4	5	6
1	1	7	7	3	1	3
2	1/7	1	3	1	1/5	1
3	1/7	1/3	1	1/3	1/9	1/5
4	1/3	1	3	1	1/5	1/3
5	1	5	9	5	1	7
6	1/3	1	5	3	1/7	1

Now, the eigenvector should be found.

The 4th method of calculation is used. It is implemented in the following order: the elements of each row of the questionnaire are multiplied together and the data obtained are written in a row; n-th root is extracted from each element of the obtained row; its elements are added together; each element is divided by the sum obtained. Using any of the four possible techniques in the case of an ideal matrix, we will get the same accurate result (Шикин, Чхартишвили 2000).

Based on the data presented in Table 2, we can find eigenvector by using the 4-th method of calculation. The steps of eigenvector's calculation and their results are given in Table 3.

Now, the largest eigenvalue $\lambda_{\max}$ should be found in the considered matrix.

Matrix $\boldsymbol{A}$ is multiplied by eigenvector $\boldsymbol{\omega}$ (step 4):

$$\boldsymbol{A\omega} = \begin{pmatrix} \frac{\omega_1}{\omega_1} & \frac{\omega_1}{\omega_2} & \cdots & \frac{\omega_1}{\omega_n} \\ \frac{\omega_2}{\omega_1} & \frac{\omega_2}{\omega_2} & \cdots & \frac{\omega_2}{\omega_n} \\ \cdots & \cdots & \cdots & \cdots \\ \frac{\omega_n}{\omega_1} & \frac{\omega_n}{\omega_2} & \cdots & \frac{\omega_n}{\omega_n} \end{pmatrix} \begin{pmatrix} \omega_1 \\ \omega_2 \\ \cdots \\ \omega_n \end{pmatrix} = \lambda\, \boldsymbol{\omega}. \quad (7)$$

The 1st row elements of Table 2 are multiplied by eigenvector $\boldsymbol{\omega}$:

$$1 \cdot 0.3178 + 7 \cdot 0.0765 + 7 \cdot 0.0306 + 3 \cdot 0.0733 +$$
$$1 \cdot 0.3929 + 3 \cdot 0.1089 = 2.0071.$$

Dividing the 1st element from the obtained row by the respective (first) element of the initial multiplication row (step 4), we get:

$$\frac{2.0071}{0.3178} = 6.3160.$$

Their closest average value is found. Then, we get:

$$\frac{1}{6}(6.3160 + 6.2047 + 6.2512 + 6.3056 +$$
$$6.3572 + 6.6166) = 6.3419.$$

We get largest eigenvalue:

$$\lambda_{\max} = 6.34.$$

It is known that the largest eigenvalue of the inverse symmetrical n -row matrix is $\lambda_{\max} \geq n.$ In the case considered, the matrix row or size is $n = 6.$ Therefore, $6.34 > 6.$ The condition is satisfied.

Now, it is easy to calculate the consistency index CI, which is expressed as follows:

$$CI = \frac{\lambda_{\max} - n}{n - 1}; \quad (8)$$

$$CI = \frac{\lambda_{\max} - n}{n - 1} = \frac{6.3419 - 6}{6 - 1} = 0.0684.$$

The smaller the CI value, the higher consistency of the matrix.

The relationship between the consistency index of the matrix CI and the average value of the random index RI, found from the table (Saaty 1980), is referred to as consistency ratio, $C.R.$, showing the degree of matrix consistency:

$$C.R. = \frac{CI}{RI}; \quad (9)$$

$$C.R. = \frac{CI}{RI} = \frac{0.0684}{1.24} = 0.0551.$$

Table 3. Steps of eigenvector's calculation and the results obtained in each step

Steps of eigenvector's calculation	Evaluation criterion No. 1	2	3	4	5	6	
	The data obtained in eigenvector's calculation						
Step 1	ω''_1	ω''_2	ω''_3	ω''_4	ω''_5	ω''_6	
The elements of each row are multiplied together $\omega''_i = \prod_{j=1}^{6} a_{ij}$ and the data obtained are written in a row							
The elements of the 1st row of Table 1 are multiplied together	$\omega''_1 = 1 \cdot 7 \cdot 7 \cdot 3 \cdot 1 \cdot 3 = 441$						
The results of multiplying together the elements of the 1st, 2nd, 3rd ..., 6th rows of Table 2 are as follows:	441	0.0857	0.0004	0.0667	1575	0.7143	The results obtained in step 1
Step 2	ω'_1	ω'_2	ω'_3	ω'_4	ω'_5	ω'_6	
n-th root is extracted from each element of the obtained row (since the number of the criteria compared is $n = 6$, 6th root is extracted) $\omega'_i = \sqrt[6]{\prod_{j=1}^{6} a_{ij}}$							
6th root is extracted from the 1st element of the obtained row:	$\omega'_1 = \sqrt[6]{441} \approx 2.7589$						
The following values are obtained by extracting 6th root from the 1st, 2nd, 3rd ... 6th element of the obtained row:	2.7589	0.6640	0.2658	0.6368	3.4110	0.9455	The results obtained in step 2
Step 3							
The elements of this row are added together $\sum_{i=1}^{n} \omega'_i = \sum_{i=1}^{6} \sqrt[6]{\prod_{j=1}^{6} a_{ij}}$:	$2.7589 + 0.6640 + 0.2658 + 0.6368 + 3.4110 + 0.9455 = 8.6820.$						The results obtained in step 3
Step 4	ω_1	ω_2	ω_3	ω_4	ω_5	ω_6	
Each element of this row is divided by the sum obtained $\omega_i = \frac{\sqrt[6]{\prod_{j=1}^{6} a_{ij}}}{\sum_{i=1}^{6} \sqrt[6]{\prod_{j=1}^{6} a_{ij}}}$							
The 1st element of this row is divided by the sum obtained	$\omega_1 = \frac{2.7589}{8.6820} = 0.3178...,\quad \omega_6 = \frac{0.9455}{8.6820} = 0.1089$						
The following values are obtained by dividing the 1st, 2nd, 3rd ... 6th element of this row by the sum obtained:	0.3178	0.0765	0.0306	0.0733	0.3929	0.1089	The results of step 4 (eigenvector) $\sum_{i=1}^{6} \omega_i = 1.0000$

The matrix is considered to be consistent if the value of *C.R.* is smaller than or equal to 0.1. Since $0.0551 < 0.1$, the considered matrix is consistent.

3.3. The estimates consistency of the group of respondents or experts

The idea of the concordance coefficient is associated with the sum of ranks of each criterion c_i with respect to the estimates of experts and respondents:

$$c_i = \sum_{j=1}^{m} c_{ij} \, (i = 1,...,n), \quad (j = 1,...,m), \tag{10}$$

where: m is the number of respondents or experts, or, more exactly, to the deviation of values c_i from the sum of squares S of the average value $\overline{c}$ (the analogue of variance):

$$S = \sum_{i=1}^{n} (c_i - \overline{c})^2. \tag{11}$$

The average value $\overline{c}$ is calculated by the formula:

$$\overline{c} = \frac{\sum_{i=1}^{n} c_i}{n} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}}{n}. \quad (12)$$

The level of consistency of respondents' and experts' estimates is shown by the concordance coefficient W:

$$W = \frac{12S}{m^2 n(n^2 - 1)}, \quad (13)$$

where: S calculated by the equation (11).

If the estimates of the respondents or experts are consistent, the concordance coefficient W is about one (unity). When the estimates differ to a great extent, W is about zero.

The smallest value of the concordance coefficient $W_{\min}$, not allowing us to state that the estimates of the quality of the research object described by n criteria provided by all m respondents or experts with the prescribed significance level α and degree of freedom $\nu = n - 1$, are consistent, may be calculated by the suggested formula:

$$W_{\min} = \frac{\chi^2_{\alpha,\nu}}{m(n-1)}, \quad (14)$$

where: $\chi^2_{\alpha,\nu}$ is critical chi-square (Pearson) statistics, found from the table (Montgomery 2008) by assuming the degree of freedom $\nu = n - 1$ and the significance level α.

The concordance coefficient can be calculated based on the ranks of the criteria assigned by experts. If their estimates were presented in any other form, they should be ranked. Ranking is a procedure, when the most significant criterion is given the rank of one, the second is ranked by two, etc.

3.4. A numerical illustration of consistency from respondents' (passengers') estimates

The ranking of the criteria, describing ticket price (group C) according to their significance, carried out by ten respondents (passengers) is demonstrated in Table 4.

The example of criteria ranking which describes the ticket price according to their significance performed by the respondent (passenger) No 4 is given in Table 5.

The sum of ranks of all the criteria (of the last elements of Table 4) which is $\sum_{i=1}^{m} c_i = 210$. The average value of the criteria ranks, calculated by formula (12) is $\overline{c} = 35$, or, calculating by another method, it is $\overline{c} = 210/6 = 35$. The sum of deviations of the squares is $S = 853.5$.

The concordance coefficient of the criteria associated with the ticket price obtained from a group of respondents (ten passengers) by formula (13) is expressed as $W = 0.49$.

A random value:

$$\chi^2 = Wm(n-1) = \frac{12S}{mn(n+1)} \quad (15)$$

is distributed according to χ^2 distribution with the degree of freedom $\nu = n - 1$. Based on the selected significance level α (which is usually 0.050 or 0.010), the critical value $\chi^2_{\alpha,\nu}$ may be found from the distribution table of χ^2 with the degree of freedom $\nu = n - 1$. If the value of χ^2 calculated by formula (15) is larger than $\chi^2_{\alpha,\nu}$, the estimates of respondents are consistent.

Table 5. The ranks assigned by respondent (passenger) No 4 to the criteria describing ticket price according to their significance

Criteria	Criterion weight	Rank
1	0.3178	2
2	0.0765	4
3	0.0306	6
4	0.0733	5
5	0.3929	1
6	0.1089	3
Total	1.0000	21

Table 4. Ranking of ticket price-related criteria in respondent questionnaires

Criteria	Respondent No.										Sum of ranks
	1	2	3	4	5	6	7	8	9	10	
1	1	1	1	2	1	1	3	1	3	4	18
2	3	5	2	4	4	5.5	3	2	4.5	3	36
3	4	6	4.5	6	6	5.5	6	4	6	6	54
4	5	3	4.5	5	4	3	3	5	2	2	36.5
5	2	2	6	1	2	2	3	3	1	1	23
6	6	4	3	3	4	4	3	6	4.5	5	42.5
Total	21	21	21	21	21	21	21	21	21	21	210

Using the data given in Table 3 and calculating by formula (15), we get $\chi^2 = 24.39$. The value of χ^2 was calculated to be equal to 24.39, while the value of $\chi^2_{\alpha,\nu}$ taken from the distribution table with the degree of freedom $\nu = 6 - 1 = 5$ and the significance level $\alpha = 0.050$ is equal to 11.07. The empirical value $\chi^2 = 24.39$ is larger than the critical value; therefore, the estimates of respondents are consistent.

Now, let us calculate the smallest value of the concordance coefficient W_{min}. The minimum value of the concordance coefficient W_{min} is calculated by formula (14) (Айвазян, Мхитарян 2001), with the significance level $\alpha = 0.050$ and the degree of freedom $\nu = n - 1 = 6 - 1 = 5$, allowing us to state that the respondents' estimates are still consistent: $W_{min} = 0.22 < 0.49$. The critical value $\chi^2_{\alpha,\nu}$ (taken from the distribution table with the respective degree of freedom and the significance level $\alpha = 0.050$) and the smallest concordance coefficient W_{min} values found in the questionnaires aimed to evaluate the significance of the criteria groups A, B, C, D, which were elicited from respondents and experts of various categories (10 passengers, 11 service people and 3 representatives of the administration staff) are given in Table 6. It can be noticed that the estimates of the significance of the criteria of the group D elicited from the experts of category A (i.e. administration staff) are not consistent (see Fig. 3d and Table 6). The calculated value is $\chi^2 = 10.39$, while the critical value $\chi^2_{\alpha,\nu}$ taken from the distribution table with $\nu = 8 - 1 = 7$ degree of freedom and the significance level $\alpha = 0.050$ is 14.07. The empirical value $\chi^2 = 10.39$ is smaller than the critical value $\chi^2_{\alpha,\nu} = 14.07$, therefore, the estimates of respondents are not consistent. The smallest value of the concordance coefficient $W_{min} = 0.67$ is larger than the concordance coefficient $W = 0.49$.

4. The significance of determined criteria based on passengers' estimates

Based on the judgments of the surveyed respondents, the significance of the criteria A1–16, B1–19, C1–6, D1–8 (Fig. 1) was determined.

The mean values of the criteria weights computed using the AHP method and the respective positions of the criteria in the questionnaire of each respondent help to determine the significance of the criteria defining the quality of passenger transportation by Lithuanian railways (Maskeliūnaitė *et al.* 2009).

5. The evaluation of the criteria significance by service staff of the train

The questionnaires of the same type were used in the research (Fig. 1). The analysis has shown that the estimates given by the service staff are quite consistent (Fig. 2a, b, c, d).

The bar diagram significance of the criteria of the group A1–16 to service staff is given in Fig. 2a. As shown by the diagram, the highest ranks are assigned by service people to the criteria A6, A8 and A7 (Figs 1 and 2a), while the lowest ranks are given to the criteria A1, A12 and A3. We think that service people of the train could not avoid the influence of their work and its specific nature and therefore were not able to assess the criteria from passengers' perspective. The comfort of the trip described by the criteria A6, A8 and A7 is important for them, while the criterion A1, influencing the speed of the train (trip duration) does not seem to be significant because the train is their workplace (Maskeliūnaitė and Sivilevičius 2009).

A bar diagram showing the significance of the group of criteria B1-19 to service staff is given in Fig. 2b. As shown in the diagram (Figs 1 and 2b), the criteria B15, B1 and B19 are significant to service people, while the criteria B4, B8 and B11 seem to be insignificant to them. We think that the criteria B15 and B1 are considered to be important for service people because they are perfectly aware of the troubles caused to passengers by delayed trains. They also often witness the detraining of passengers at the cross-border station because of some problems with their visas or other documents. In this case, a passenger is forced to interrupt the trip. Therefore, his/her mood is spoiled and plans are ruined. The criterion B19 is important for service staff because the behaviour, competence, objectivity and contacts with people such as custom's officers and frontier guards is perceived to be a sort of visiting card of the country they represent. The criteria B4, B8, B11 are insignificant to the service staff of

Table 6. The value of the concordance coefficient W the calculated value χ^2 and the lowest value of the concordance coefficient W_{min} for the criteria of the groups A, B, C, D, obtained in the questionnaires elicited from respondents (K) and experts (P, A)

The category of respondents or experts*	Groups of criteria											
	A			B			C			D		
	Value											
	W	χ^2	W_{min}	W	χ^2	W_{min}	W	χ^2	W_{min}	W	χ^2	W_{min}
K	0.33	49.03	0.17	0.38	68.49	0.16	0.49	24.39	0.22	0.45	31.75	0.20
P	0.21	35.10	0.15	0.36	71.54	0.15	0.42	22.84	0.20	0.47	36.05	0.18
A	0.73	32.77	0.56	0.82	44.49	0.53	0.83	12.52	0.74	0.49	10.39	0.67
$\chi^2_{\alpha,\nu}$		25.00			28.87			11.07			14.07	

* The categories of respondents and experts: K – passengers, P – service staff of the train, A – administration staff

the train. This attitude may be explained by the specific character of their work because car attendants (as service people) provide these services. Sometimes, the criterion does not have any influence on the comfort of a service person, e.g. the criterion B8.

A bar diagram evaluating the significance of the criteria in group C1–6 to service staff of the train is given in Fig. 2c. It can be observed that the criteria C5, C1 and C4 are significant to service people (see Figs 1 and 2c) because passengers spend most of their money on these services during the trip. The criteria C6, C2 and C3 are of no importance to service people.

A bar diagram showing the estimates significance of the criteria in the group D1–8 provided by the service staff of the train is given in Fig. 2d. It is thought that the criteria D4, D7 and D1 are important for service staff because as specialists they realize the significance of these criteria for ensuring trip safety. The criteria D3, D8 and D6 are assessed as being not important because all failures during the trip are fixed by the train electrician. Besides, they do not affect the safety of the trip. No problems arise if it is necessary to call the emergency service or the police (militia) from the train.

6. The evaluation of the significance of criteria by the administration staff

The significance of the criteria groups A, B, C, D (Figs 1 and 3a, b, c, d) was determined by the administration staff of the Passenger Transportation Board of the Joint-Stock Company 'Lithuanian Railways' (AB „Lietuvos geležinkeliai").

The analysis has shown that the estimates of the significance of the criteria in groups A, B and C made by the administration staff are completely consistent (see Fig. 3a–c). However, the estimates of the criteria of the group D are not consistent (Fig. 3d).

A bar diagram showing the significance of the criteria of the group A1–16 to the administration staff is given in Fig. 3a (see Figs 1 and 3a). It can be observed that the criteria A2, A7 and A6 are important for the administration staff because the quality of railway trip largely depends on them. The criteria A12, A11 and A15 were assessed as unimportant. The members of the administration staff do not attach high significance to these criteria because there are special areas for smoking in the trains on international routes. Moreover, a passenger is

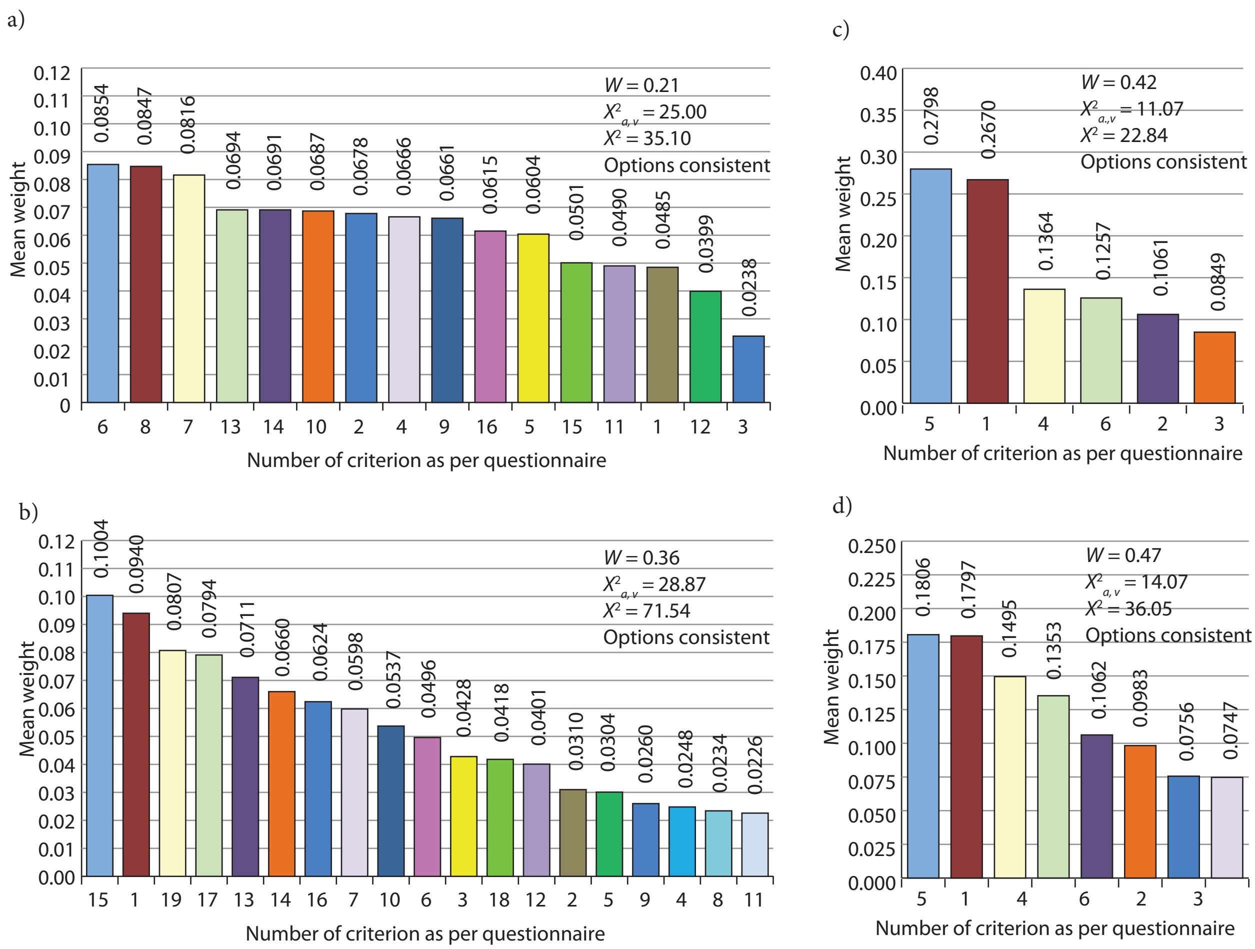

Fig. 2. The data on the evaluation of the significance of the grouped criteria describing the quality of passenger transportation by rail elicited from the service staff of the train (category of experts P): a – the technical state of the train parts and the railway (group A); b – denotes the organization and technology of railway trip (group B); c – the ticket price (group C); d – railway trip safety (group D)

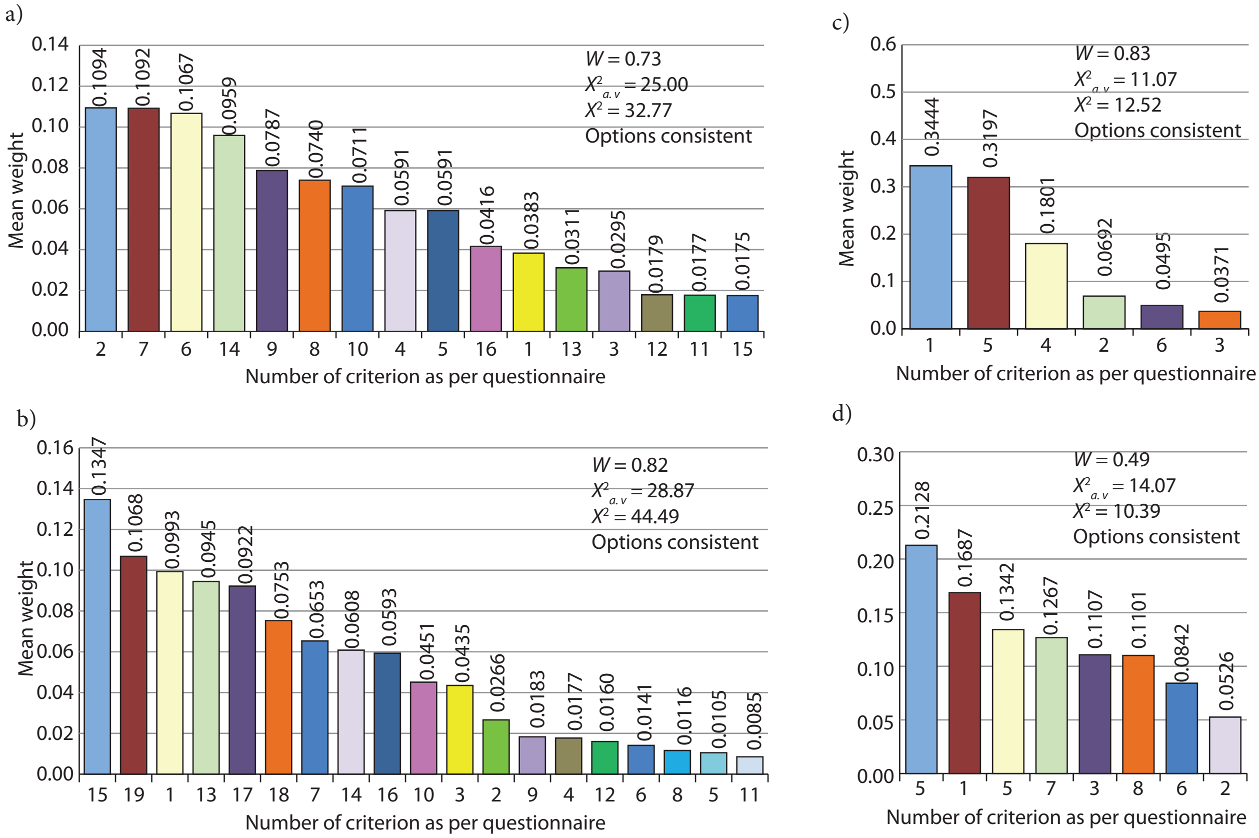

Fig. 3. The data on the evaluation of the significance of the grouped criteria describing the quality of passenger transportation by rail elicited from the administration staff (category of experts A): a – the technical state of the train parts and the railway (group A); b – denotes the organization and technology of railway trip (group B); c – the ticket price (group C); d – railway trip safety (group D)

allowed to carry a bicycle with him/her if it is taken apart (the wheels are removed) and packed, while two-birth compartments of the first-class cars are provided with the buttons for emergency calling or for car attendant. It seems that service people do not attach great importance to the criteria given above for these reasons.

The service people of the train consider the criteria B15, B19 and B1 (Figs 1 and 3b) to be significant because they, as experienced specialists, are aware of their important role in ensuring high quality of railway trip. The experts consider the criteria B8, B5 and B11 to be unimportant.

A bar diagram, showing the significance of the criteria in the group C1–16 to the administration staff, is given in Fig. 3c. As shown in this figure, the criteria C1, C5 and C4 (see Figs 1 and 3c), describing the ticket price, are considered to be the most important, while the criteria C2, C6 and C3 are assessed as insignificant.

A bar diagram showing the estimates significance of the criteria in the group D1–8 and provided by the administration staff is presented in Fig. 3d (Figs 1 and 3d). It can be observed that the criteria D4, D17 and D5 determining trip safety are important for service people, while the criteria D8, D6 and D2 are considered to be insignificant to them. However, as mentioned above, the estimates of the criteria in the group D are not consistent. It is assumed that the lack of carefulness, logical thinking or even competence of the administration staff has an impact on the evaluating the criteria.

7. The comparative analysis of the respondents and experts estimates

The significant estimates of the the i-th criterion in the group A elicited from the respondents and experts of all three categories (K, P, A) are expressed by the weight coefficient $\bar{Q}_{Ai}$ calculated by the formula:

$$\bar{Q}_{Ai} = \frac{\sum_{e=1}^{3} Q_{Aie}}{3} = \frac{Q_{AiK} + Q_{AiP} + Q_{AiA}}{3}, \qquad (16)$$

where: Q_{Aie} is weight coefficient $(i = 1,2,...,n)$ assigned to j-th criterion of the criteria group A (in the questionnaires) by experts (representing the respondents' category e); Q_{AiK} is weight coefficient assigned to i-th criterion of the criteria group A by passengers; Q_{AiP} is weight coefficient assigned to j-th criterion of the criteria group A by service staff; Q_{AiA} is weight coefficient assigned by administration staff to j-th criterion of the criteria group A.

Mean weight coefficients $\bar{Q}_{Bi}$, $\bar{Q}_{Ci}$, $\bar{Q}_{Di}$ of the criteria in other groups (B, C, D) were calculated using similar formulas (Table 7).

Table 7. Summary table of respondents' and experts' estimates

Criterion number in a questionnaire	Group of criteria																			
	A					B					C					D				
	Criterion																			
	Mean weight $\bar{Q}_{Ai}$	Rank	Category (rank) of respondents and experts*			Mean weight $\bar{Q}_{Bi}$	Rank	Category (rank) of respondents and experts*			Mean weight $\bar{Q}_{Bi}$	Rank	Category (rank) of respondents and experts*			Mean weight $\bar{Q}_{Bi}$	Rank	Category (rank) of respondents and experts*		
			K	P	A			K	P	A			K	P	A			K	P	A
1	0.0400	12	15	14	11	0.1072	1	1	2	3	0.3258	1	1	2	1	0.1514	2	2	3	2
2	0.1035	2	1	7	1	0.0293	14	16	14	12	0.0982	4	4	5	4	0.0957	7	3	5	8
3	0.0307	16	12	16	13	0.0509	9	4.5	11	11	0.0551	6	6	6	6	0.1087	5	7	6	5
4	0.0562	8	9	8	8.5	0.0300	13	10	17	14	0.1517	3	3	3	3	0.1726	1	5	1	1
5	0.0560	9	8	11	8.5	0.0276	15	12	15	18	0.2844	2	2	1	2	0.1297	4	6	4	3
6	0.0997	3	3	1	3	0.0401	12	7	10	16	0.0849	5	5	4	5	0.0953	8	4	8	7
7	0.1042	1	2	3	2	0.0600	6	8	8	7						0.1504	3	1	2	4
8	0.0813	5	4	2	6	0.0221	17	15	18	17						0.0963	6	8	7	6
9	0.0624	7	10	9	5	0.0219	18	19	16	13										
10	0.0709	6	6	6	7	0.0467	11	13	9	10										
11	0.0345	15	13	13	15	0.0180	19	17	19	19										
12	0.0360	13	7	15	14	0.0262	16	18	13	15										
13	0.0450	11	14	4	12	0.0898	3	2	5	4										
14	0.0822	4	5	5	4	0.0587	7	9	6	8										
15	0.0359	14	11	12	16	0.1030	2	3	1	1										
16	0.0452	10	16	10	10	0.0560	8	11	7	9										
17						0.0794	5	4.5	4	5										
18						0.0507	10	14	12	6										
19						0.0826	4	6	3	2										

* The categories of respondents and experts: K – passengers, P – service staff of the train, A – administration staff

The comparative analysis of railway trip evaluation by three categories of passengers and administration staff has shown that the criteria A2, A7 and A6 are significant for all of them. It can be considered that the estimates provided by the administration staff match those of passengers because they do not work in the train and therefore can easier assess the criteria significance from passengers' perspective. However, different estimates were given to insignificant criteria (Figs 1 and 2a, 3a). The similarity could be only observed in the estimates of the criterion A1 provided by passengers (Maskeliūnaitė *et al.* 2009) and service staff and in the evaluation of the criterion A12 by the service and administration staff.

The significance of the criteria in the group B was actually determined in a similar way (Figs 1 and 2b, 3b) by the service and administration staff. They considered the criteria B15, B19 and B1 to be significant. The experts, being highly experienced in the discussed issues are aware of the significance of these criteria to passenger transportation quality. The estimates which were given for insignificant criteria B8 and B11 were not much different as well.

The estimates given by the passengers and administration staff to the significance of all criteria in the group C are actually the same, and the judgments of the service staff are similar to them (Figs 1 and 2c, 3c).

The criterion D4 was assessed to be equally significant to all experts (Figs 1 and 2d, 3d). As specialists, they are aware of its importance for traffic safety. The criterion D1 was similarly assessed by passengers and administration staff (Figs 1 and 3d). Moreover, the estimates given by 3 groups of respondents to the criteria D3, D8 and D6 (Figs 1 and 2d, 3d) as insignificant ones did not differ much.

Thus, the profound analysis of the significance estimates of passenger transportation (trips by rail) quality criteria has shown that the criteria A7, A2 and A6, B1, B15 and B13, C1, C5 and C4, D4, D1 and D7 are the most significant to respondents and experts (Fig. 1 and Table 7).

The estimates provided by respondents (passengers) and experts (administration staff) show the highest similarity (Table 8).

Table 8. The number of matching estimates (ranks) provided by respondents and experts

Group of criteria	K=P	K=A	P=A
A	3	4	2
B	2	0	3
C	2	6	2
D	0	1	1
Total	7	11	8

8. Conclusions

1. The statistical data processing of the questionnaires elicited from respondents (passengers) and experts (service staff of the train and representatives of the administration staff of Passenger Transportation Board of the Joint-Stock Company 'Lithuanian Railways' (AB „Lietuvos geležinkeliai") for the significance of the criteria in the groups A, B, C, D, allowed the authors to identify the most significant criteria describing passenger railway trips. Based on the values obtained, the importance and influence of these criteria, allowing the quality of passenger transportation to be increased, were demonstrated.
2. The AHP suggested by T. Saaty, and used in evaluation requires highly developed logical thinking of decision-makers. Highly qualified experts are required because the consistency of estimates. The estimate of a single highly competent expert is more important than the estimates provided by several or even tens of inexperienced specialists (not capable of thinking logically).
3. The researchers were faced with some difficulties trying to apply the method AHP to the survey conducted in the train. Passengers did not show any initiative as respondents. The motivation of the service staff of the train which was discussed in the research also plays an important part. The significant estimates of the criteria in all groups elicited from passengers are completely consistent.
4. The estimates provided by the service staff of the train are completely consistent. Service people may be considered to be qualified appraisers, though they could not completely avoid the influence of their work on evaluation and assess the criteria from the perspective of passengers.
5. The estimates of the criteria, relating to the significance of railway trip safety, elicited from the representatives of administration staff are not consistent. It may be explained by their lack of carefulness, logical thinking or competence in evaluating these criteria.
6. The highest similarity of the estimates provided by passengers (respondents) and experts (administration staff) can be observed. The train is not their workplace (as it is for the service staff), therefore, it seems easier for them to evaluate the criteria from passengers' perspective.
7. The plan of improving the quality of the issues expressed by the most significant criteria, including practical measures and actions to be taken for this purpose, was developed.

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