Basic approaches to the choice of methods of passenger traffic flow analysis

A V Kulev, M V Kulev* and N S Kuleva

Orel State University, 95 Komsomolskaya str., Orel, 302026, Russia

*maxim.ka@mail.ru

Abstract. Analysis of passenger traffic flow is considered to be one the most important stages of planning and construction of the most appropriate route network of public municipal passenger transport. At the same time, a great variety of methods of passenger traffic flow analysis confuses and prevents from a proper choice of the precise methods to conduct a research. The aim of this article is to find and substantiate basic approaches which can help to find a practical set of methods for analysis of passenger traffic flow in particular cities. To achieve this aim the article analyzes basic advantages and disadvantages of each method, their application fields, restrictions which are set by conditions of different populated areas. The article also suggests research and methodological approach to finding the most appropriate methods of passenger traffic flow analysis.

1. Introduction

The study of passenger traffic flows is one of the main stages of organization of work of public municipal passenger transport system because completeness and accuracy of information influences whether new routes, traffic schedule and passenger capacity of public transport and other parameters will be appropriate or not. However, at present there is no scientific approach to the choice of methods of passenger traffic flow analysis which would take into consideration conditions of particular populated areas [1,2,4,5]. The aim of this article is to find and substantiate basic approaches which can help to find a practical set of methods for a study of passenger traffic flow in particular cities. To achieve this aim it is necessary to fulfill the following tasks: find the most complete classifications of existing methods for passenger traffic flow analysis; analyze methods of passenger traffic flow from the point of view of completeness of obtained information; develop a scientific approach to finding a set of methods of passenger traffic flow for a particular city.

2. Material and methods

To create a route traffic network of a city it is necessary at least to know directions, the amount of traffic in different city areas, quantitative value of passenger traffic flow. To find out the mentioned common factors is possible by means of regular examination of passenger traffic flow. Figure 1 depicts the most complete classification of methods of passenger traffic flow examination [1,2,7,8,9,10,11,13].
Figure 1. Classification of methods of passenger traffic flow examination.

The choice of methods for the study is based on the nature, completeness, volume and accuracy of information received by this or that method (Figure 2).

Figure 2. Analysis of methods of research of passenger traffic flow from the point of view of information quality
From the point of view of the given criteria the basic methods are schedule, questionnaire, transport tickets and computer-aided methods [14,15]. The least useful methods are statistical, visual, contingent valuation, expert evaluation methods and methods of mathematical modeling [12]. When choosing a method one needs to take into consideration the cost and effort-intensity of the analysis, possibilities of application of any particular method in the analysis of passenger traffic flow in a reviewed municipal entity.

The performed analysis allows us to make a set of methods for passenger traffic flow analysis which will make it possible to obtain the most complete and accurate information necessary to improve public transport network at minimum cost of research and, not the least, possible to apply in Orel. To find the most appropriate set of methods for passenger traffic flow analysis we used the most theoretically validated and well-behaved method of prior grading [11,12].

3. Theory
Exclusion of some factors took place at an initial stage. We excluded computer-aided, statistical and expert-evaluation methods of passenger traffic flow analysis. The fact that computer-aided method was excluded is because of its high cost, so the application of such a method for a single passenger traffic flow analysis is not rational. Statistical methods will not help to obtain complete and accurate information concerning passenger traffic flow in Orel because there are no conductors in private public transport buses. That is why paying the fare passengers do not get and take any ticket. Expert-evaluation methods are also of little use what concerns accuracy of information because experts whose judgment should be taken into consideration are the drivers of private public transport buses who will certainly understate passenger traffic flow, mainly because they would not like to disclose their profits. Methods of transport traffic flow analysis which we did not exclude were considered to be factors which the prior grading would be based on. Assessments given by experts of grading concerning each viewed factor were presented as grades/points (Table 1).

4. Results
The algorithm of evaluation of methods of passenger traffic flow analysis by means of a prior grading presupposes the following calculations [3]:
1. The rank sum of each method out of analyzed methods \( k \) by all experts is calculated according to the following equation [3]:
\[
\Delta_k = \sum_{n=1}^{m} a_{in} ,
\]  
where \( m \) is the number of interviewed experts, 
\( \kappa \) is the number of methods of passenger traffic flow analysis (factors).
2. The method of a prior grading requires certain checkups based on the following criteria [3]:
Maximum sum of ranks of each method ( \( a_{in} \) ) should be less than the total number of methods:
\[
a_{in} \leq k = (a_{in})_{\text{max}} .
\]  
Maximum sum of ranks of each method should be less than the product of a maximum rank and the number of experts:
\[
(\Delta_k)_{\text{max}} \leq (a_{in})_{\text{max}} \cdot m .
\]  
Minimum sum of ranks of each method should be higher than the product of the minimum rank and the number of experts:
\[
(\Delta_k)_{\text{min}} \geq (a_{in})_{\text{min}} \cdot m .
\]  
These conditions are observed for every factor: \( a_{in} \leq 7 = (a_{in})_{\text{max}} , \Delta_k \leq 56 = (\Delta_k)_{\text{max}} , \Delta_k \geq 8 = (\Delta_k)_{\text{min}} . \)
Table 1. Results of a prior grading of passenger traffic flow analysis.

| Factors under analysis | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Experts, m | Sum of ranks $\Delta k$ | Variations in the sum of ranks $\Delta k'$ | $(\Delta k')^2$ | Rank M1 | Weighting factor $q_k$ |
|------------------------|---|---|---|---|---|---|---|---|-------------|-----------------|---------------------|-----------------|---------|-------------|
| Evaluative ranks $a_{km}$ |   |   |   |   |   |   |   |   | Schedule method (k=1) | 2 | 1 | 1 | 3 | 2 | 1 | 2 | 1 | 13 | -19 | 5 | 1 | 0,25 |
| Outline method (k=2) | 4 | 5 | 3 | 2 | 4 | 4 | 3 | 4 | 29 | -3 | 9 | 4 | 0,14 |
| Ocular estimate method (k=3) | 1 | 2 | 2 | 4 | 3 | 2 | 1 | 2 | 17 | -15 | 225 | 2 | 0,21 |
| Questionnaire method (k=4) | 3 | 3 | 4 | 1 | 1 | 3 | 4 | 3 | 22 | -10 | 100 | 3 | 0,18 |
| Contingent valuation method (k=5) | 6 | 7 | 6 | 7 | 6 | 7 | 6 | 7 | 52 | 20 | 400 | 7 | 0,04 |
| Transport ticket method (k=6) | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 40 | 8 | 64 | 5 | 0,11 |
| Methods of mathematical modeling (k=7) | 7 | 6 | 7 | 6 | 7 | 6 | 7 | 5 | 51 | 19 | 361 | 6 | 0,07 |
| Overall | Sum of $\Delta k=224$ | S=1520 | 1,0 |

3. The sum of ranks is calculated as follows [3]:

$$\sum_{i=1}^{7} \Delta_i,$$

$$\sum_{i=1}^{7} \Delta_i = 51 + 22 + 40 + 29 + 52 + 17 + 13 = 224$$

4. Average sum of ranks is calculated according to the following equation [3]:

$$\Lambda = \frac{1}{k} \sum_{i=1}^{7} \Delta_i,$$

$$\bar{\Lambda} = \frac{\sum_{i=1}^{7} \Delta_i}{7} = \frac{224}{7} = 32.$$ 

5. Correctness assessment of the sum of ranks is calculated according to the following equation [3]:

$$\sum_{i=1}^{7} \Delta_i = m \cdot k \cdot \bar{\Lambda},$$

where $\bar{\Lambda}$ is an average rank which is calculated as follows [3]:

$$\bar{a} = \frac{1}{k} \sum_{i=1}^{7} \Delta_i,$$

$$\bar{a} = \frac{1+2+3+4+5+6+7}{7} = 4.$$

Sum of $\Delta_i = 8 \cdot 7 \cdot 4 = 224$, which totally corresponds to values presented in Table 1.

6. The difference between the sum of ranks of all methods and an average sum of ranks can be calculated according to the following equation [3]:

$$\Delta_i' = \Delta_i - \bar{\Lambda},$$

$$\Delta_1' = 13 - 32 = -19,$$

$$\Delta_2' = 29 - 32 = -3,$$

$$\Delta_3' = 17 - 32 = -15,$$

$$\Delta_4' = 22 - 32 = -10,$$

$$\Delta_5' = 52 - 32 = 20,$$

$$\Delta_6' = 40 - 32 = 8,$$

$$\Delta_7' = 51 - 32 = 19.$$
7. Kendalls' coefficient of concordance $W$ characterizes the level of concordance of experts' opinions [3]:

$$W = \frac{12 \cdot S}{m^2 \cdot (k' - k)}, \quad (10)$$

where:

$$S = \sum_{i=1}^{k} (\Delta_i)^2, \quad S = \sum_{i=1}^{k} (\Delta_i')^2 = 361 + 9 + 225 + 100 + 400 + 64 + 361 = 1520,$$

$$W = \frac{12 \cdot 1520}{8^2 \cdot (7' - 7)} = 0.85.$$

The calculated coefficient of concordance allows to conclude that experts display their agreement in their assessment.

8. Incidental of concordance among experts' opinion is calculated by Pearson's criteria ($\chi^2$-square) [3]:

$$\chi^2 = W \cdot m \cdot (k - 1), \quad (11)$$

$$\chi^2_p = 0.85 \cdot 8 \cdot (7 - 1) = 40.8,$$

where $(k - 1)$ is the number of degrees of freedom.

Chechup based on Pearson's criteria $(\chi_p^2 > (\chi^2_t)^2)$ showed that experts had a significant agreement in their opinions. And taking into consideration the calculated concordance coefficient we can conclude that experts' assessment are accurate and can be taken into account.

9. Depending on a sum of rank $\Delta k$ we carried out grading of the methods. A method which is characterized by minimal sum of ranks $(\Delta k)_{\text{min}}$ is the most essential. The importance of methods is found by the sum of ranks in ascending order.

10. Weighting factor of each method is calculated according to the following equation [3]:

$$q_k = \frac{2 \cdot (k - M + 1)}{k \cdot (k + 1)}, \quad (12)$$

where $M$ is a rank of a method as a result of a prior grading.

Calculation results are shown in Table 1.

5. Discussion

A prior rank diagram is presented in Figure 3. It enables to see the most essential methods of passenger traffic flow analysis by condition that $\Delta k < \bar{X}$.

![Figure 3](image_url)

**Figure 3.** A prior rank diagram of methods of passenger traffic flow analysis $k_1$ – a schedule method, $k_2$ – an outline method, $k_3$ – an ocular estimate method, $k_4$ – a questionnaire method, $k_5$ – a contingent valuation method, $k_6$ – a transport ticket method, $k_7$ — methods of mathematical modeling.
6. Conclusion

The rank diagram derived from a prior grading procedure displays the most appropriate methods for passenger traffic flow analysis: $k_1$ – a schedule method ($\Delta_1=13$); $k_3$ – an ocular estimate method ($\Delta_3=17$); $k_4$ – a questionnaire method ($\Delta_4=22$); $k_2$ – an outline method ($\Delta_2=29$).

In their turn such methods as $k_6$ — a transport ticket method ($\Delta_6=40$); $k_7$ – methods of mathematical modeling ($\Delta_7=51$); $k_5$ – a contingent valuation method ($\Delta_2=52$) are considered to be less effective from the point of view of application in passenger traffic flow analysis in the city of Orel.

Therefore, to analyze passenger traffic flow the following methods have been chosen as the most appropriate: a schedule method, an ocular estimate method, a questionnaire method.

References

[1] Blatnov M D 1981 Passenger transportation: textbook for motor transport colleges 3rd edition Moscow: Transport p 294

[2] Bogomolov A A 2002 Route optimization of public municipal passenger transport in cities of medium sizes Doct. Diss. Vologda p 126

[3] Beshelev S D and Gurvich F G 1973 Expert assessment Moscow: Nauka p 142

[4] Novikov A N, Katunin A A, Kulev M V and Kulev A V 2017 Optimization of city passenger transport routes in the regional centers of Russia Journal of Engineering and Applied Sciences 12(13) pp 3407-3412

[5] Zhankaziev S V, Novikov A N, Vorobyev A I, Kulev A V and Morozov D Y 2017 Definition of accuracy of qualitative correspondence matrices for indirect traffic flow control and regulation International Journal of Applied Engineering Research 12(13) pp 3653-3658

[6] Zhankaziev S V, Novikov A N, Vorobyev A I, Kulev A V and Morozov D Y 2017 Efficiency of operation and functioning of the system of an indirect transport flow regulation and control International Journal of Applied Engineering Research 12(13) pp 3645-3652

[7] Gudkov V A, Mitotin L B, Ve'mozhin A V and Shiryev S A 2006 Passenger transportation: college textbook Moscow: Goryachaya liniya – Telekom p 272

[8] Kulev A V 2015 Methods of route network arrangement of public municipal passenger transport The world of transport and technological machinery 1 (48) p 85-92

[9] Larin O N 2005 Passenger transportation regulation: a study guide Chelyabinsk: Izd-vo YUUrGU p 153

[10] Lebedeva O A 2014 Improvement of methods of passenger transport traffic monitoring on routes of public municipal transport Doct. Diss. Irkutsk p 265

[11] Rassoja V I 2010 Improvement of the effectiveness of motor transport use based on scientific, technical, technological and managerial decisions Doct. Diss. Orenburg p 245

[12] Loginov P V, Shirobakin S E and Kuziitsev S N 2015 Creation of labor correspondence matrix on the basis of public statements for the development of computer transport model of the region International Journal of Applied Engineering Research 10 (24) pp 45449-45453

[13] Shavyraa Ch D 2009 Development of methodology for provision of the public by bus transport in small towns. Doct. Diss. Saint-Petersburg p 192

[14] Korchagin V A, Novikov A N, Lyapin S A, Rizaeva J N and Novikov I A 2016 Complex self-developing transport systems International Journal of Pharmacy and Technology 8 (3) pp 15253-1526

[15] Korchagin V A, Novikov A N, Lyapin S A, Novikov I A and Konovalova V A 2016 Process modelling in the subsystem of traffic accident consequence liquidation International Journal of Pharmacy and Technology 8 (3) pp 15262-15270