Optimization of work of urban passenger transport

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Abstract. Recommendations for improving the organization of the logistics system of urban passenger traffic based on the formation of adaptive properties proposed. Definitions of organization and lack of organization of the system, target entropy, orderliness, disorder are considered. The calculation of these indicators allows us to conclude how the company is adapted to the external environment. An important feature of all production systems is the focus of their functioning. If such a system is functioning, it means, first of all, that it solves a finite set of tasks to ensure the adaptability of the urban passenger traffic management system to the flow of passengers and with a certain accuracy the goals of organization and management, of which there is also a finite set. The authors come to a fair conclusion that the lack of organization of functioning is a consequence of the influence of the external environment on the control object, while organization is a quantitative measure of the ability of the system to adapt to the effects of environmental factors. The indicator of organization can be proposed as a criterion that assesses the efficiency of the urban passenger transport system. The worse the internal structures are organized, the less efficiently the control system works and the more mobile and uncertain the external environment, the greater the discrepancy between the goal and the final result.

1. Introduction
The problems of development of logistic methods and their use in the field of transportation dedicated a number of works – B. A. Anikin [1], L. B. Mirotin [2], V.V. Shcherbakov [3], D. Bowersox, D. Kloss [4], S. Keller [5].

The object of the study is the system of urban passenger traffic as part of passenger traffic, as well as providing them with information flows, flows of material, financial and labor resources.

The subject of the study is the organizational, economic, administrative relationships and relationships of participants in the system of urban passenger transport [6].

The aim of the study is to develop methodological approaches to the harmonization of urban passenger transport processes using the strategy of logistics outsourcing.

Research problem - to assess the level of organization of the logistics system of urban passenger transport and the rationale for the transformation of the existing system of urban passenger transport in the logistics system in the light of solving public transport problems [7].

At the same time, the specific application of logistics tools to the passenger transport market has not yet been adequately reflected. Meanwhile, it seems that this issue requires a special approach, since the organization of passenger traffic and the quality of providing various categories of consumers with transport services depend on taking into account the specifics of transport logistics in the field of passenger transportation, which makes the scientific search for organizational and economic solutions for the logistics of this sphere very important [8].

For traditional approaches to the organization of urban passenger traffic, there is a tendency to increase the density of the route network, observe the minimum interval of vehicle traffic and locate stopping points on routes through lines of approximately the same length. Explicitly or implicitly, there is a desire to cover the territory of the city with a route network of passenger transport as much as possible [9].
In passenger traffic, as well as in the traditional understanding of logistics, the requirement to minimize the total costs with an agreed level of quality of services provided remains in force [10]. The formation of the urban passenger transportation system using logistic principles should begin with the identifying the transport needs of city residents.

The logistic approach to the organization of passenger traffic involves the fullest possible consideration of the passengers’ requirements who are consumers of urban transport services. An important factor in the quality of transport service is the speed of the message, which directly determines the time spent by the passenger on the trip [11].

2. Materials and methods

Numerous studies have established that the speed of the message is associated by power dependence with the length of the haul. The greater the distance between the stopping points, the higher the speed of the message, the less time the passenger spends on the trip.

The number of stopping points on the route affects the quality of passenger service in an ambiguous manner: if there are few stops, the span length increases and the speed of the message increases. But it may cause an increase in the time the passenger approaches the stop.

The desire to reduce the passenger’s approach time to a stop and an increase in the number of stopping points leads in some cases to the fact that the speed of a message in certain sections of the route becomes close to the speed of a pedestrian. This is especially true for urban electric transport, the route of which goes through regulated or unregulated intersections.

An excessive number of stops and an underestimated length of the haul leads to the excessive consumption of fuel and energy, increased vehicles wear and their premature failure, fatigue of drivers, and reduced road safety. Situations of transport services for city dwellers are different, the methods for their resolving should be also different [11].

3. Results and discussion

It should be ensured that vehicles provide not only communication between different areas of the city among themselves, but first of all satisfy the real, having clear temporal and spatial characteristics of the transport needs of city residents. Thereby, one of the basic principles of logistic systems: priority satisfaction of customer requirements will be implemented. Thus, the passenger transportation system of such a large city as Saratov must be considered on the basis of the logistic concept [12].

Under ideal conditions, with an optimal organizational structure, efficient management and the absence of negative impacts from the external environment, the goal of organizing an efficient system for transporting passengers by urban transport will be achieved.

In fact, the goal is not fully achieved due to non-compliance with conditions. The worse the internal structures are organized, the less efficiently the control system works and the more mobile and uncertain the external environment, the greater the discrepancy between the goal and the result obtained [12].

That is, the less the compliance of internal qualities with the urban passenger transport models with the characteristics of the passenger flow, the less it will be adapted to the objective conditions of work, the greater will be the difference between the goal and the result obtained. Quantitatively, this is a variation and consequently, the level of fitness of the organization’s models for the transport of passengers to passenger traffic, can be assessed using the level of organization of the system’s functioning [13].

Organization is a function of simpler system characteristics: orderliness and complexity.

In practice, when the goal is set, it is important to know not «the absolute» organization of functioning, but disorganization, since it is the operational information about the quality of the organization and the function of the elementary concept of disorder.

Disorder is a measure of the difference of any selected parameter, for example, \( x_j \) with respect to the standard of order \( x_{et} \), which tends to zero at \( x_j \to x_{et} \) [13].
Since in the general case, the center of order is not a point, but a certain area, which is called a quasi-ordered zone, the disorder is considered in relation to the boundaries of this zone \( f(x_j) \).

Then the model of disorder \( \bar{Y}_j \) will look like:

\[
\bar{Y}_j = |x_j - x_{ef}| - f(x_j),
\]

where \( \bar{Y}_j \geq 0 \).

In a more general form, operating with a vector quantity, one can proceed to the expression:

\[
Y = q_j - f(x_j),
\]

where \( q_j \) is the error vector module.

The complexity of the system is a function of either the number of elements included in the system, or their diversity. The complexity of the disorganization enters indirectly, that is through the number of considered parameters, possible situations and time intervals.

According to the definition, you can write the following symbolic expression for lack of organization [13]:

\[
\bar{O} = \bigcup_{i=1}^{K} \sum_{j=1}^{I} S_{i} \left[ \sum_{j=1}^{J} P_{j} \varphi(Y_j) \right],
\]

where \( \bigcup \) is the symbol of generalization of the characteristics of disorder, respectively, for the \( j \)-situations of \( i \)-elements and \( K \)-time intervals;

\( \varphi(Y_j) \) is the function with the help of which weighting of disorder is weighted by the materiality of its manifestation in relation to a certain indicator of the functioning of the system.

In the assumption of the additive nature of the lack of organization by the elements and by the time based on the formula 3, the general expression for lack of organization would be [13]:

\[
\bar{O} = \sum_{i=1}^{K} \sum_{j=1}^{I} S_{i} \sum_{j=1}^{J} P_{j} \psi(P_y) \]

where \( \psi \) is the cast function.

The disorder parameter \( P_y \) is found in the expression:

\[
P_y = \omega_j Y_j + c,
\]

where \( \omega_j \) is the weight, taking into account the difference \( \bar{Y} \) in the \( j \)-th situation compared with other situations;

\( c \) is the coefficient, the meaning of which is found from the condition \( \psi(P_y) = 0 \), with \( \bar{Y}_j = 0 \).

The property of the disorganization of the functioning of \( H_k \) with the logarithmic function \( \psi \), for the \( j \)-situation, has the form:

\[
H_k = \sum_{j=1}^{J} P_j \log_{\omega} \left[ (q_j - f(x_j)) \omega_j + 1 \right].
\]

Such disorganization is conventionally called the target entropy.

Thus, as a result of mathematical transformations, two open spaces are obtained that for the I-th position can be represented graphically (Figure 1).

The first space is the space of the original (scatter, misalignment), which characterizes the amount of disorder, and the second – strictly corresponding to the image space and the value of \( H_x \). These
two spaces are similar, i.e. each $H_X$ value in the image space (target entropy) will have its own $H_{X(q)}$ value in the original space.

**Figure 1.** Representation of the relationship between the original and image space (a – space of the original (spread in $x_1, x_2$ coordinates), b – image space (entropy) in coordinates $H_{X1}, H_{X2}$, $Y$ – spread area, $r_c$ – the radius of the target area, $H_{X(q)}$ – the average radius of the scatter, $q_i$ – the module of the vector of the error, $H_{X(q)}$ – the area of the target entropy, $H_X$ – the target entropy, the corresponding $H_{X(q)}$ in the space of dispersion, $H_{Xi}$ – the entropy of the i-th state of the system corresponding to $q_i$ in the scatter space)

The target entropy has the following properties:
- $H_X = 0$, if all $q_j \leq f(x_j)$, $P_j = 0$, if all $q_j - f(x_j) > 0$. In this case, the system is fully adapted to the traffic flow;
- for the whole ensemble with $P_j > 0$, and if $\left[q_j - f(x_j)\right] \to \infty$, then $H_X \to 0$, then the system is adapted, if $\left[q_j - f(x_j)\right] \to \infty$, then $H_X \to 0$ in the limiting case is not fully adapted;
- when $P_j = \frac{1}{j \cdot H_s} = H_{\max}$ is found from the expression:

$$H_{\max} = \log_\omega \left\{ \max \left[q_j - f(x_j)\right] \omega_j + 1 \right\}$$

(7)
In this case, the model of management of the system of transportation of passengers and the flow of passengers are fully not adapted to each other.

Hereinafter, the entropy having been found in accordance with expression 7 will be called the maximum entropy [13].

Despite the fact that the disorganization of the form (6) was conventionally called the target entropy, its consistency under certain conditions can be shown in relation to the classical Shannon entropy. If we take as a parameter the prior probability \( P_j \) as the standard of order \( \omega_j = 1 \) and substitute these meanings into expression (1), assuming \( f(x_j) = 0 \), then the absolute disorder in the j situation:

\[
\overline{Y}_j = \frac{1}{P_j} - 1.
\]  

(8)

Obviously, when \( P_j \to 0 \) \( \overline{Y}_j \to \infty \), and when \( P_j \to 1 \) \( \overline{Y}_j \to 0 \), which does not contradict the definition of disorder.

Substituting (8) into (5) and assuming that \( \omega_j = 1 \):

\[
\overline{O} = H = -\sum_{j=1}^{m} P_j \log P_j
\]  

(9)

Then we take the logarithmic character \( \psi \) and substitute (9) into the expression (4) for the j-situation. As a result, we obtain the well-known expression for Shannon’s entropy:

\[
\overline{O} = H = -\sum_{j=1}^{m} P_j \log P_j
\]  

(10)

The solution to the problem of evaluating the effectiveness of the functioning of subsystems of urban passenger transport consists primarily in the choice of evaluation criteria. The target entropy fully satisfies the requirements of the universality of the reflection of the specifics of the problem under consideration, consistency with previous theories and dynamism. However, it is more convenient to use relative indicators [14-16].

The increment of organization \( \Delta Q_{id} \) in a symbolic form, which is expressed through a change in the system’s lack of organization under the influence of the organization’s means, looks like this:

\[
\Delta Q_i = -\Delta Q_i = \Delta Q_{id} - Q_{id},
\]  

(11)

where \( \Delta Q_{id} \), \( Q_{id} \) is the lack of organization in relation to the i-th goal, respectively, before and after the action of the means of the organization.

Then the relative increment of organization due to the action of the organization’s funds is called the lack of organization in the functioning of the system and is derived from the expression:

\[
Q_i = \left(\frac{Q_{id} - Q_{in}}{Q_{id}}\right).
\]  

(12)

Taking the logarithmic form of the disorganization function, it is possible to present the relative increment of organization \( Q_i \) by increasing the adaptive properties of the system and, taking into account expressions 6 and 7, as a function of the system’s target and maximum entropy [17]:

\[
Q_i = \left(\frac{H_{max} - H_{ic}}{H_{max}}\right) = 1 - \frac{H_{ic}}{H_{max}},
\]  

(13)

where \( H_{ic} \), \( H_{max} \) is respectively, the target and maximum entropy for the i-th target.

Functioning organization of the system has a number of useful properties:
− the scope of this indicator is limited to the top and bottom;
− organization → 1, if the probability of achieving the goal → 1;
− organization → 0, if the probability of achieving the goal → 0.

Therefore, the target entropy can be considered as a mathematical model of the process of harmonization of urban passenger traffic:
− the measure of disorder is used as an indicator of not achieving the goal;
− the indicator of failure to achieve the goal, taking into account the probability of occurrence of mismatch \( X_j \) with respect to the border of the quasi-ordered zone \( f(x_j) \), caused by insufficient adaptation of the enterprise to external conditions, is taken as a measure of disorganization of functioning [18].

In the functioning of the system of urban passenger traffic, the compromise of its constituent elements is achieved on the basis of centralized management of its constituent elements, achieved on the basis of centralized management by municipal and federal authorities. Structurally, the logistics information system can be represented as the following components: a database and a bank of models. The functioning of the information system allows to get an idea of the status of the rank of passengers and to adjust the work of the transport's to ensure accurate compliance with the needs of passengers [18].

**Conclusion**

Thus, the lack of organization of functioning is a consequence of the influence of the external environment on the control object, while organization is a quantitative measure of the ability of the system to adapt to the influence of environmental factors and can be proposed as a criterion for the efficiency of the urban passenger transportation system.

Thus, the target entropy can be considered as a mathematical model of harmonization of passenger work. Depending on the level of organization of the system, we will be able to assess how it is adapted to the external environment.

Scientific novelty - improving the organization of the logistics system of urban passenger traffic on the basis of the formation of adaptive properties through the implementation of the strategy of logistics outsourcing.

**References**

[1] Anikin B A et al 2015 *Fundamentals of Logistics: Transport infrastructure Logistics* (Publishing House Prospekt, Moscow) p 406
[2] Mirotin L B and Pokrovsky A K 2016 Logistics and resources *Journal of transport* 4 pp 15-17
[3] Shcherbakov V V and Ivanova D P 2013 Positioning of logistics innovation *Innovative activity* 3 pp 98-102
[4] Bowersox D J and Closs D J 2008 *Logistical management The Integrated Supply Chain Process* (Publishing House Olimp-Business, Moscow) p 640
[5] Keller S B 2001 Logistics outsourcing – a management guide *Transportation Journal* 2 pp 52-58
[6] Islam M R, Hadiuzzaman M, Hossain S, Banik R, Hasnat M M and Musabbir S R 2016 Bus service quality prediction and attribute ranking: a neural network approach *Public transport* 2 pp 295-313
[7] Chefranova O V and Zhigulsky V I 2015 Controlling and monitoring in the implementation of policies and strategies for the development of the transport and road complex *Nauchnaya Mysl*[Scientific Thought] 2 pp 144–147
[8] Oziomek J and Rogowski A 2018 Improvement of regularity of urban public transport lines by means of intervals synchronization *Transport Problems* 13 pp 91–102
[9] Palach S 2014 Trip coordination in municipal passenger transport *Transport Problems* 9 pp 111–117
[10] Vitvitsky E E and Khoroshilova E S 2015 On the manifestation of the random nature of the transport process in the functioning of the delivery motor transportation system in the conditions of the city Nauchnaya Mysl' [Scientific Thought] 2 pp 178–181

[11] Yarmen M and Sumaedi S 2016 Perceived service quality of youth public transport passengers Transport Problems 11 pp 99–111

[12] Rybicka I, Droździel P, Stopka O and Lupták V 2018 Methodology to propose a regional transport organization within specific integrated transport system: a case study Transport Problems 13 pp 115–125

[13] Klochkov V N 1999 Adaptation and competitiveness of road transport systems in market conditions (St. Petersburg State University of Engineering and Economics Press, St. Petersburg) p 215

[14] Morchadze T and Rusadze N 2018 Ways to address the challenges in passenger traffic within the urban transport systems Transport Problems 13 pp 65–67

[15] Olivkova I 2008 Public transport in Czech Republic Ways to address the challenges in passenger traffic within the urban transport systems Transport Problems 3 pp 53–58

[16] Mindur L and Hajdul M 2013 The concept of organizing transport and logistics processes, taking into account the economic, social and environmental aspects Transport Problems 8 pp 121–128

[17] Stock J R and Lambert D M 2005 Strategic logistics management (Publishing House INFRA-M, Moscow) p 797

[18] Wardlow D, Wood D F, Murphy P R and Johnson J C 1999 Contemporary Logistics (Pearson Education, New Jersey) p 608

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