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Development of a Method for Assessing the Quality of Public Transport Services within Urban Transportation Planning Systems

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ABSTRACT

This article discusses the issues of assessing the perceived quality of services provided by ground urban passenger transport. The implementation of a marketing approach to development of transport services means the need to consider the opinion of a potential consumer regarding a planned or completed trip. Integrating the perceived quality of transport services into development and implementation of urban transport policy will allow us to shape more effectively sustainable transport behaviour, focusing on taking measures that give the greatest return, maintaining the loyalty of existing passengers and attracting new ones.

Based on the focus of the transport service on the final consumer, the article analyses methods for assessing quality indicators for the transport chain. The issues of using a gravity model to assess the quality of a multimodal transport chain are considered with the account for the point of view of an individual passenger and user groups.

Keywords: *urban transport systems, passenger transport, quality of transport services, perceived quality, Avoid–Shift–Improve strategy.*

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INTRODUCTION

Urban passenger transport, being an integral part of the city's life support system, is subject to a wide range of external influences that affect transport demand. Hence, the growing importance of mutually interconnected goals and capabilities of city transport administrations, the capacity of transport companies and the expectations of the population from the provided transport service allowing to reduce the excessive number of trips by personal vehicles.

This interconnection is implemented within the framework of a marketing approach to management of public urban passenger transport. This approach is based on the provisions of the Avoid–Shift–Improve strategy [1], which is the basis for developing a set of measures to create sustainable urban transport systems, including by changing the transport behaviour of the population and switching passenger traffic from personal to public transport.

The system of transport planning and provision of transport services that is being built should be based on consideration of various aspects of assessing the quality of transport services to the population: the provided quality of transport services (i. e., the level of quality provided by service providers), target quality (i. e., quality standards established by regulators), perceived quality (i. e., quality subjectively perceived by customers) and, finally, desired quality (i. e., characteristics of the expectations and desires of potential and actual passengers).

Accepting the statement that the passenger, as a decision maker, is rational and, accordingly, from the entire set of alternative modes of transportation and travel routes, he will choose the best one for himself, implies the need for a formal description of such a decision-making process, and that is the *objective* of the study. At the same time, the subjectivity of each of the individual assessments determines the advisability of formalising indicators of perceived quality [2–6].

RESULTS

Indicators of the Quality of Transport Services in Urban Transport Policy

Assessing the quality of transport services for the population can be used both for the purposes that city transport administrations face (planning the prospects for development of urban transport systems, developing transport planning documents, monitoring the work of urban transport, etc.), and for the purposes pursued by transport enterprises while preparing proposals on organising new routes and changing the parameters of existing ones.

Accordingly, there is a need to develop a mechanism for assessing the quality perceived by the user and integrate it into the processes of planning, providing and controlling of the provision of transport services.

Table 1 presents an analysis of the structure of quality indicators of transport services based on methods used in Russia, the EU, China, and the USA.

The results of the analysis indicate that there is currently no harmonised nomenclature of quality indicators used.

There is no doubt that transportation managing organisations, carriers and the population evaluate the quality of transport services based on the different goals they face. E.g., in Russia, the standard for quality of transport services for the population is established by the city (regional) administration for carriers operating on certain routes. At the same time, a particular user is more interested in the quality of service not on a separate route or within the transport system as a whole, but on his own travel route («transport chain»), which may include sections of various routes, several types of urban passenger transport, movement using active mobility or personal mobility vehicles, as well as transfers, the quality of which must also be taken into account. In this regard, to obtain a more complete picture related to passenger service quality indicators, it is necessary to ensure that issues of transport service quality are considered in a broader context, as shown in Pic. 1.

In addition, different categories of users and in different circumstances perceive the quality indicators of the service provided differently. As a rule, to assess quality, a principle is applied according to which focus groups of potential passengers are determined (employed in the economy, students, pensioners, etc.). For each of these groups, the points of formation and absorption of transport demand and its characteristics are determined (requirements for quality, price, availability, etc., time characteristics of demand distribution for each group). Based on the results of such decomposition and subsequent aggregation, the requirements for the route network and service on it are determined.

However, if administrations and operators do not consider users' requirements for the quality

Table 1

Quality indicator	Meter	EU*	Russia**	China***	USA****
Availability	frequency and reliability of service	+	+		+
	working hours	+	+		+
	ease of boarding and disembarking	+			+
	route network coverage	+			+
	affordability	+	+	+	+
	distance from/to the end and start points of the route				
Information support	at stopping points	+	+		+
	online	+	+		
	schedule, routes	+		+	+
	waiting time, delays	+			+
	timely notification of changes				+
Time	en route	+		+	+
	at the stop/approaching it/during a transfer	+		+	
	on-time trips	+	+	+	+
	relativity to other modes of transportation				
Comfort	temperature, ventilation/air conditioning in the cabin, absence of odours and vibrations	+	+	+	+
	cabin occupancy / ability to occupy a seat	+	+	+	+
	appearance of the vehicle (cleanliness, paint, absence of extraneous inscriptions)	+			+
	suitability for travel in special cases (with luggage, stroller, bicycle/PMV)	+	+		
Service for clients	service culture	+	+		+
	responsiveness of the staff	+			+
	availability of feedback	+			+
	possibility of improving the service through feedback				+
Safety/Security	at stopping points	+		+	+
	on the way to stopping points				
	on the move for vehicles	+		+	+
	on the move for a passenger	+		+	
	inside the vehicle (illegal actions)	+		+	+
Environmental impact	environmental friendliness of the service in general	+	+		
	reduction of congestion	+			
	reduction in emissions	+			

* Based on EU standard EN 13816:2002. Transportation – Logistics and services – Public passenger transport – Service quality definition, targeting and measurement.

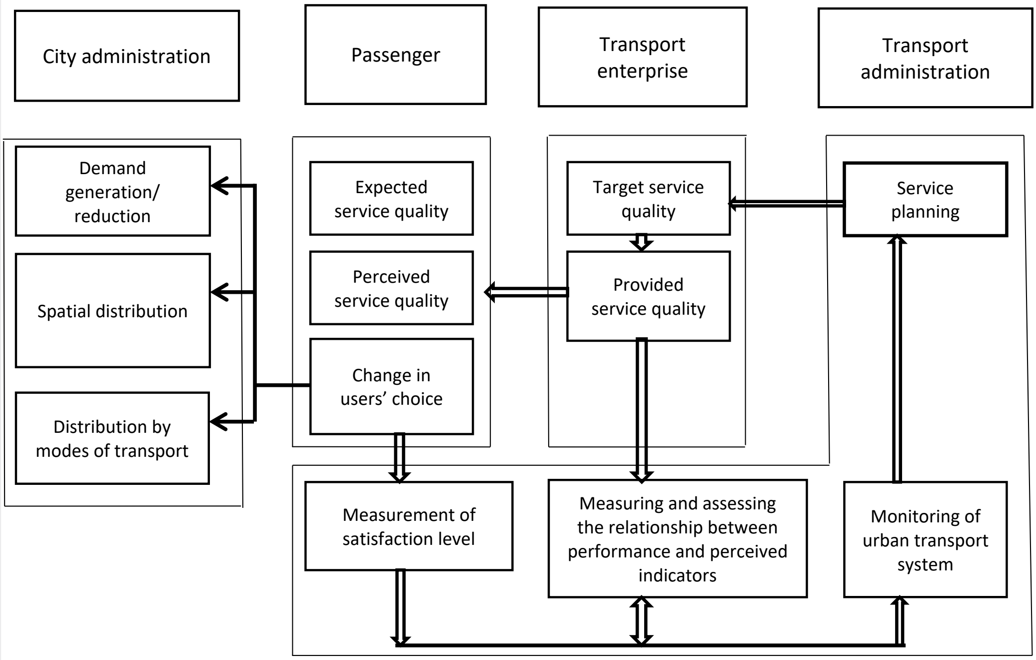
** Based on the Social Standard of Transport Services for the Population when Transporting Passengers and Baggage by Road and Urban Ground Electric Transport (approved by the Order of the Ministry of Transport of Russian Federation dated January 31, 2017, No. NA-19-r, as amended on March 10, 2021.

*** Based on the methodology for assessing the perceived quality of bus transport services for Beijing (PRC), set out in the work of J. Wen [*et al*] [9].

**** Based on determinants set in the USA by Handbook for Measuring Customer Satisfaction and Service Quality [Electronic resource]: https://www.trb.org/Publications/Blurbs/153801.aspx.

of services provided, this may result in the fact that sustainable transport behaviour of the population will not be formed. Even though the transport service will be accepted by users in its current version, with an increase in the well-being of the population or with an improvement of other conditions associated with social differentiation, society may abandon public urban transport services in favour of the use of passenger vehicles (private car, taxi, car sharing, etc.). This trend in the future will negatively affect a wide range of problems related to traffic and the environment [7].

An integrated approach aimed at including perceived indicators of the quality of transport services in the design of urban passenger



Pic. 1. A scheme for planning, providing, and monitoring the quality of transport services based on a «quality loop» taking into account feedback [developed by the author].

transport systems and monitoring the provision of these services involves identifying the following subtasks:

– Determining the list of indicators of quality of transport services to be assessed, their internal hierarchy and target indicators.

– Determining the principles for assessing quality indicators (using industry performance indicators, obtaining quantitative indicators through surveys, the «secret shopper» method, etc.).

– Determining the entire group of transport service users and its decomposition (according to age, social criteria, goals, and circumstances of the trip).

– Revealing relationships between quality indicators, considering the degree of their perception by each user group.

– Development of a mathematical apparatus used to assess the quality of transport services for each category of users.

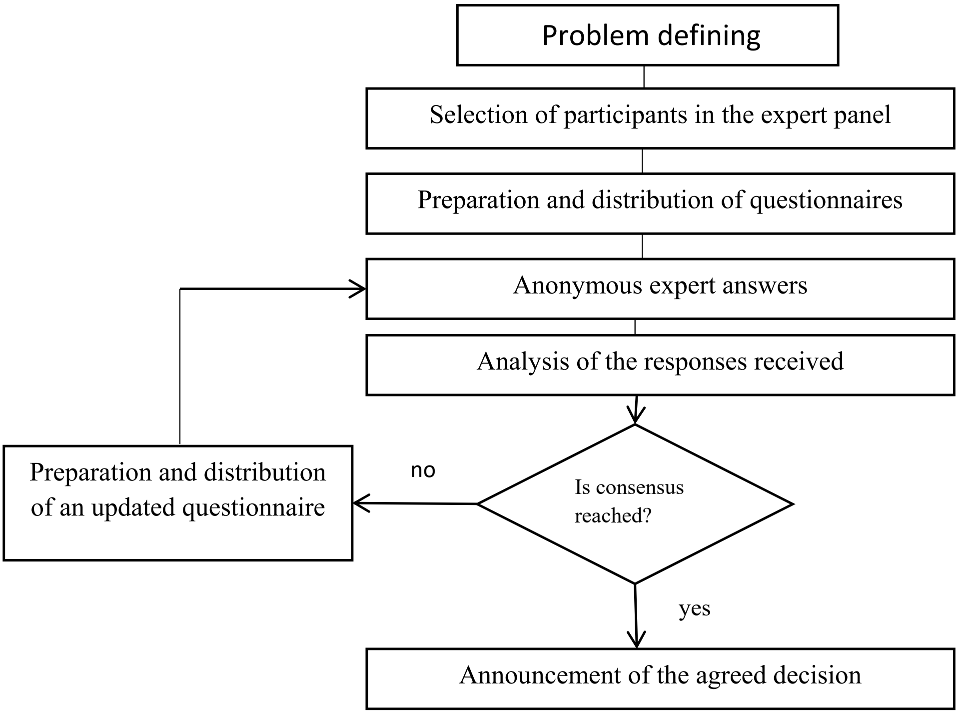
It is important to assume that with growing prosperity, consumers are constantly raising their quality expectations in all areas, including the transport services market. Therefore, the market for transport services is a dynamic system: it is continuously influenced by public, economic and social developments, as well as by sectoral measures directly undertaken in the transport industry.

Shifts in the level of well-being (both of society and of an individual), and the demographic characteristics of society change the perception of the quality of transport services. Sudden changes due to changes in the route network, schedules, tariffs, etc., as a rule, are perceived with caution by users, unless they lead to an equally dramatic increase in the quality of service.

In this regard, several recommendations are used that establish the framework for future changes in transport services (for example, reforms are not recommended to affect more than 15–20 % of the route network)[1].

To a large extent, all calculations necessary to assess the quality of the services provided by ground urban passenger transport are now made for monomodal routes, and the influence of the characteristics of a particular type of transport on the choice of consumers still appears to be insufficiently studied. It can, however, be assumed that the user's choice of a multimodal route based on the integral quality of transport services provided by it can also be formalised using the following indicators: vehicle availability, travel time, level of service, comfort, visual acceptability, safety at the stop and en

[1] Guidelines for drawing up rational schemes of bus routes in cities. Moscow, NIIAT of the Ministry of Automobile Transport of the RSFSR, 1984.



Pic. 2. Scheme of using the Delphi method [developed by the author].

route, environmental friendliness, personal preferences, number of transfers, their reliability and convenience.

Methods for Assessing the Quality of Transport Services

User surveys can be used to obtain data on the provided and perceived quality of transport services, although this method of obtaining data can produce rather subjective results and, in addition, requires the formulation of questions for respondents that are understandable to them. The indicators used in these questions should not be exclusively general (for example, «availability» or «reliability»), since in this case they can be interpreted differently by the passenger answering the questions, and on the other hand, they should be easily quantifiable.

Methods for expert assessment of quality indicators involve the use of coefficients of their relative importance (weight of criteria) or absolute significance (score). Such methods are used both to compare quality indicators of transport services before and after the adoption of appropriate regulatory measures, and to assess the dynamics of changes in the integral quality indicator [8; 9].

At the same time, when constructing integral quality indicators, it is important to create a set of component indicators that ensure full coverage of the user's needs. If they are multidirectional, the corresponding correction factors are introduced into the formula for calculating the integral quality indicator.

Algorithms for evaluating transport projects and programs using complex (composite) criteria are outlined, e. g., in the textbook[2]. When analysing the opinions of a limited number of qualified experts surveyed, for example, the Delphi method (Pic. 2) or the method of paired comparisons can be used. In both cases, appropriate attention should be paid to the issue of interviewee selection to form a representative sample.

An important indicator of the quality of a trip is its *duration (time)*. However, this indicator is multicomponent in nature, each element of which is perceived differently by a passenger [10–12]. Therefore, those quality indicators that use a time basis must consider the passenger's subjective perception of the time spent at different stages of the trip: at the stop while waiting for the vehicle, on the approaches to it, during a direct trip or trip with a transfer, transfer time and

[2] Donchenko, V. V. Sustainable urban transport systems: changing the paradigm of planning and development of urban transport: Textbook [Ustoichivie gorodskie transportnie sistemy: izmenenie paradigm planirovaniya i razvitiya gorodskogo transporta: Uchebnik]. Moscow, Radar publ., 2023, 402 p. ISBN-978-5-6048/401-2-2.

waiting for a vehicle to continue the route. At the same time, the values of quality indicators associated with the perception of waiting may have a nonlinear relationship with waiting time.

This applies, in particular, to the transport chain, where the acceptability of a transfer for a passenger may depend not only on external factors (comfort and equipment at transfer points, weather conditions, walking distance during transfer), but also on the total duration of the trip, that is, on the share of the journey spent by a passenger in the cabin of the same vehicle.

Different user perceptions of the time spent at individual stages of the transport process: walking towards/departing from a stop, being in transport (within an interval not exceeding the transport fatigue indicator) result in the phenomenon that waiting time and transfer time are assessed twice as negatively, than the time spent inside the vehicle [13].

One of the main indicators of the quality of transport services is their *availability*. The need to evaluate it in terms of perceived quality is associated with the user's choice, when planning a trip, of the best route to arrive at the destination and the transport chain corresponding to this route. A potential passenger evaluates the availability of locations, modes of transport and individual routes based on his or her physical and financial capabilities, available time, time and weather conditions, etc.

The [14] proposes to use a gravitational model to assess the accessibility of locations for the user. According to this model a certain weight corresponds to a particular transport chain:

$$A_i = \sum_i P_i \cdot f\left(C_{ij}\right), \qquad (1)$$

where A_i – availability of the i-th zone;

P_i – possibilities of arriving at destination from the i-th zone;

i – departure zone indicator;

j – destination zone index;

$f(C_{ij})$ – function that determines the cost of a trip.

In this case, it is assumed that cost is the factor that determines the level of accessibility.

However, based on the complex concept of accessibility, other factors also influence it. To take them into account, the concept of impedance of travel is introduced, that is, the ease/difficulty of travelling from i to j.

In its classical form, the function $f(d_{ij})$ of impedance of travel assumes a dependence only on the distance between two points, but it can also be used to consider a wider range of factors affecting accessibility.

From the point of view of this approach, locations have more weight the closer they are to the target point (i. e., they are more likely to be selected by the user):

$$P_j^{ip} = \frac{x_j^p\, f\left(d_{ij}\right)}{\sum_{j' \in L^{ip}} x_{j'}^p f\left(d_{ij'}\right)}, \qquad (2)$$

where L^{ip} – a set of locations of the type p in the set of selection for the zone i;

x_j^p – a size of type p activity (number/power of points of production activity, as well as other points of attraction of passenger flow) in the location j.

The concept of «proximity» in this case can be extended to cost and time indicators, to the level of comfort provided, etc.

According to the model described by formula (2), the probability of choosing location j will continuously decrease with increasing distance/time required to reach the target destination. It should also be considered that this probability is not the same for different categories of passengers and purposes of the trip.

The above allows us to use the gravity model to assess the quality indicators of the transport chain (door-to-door) using perceived quality. In this case, the transport service quality function $f(q_{ij})$, which depends on the perceived quality of links in transport chains, is included in the impedance function.

In this case, it is assumed that the user selects a transport chain with the maximum integral quality indicator Q_{choice}:

$$Q_{choice} = max\, Q_i \left(i \in 1..n\right), \qquad (3)$$

where n – the number of possible transport chains from the start to the end point of one's trip with quality Q_i, considered by an individual (potential passenger).

In turn, each chain consists of a sum of links, each of which is characterised by its own quality:

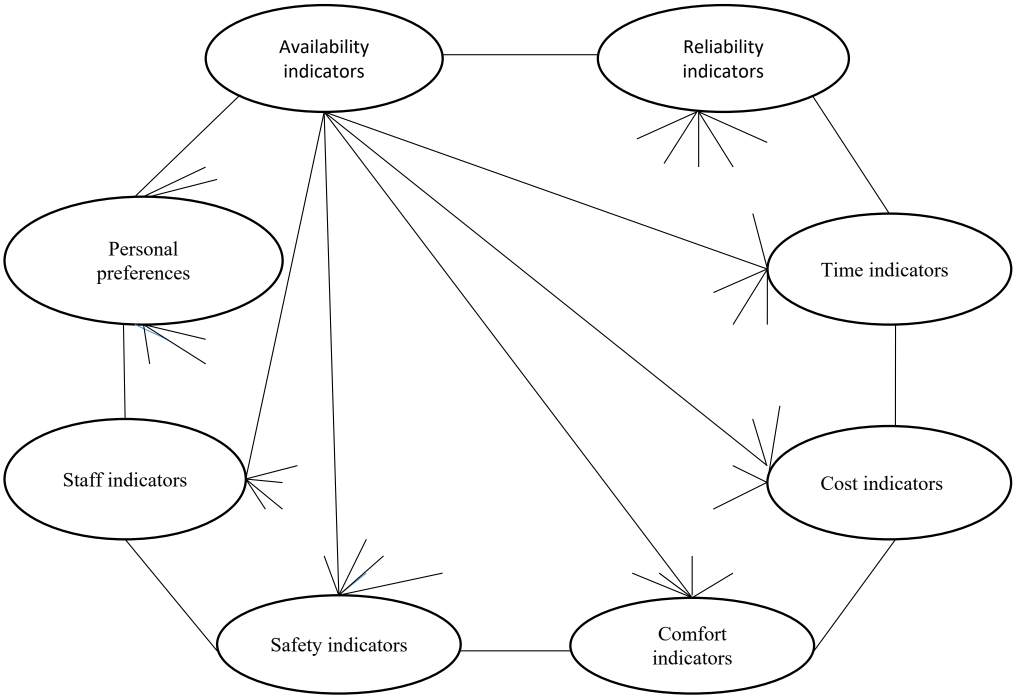
$$Q_i = \sum_{j=1}^{m} q_j\,, \qquad (4)$$

where q_j – the quality of the individual j-th link of the transport chain, and m is the number of its links.

In the simplest case

$$Q_i = \sum_{j=1}^{m} q_j = \sum_{j=1}^{m} \sum_{k \in K} q_{jk} \cdot p_k, \qquad (5),$$

where q_{jk} –the quality indicator of the transport service of the j-th link according to the k criterion;



Pic. 3. General case of mutual overlap of indicators of perceived quality of transport services [developed by the author].

p_k is the weighting coefficient of the k-th criterion of the quality of the transport service belonging to the set K.

At the same time, the physical distance within the corresponding chain may be shorter, but this distance may be inferior in quality (have a high impedance) and, accordingly, be rejected when a potential passenger makes his decision.

In fact, the assessment of the quality of the trip may vary depending on the time of its implementation, the category of the user, etc. Therefore, in less simplified cases, it is possible to use functions that characterise the dependence of the quality of transport services on the category of users, travel purposes, time of day, etc., as well as to group assessments and generate summary characteristics.

Due to the complex nature of the transport service, it is also necessary to consider the mutual influence of several quality indicators on each other. For example, the values of some indicators may be in antiphase with the values of others (an increase in speed as a result of a reduction in travel time can lead to a decrease in safety, etc.). At the same time, their mutual overlap leads to the fact that a negative perception of one of the indicators (cost, transferability) can be compensated by an improvement in other indicators (time, comfort). Such relationships can form network models, where the vertices are the corresponding quality indicators (Pic. 3).

For a specific indicator (for example, transferability), the corresponding graph describing its relationship with other quality indicators is shown in Pic. 4. In this case, the weights of the edges characterising the significance of the relationship will have different weighting coefficients for different categories of users and trip categories. Accordingly, it is advisable to take this factor into account at the planning stage of transport services.

A dynamic physical model of perceived quality can be described by a change in the satisfaction index in a multidimensional space, each of the axes of which relates to a specific quality indicator:

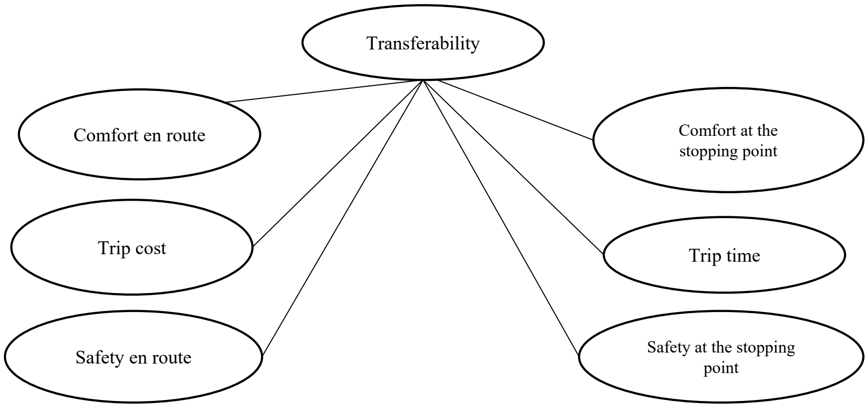
$$S = \sum_{i=1}^{k} \frac{a_i \times x}{x_i}, \qquad (6)$$

where S – satisfaction index;

a_i – satisfaction rating according to the attribute i;

x_i – relative importance of the attribute i,

$i = 1,\ldots, k$.



Pic. 4. An example of the mutual influence of indicators of the perceived quality of transport services [developed by the author].

Besides traditional methods, the solution to the problem of assessing perceived quality can be carried out using the apparatus of interval mathematics for each group of transport service users, followed by obtaining an integral assessment.

Let us note that the satisfaction index can be used as a value inversely proportional to the impedance of the trip, the function of which includes quality indicators.

Each of these indicators for a certain group of users is within the «tolerance zone», while going beyond the maximum value of the zone leads to the formation of «excess quality», that is, such quality, the increase of which does not lead to either increased satisfaction with the overall quality of the transport service, either to growth in the volume of its consumption (number of trips) [15–17].

Going beyond the lower limit of such a zone leads to a critical (negative) assessment of the transport service and creates a desire to abandon it, that is, provokes negative transport behaviour. Accordingly, due to deterioration of the cost-benefit ratio for the user, the accessibility of the trip target is reduced, which is an incentive to search for alternative ways to arrive at destination. A description of the relationship between transport behaviour and accessibility and usefulness for the user is presented in [18].

Thus, under the conditions of limited resources, the task is to maximise focus on on those measures that affect the integral quality indicator, bringing its value closer to the point located as far as possible from the lower boundaries of these zones. Accordingly, the loyalty of the passenger as a user of urban passenger transport services is ensured, both immediately and in the future.

At the level of an individual (potential passenger), the process can be described as follows. At the pre-transport stage, the user determines the existing constraints and acceptable compromises and formulates for himself criteria characterising the expected quality of the trip, which is a vector of ranges of quality indicators. The range of values of each of these criteria acceptable to the user represents the tolerance zone T_i.

As described in [19], in the decision-making process, alternatives that satisfy the requirements (constraints) are acceptable, and the alternative that reaches the extremum of the priority criterion or set of criteria becomes the optimal strategy and is implemented in the form of a trip.

CONCLUSIONS

It is advisable to integrate indicators of the quality of transport services into the processes of planning the development of urban transport systems and monitoring the implementation of transport work based on a methodology that considers the expectations and perceptions of the passenger. Focusing on those measures that seem to be a priority for the passenger counteracts the desire of the passenger to choose personal transport in search of a better transport service, reduces the load on the road network and helps reduce the harmful impact of transport on the environment.

To assess the perceived quality of a transport service, a gravity model can be used, according to which the user seeks to choose a transport chain that would have the least impedance of travel, that is, the highest quality indicators. The use of an integral indicator of the quality of transport services, considering the impedance function, allows city and transport administrations to assess the level of user satisfaction and to focus on those activities to improve the city transport system (route network, mode of transport, type of rolling stock, tariff policy, etc.) which offer the greatest return.

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