PLANNING METHODOLOGY FOR ROAD PASSENGER TRANSPORTATION

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ABSTRACT

The need for theoretical and methodological assessments of organization of the transport process, of the features of the passenger transportation market in the modern city is explained by the changing economic conditions in the country and transformation of legal foundations of production and business activities. The planning methodology, which is discussed in the first place, is considered in retrospect, successive development and is open to continuations, allowing to permanently obtain scientifically based results, verified solutions and reliable forecasts.

The current Russian legislation binds public authorities, regional and local governments to carry out organization of regular transportation of passengers and their baggage on the routes of the road and urban ground electric transport. The main act defining the competence of the executive authorities in development of regular passenger transportation is a document on planning of regular transportation. As such a document has not previously been implemented, its development should be carried out permanently at all levels of public administration and city management.

The analysis shows that it is advisable to develop a guide to transport planning, which would set forth methods of solving routing problems and technological organization of passenger transportation on regular routes of urban motor and urban electric transport, include the possibility of using modern software for modeling mobility and passenger transportation, as well as information obtained from georeferencing tools and the use of electronic IT. The guide should be based on the concept of sustainable development of transport systems and facilities; transport accessibility of various territories and objects for potential passengers; integration of urban planning, transport, environmental, social and other types of legislation; capabilities of modern «smart cities»; technical innovations in the field of transport engineering; an integrated approach and the concept of logistics of passenger traffic; permanent monitoring; improved staff qualifications.

Keywords: transportation market, road transport, management, planning methodology, passenger flow, demand, legal support, retrospective analysis.

Background. *Russian federal legislation establishes the obligation of the authorized public administrations, regional and local governments to carry out organization of regular transportation of passengers and their baggage on the routes of the road and urban land electric transport. The main act defining the competence of the executive authorities in development of regular passenger transportation is a document on planning of regular transportation [1].*

Such a document has not previously been prepared and has not been used. Its development should be carried out permanently at all levels of public administration and municipal management by specialists involved in this. The widespread preparation of regular transportation planning documents will require a large number of specialists throughout the country who must possess the necessary knowledge and competencies.

Objective. *The objective of the authors is to consider planning methodology for road passenger transportation.*

Methods. *The authors use general scientific methods, historical and comparative analysis, evaluation approach, statistical method.*

Results.

1. Legal context and approaches

Management actions in the context of the provisions of the Federal Law «On organization of regular transportation of passengers and baggage by road and urban land electric transport in the Russian Federation and on amendments to certain legislative acts of the Russian Federation» dated July 13, 2015 No. 220-FZ (hereinafter – FZ-220) comprise [1, art. 1; ch. 2–5]:

a) establishment, modification or cancellation of regular routes;

b) approval of the timetable for the route on the basis of the project submitted to the authorized body by the person initiating the route;

c) division of routes by types of regular transportation into routes with regulated or unregulated by the state (local governments) tariffs, changing the type of regular transportation on the route (bus, trolleybus, tram);

d) providing passengers with travel benefits;

e) holding a competition for the right to serve the route by carriers;

f) maintaining registers of routes of various categories and registers of stopping points;

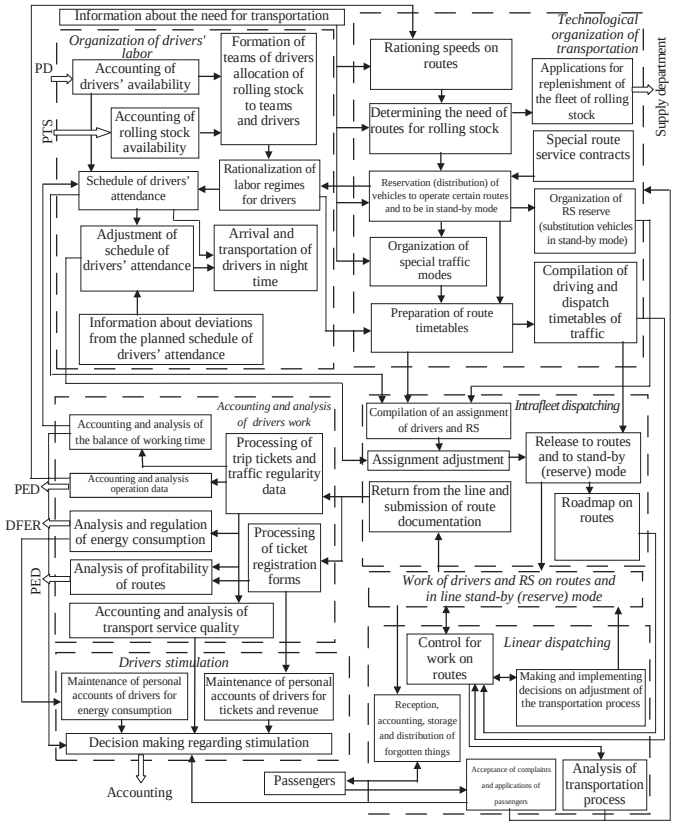
g) registration of certificates for the right to carry out transportation along routes and of route maps.

Previously existing technological developments can be considered as analogues of the tasks of transport planning only in relation to sub-items «a» and «b». The remaining tasks looked fundamentally different, as well as obviously their nonconformity with the technology of organization of transportation, developed by applied transport science. Moreover, to avoid confusion, two concepts should be distinguished: organization of transportation and technological organization of transportation of passengers and baggage. Pic. 1 shows an example of the sequence of solving problems in transportation by urban passenger transport (UPT) [2–4].

To implement the provisions of FZ-220 it is necessary to prepare:

• a regular transportation planning document, which is a regulatory legal act of the highest executive body of a government of a constituent entity of the Russian Federation or an executive body of a municipality. This document establishes a list of measures for development of regular transportation, it regulates relations connected with establishment, change and cancellation of routes, admission of carriers to service lines, use of transport infrastructure facilities, and organization of control over implementation of transportation;

• a certificate of transportation on the route of regular transportation confirms the carrier's right to carry out such transportation at unregulated tariffs;



Pic. 1. Information-logic scheme for solving problems in transportation of passengers by UPT. Dotted contours denote functional blocks of tasks, light arrows indicate – main information links with departments of the transport organization: RS – rolling stock, PED – planning and economic department, DFER – department of fuel and energy resources, PD – personnel department, PTS – production and technical service.

• a regular transportation route map is issued to the carrier for each vehicle, it contains a brief information about the route and vehicle characteristics, indicating the parameters affecting the quality of transportation – presence of a low floor, air conditioning, equipment for disabled passengers, an electronic information board, cabin air temperature control system, cashless fare systems, etc. [1];

• a «passport» (specification) of the route of regular transportation, which is compiled for each route and contains detailed information about it;

• registers of regular transportation routes are designed to record passenger lines in operation and contain a description of the type of transportation, routes, the maximum number of rolling stock units used on them, information on working hours, and carrier data. Route registries may be: a) municipal; b) intermunicipal; c) interregional; d) adjacent interregional ones;

• registries of stopping points are designed for their accounting and contain information about them.

The process of transport planning and the information and logical interconnections of its individual elements are presented in Pic. 2

Methodological approaches to planning, technological organization of regular passenger transportation in transport science were developed in accordance with:

• level of knowledge about transport systems and their technical and operational capabilities;

• understanding of current and strategic problems of transport and its impact on society, the economy, the environment, resettlement, land use and other essential aspects of life;

• methods of analysis and solving problems of planning and technological organization of passenger transportation;

• data processing technologies and data transmission tools used in this process.

Considering the listed factors in the complex, it is possible to single out the following main stages, characteristic for Russia:

• the first stage – from the 60s of 20th century to the collapse of the USSR and to transition from the command-administrative model of public transport management to market methods of production and economic activity;

• the second stage – from the beginning of formation of the modern Russian state until about 2010;

• the third stage – during last few years to the present.

It is also possible to speculatively speak about the fourth stage, meaning the predicted transformations of the passenger transport system in the foreseeable future.

At each of three stages, the basic issues of planning and developing regular passenger transportation by road and urban land electric transport were assessed differently:

• objectives and strategic priorities in implementation of planning and prospects of passenger transport;

• technologies of planning and shaping the future of transport systems;

• information and analytical support for the planning process;

• economic justification for planning and development of transport systems.

2. Methodological transport planning support

Methodological bases for planning the development of transport systems were formed by several scientific schools that carried out research and development in the transport, urban planning and transport and operational areas in Moscow (NIIAT, MADI, MISI, NIPI

of the General Plan, MARHI) [research institute of road transport, Moscow automobile and road construction institute, Moscow construction institute, research and design institute of general planning, Moscow institute of architecture], Leningrad (branch of NIIAT, LISI), Kiev (KievNIIP of urban planning) and other cities.

In a methodological sense, transport and town planning developments have found their normative and technological implementation in SNiP – building codes and regulations, the use of which by designers was considered mandatory. A large number of rules were developed that regulate various aspects of architectural and construction activities, including the transport design of the urban environment, construction of roads and artificial structures on them.

A significant methodological innovation for urban planning with the use of an integrated approach was formation and implementation of integrated transport schemes (KTS), which were carried out in large cities with a population of 250–500 thousand or more people in accordance with typical recommendations to designers [5, pp. 4–93]. The main task of the KTS was definition of guidelines for development of urban and suburban transport for the future 10–15 years.

The guidelines [5] describe in detail the technology for implementation of design work on development of the city's KTS, including the methodology:

• performance of a transport and planning assessment of the city and of quality level of transport service of the population;

• forecasting design parameters and designing routed transport networks;

• planning the development of the main road network;

• planning for pedestrian and passenger traffic;

• development of transport infrastructure (vehicle maintenance);

• development of suburban transport zone and trunk transport, providing transport links of the city with the external environment.

Technological approaches to transport planning for urban development are summarized in the monograph [6]. The methods of design and exploration work are considered in detail, recommendations on their rational implementation are given. The computational algorithms, questionnaires for transport surveys and regulatory and methodological summaries of the source data are given.

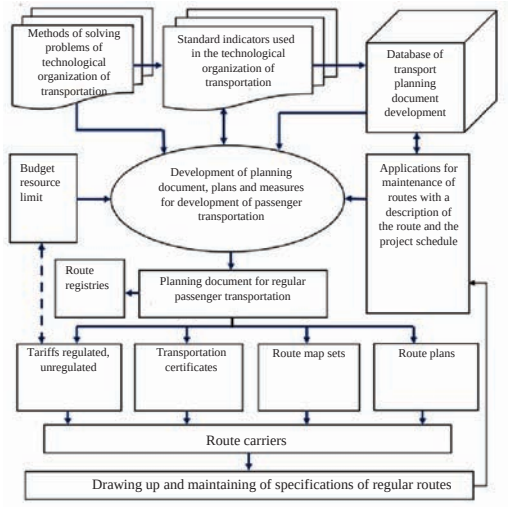
Transport planning is comprehensively presented in the works of the largest Russian scientist, professor M. S. Fishelson [7, 8]. When performing domestic developments, foreign experience was taken into account [9].

In general, the methodology of transport planning for development of the urban transport system has reached a fairly high level. Methodical, analytical and information prerequisites were created for planned calculations in semi-automatic mode using a computer. At the same time routine labor-consuming operations were performed by machine, and a group of designers carried out a qualitative comparison of the variants of the projects, choosing the best solution.

Significant achievements obtained in development of the methodology of the architectural and construction approach to transport planning were:

• formulation of a new problem and development of methods for solving a major national economic task of transport planning;

• development of hypotheses for settlement of urban residents taking into account alternative theoretical approaches and, on this basis, development of models for forecasting transport demand for passenger transportation;



Pic. 2. The process of transport planning.

• implementation of the planned development of urban transport systems;

• an attempt to link technical and operational solutions to the transport problem with economic benefits.

At the same time, problematic issues remained:

• significant analytical difficulties in performing time-consuming calculations, which did not give a sufficient number of variants of plans for their comparison and selection of the most rational, until modern methods appeared;

• the need for time-consuming collection of source data, the presence of which was completely not provided by the system of public statistical accounting;

• one-sided assessment of transport services based on indicators of traffic volume and passenger turnover, unfulfilled need for a new approach to the results of transport activities based on a marketing assessment of transportation and passenger service quality [10].

3. Routing of passengers

In the former USSR and other developed countries, significant success was achieved in the framework of the transport-operational approach to planning the development of transport systems. The main transport and operational studies were carried out in Moscow, Leningrad, Novosibirsk, Kazan and Omsk (creation of automated dispatch control systems). In contrast to the transport and urban planning approach, these studies focused mainly on routing problems on the existing network, passenger transportation technology and quality management of their services. This approach was used by almost all researchers, for example, by M. D. Blatnov [11].

The methodology for building an optimal[1] system (scheme) for UPT routes was based on apparatus for mathematical programming. In the late 1960s, M. V. Khrushchev proposed a workable method of forming a bus route scheme using a computer [13, 14]. It was replicated in many cities of Russia and other Soviet Union republics.

The main criteria for formation of route schemes (RS) were taken: reducing the time spent by passengers

[1] The optimality criterion was the minimum total cost of travel time for passengers.

on trips, reducing passenger interchange when traveling, saving carriers costs by straightening routes and increasing their speeds.

The multi-criteria nature of the task and the obligation to take into account various technological constraints do not allow to fully automate the formation of the RS. The optimal one is the scheme that best meets the clearly formulated requirements (criteria), for example, the minimum expenditure of travel time. In view of the need for a compromise solution, taking into account the requirements of a different nature and a number of non-formalized considerations, the implementation of a variant was adopted that was somewhat different from the optimal RS. It was called the rational scheme of bus routes.

A rational scheme of bus routes was formed on the basis of a guide [12], prepared on the basis of research results. Preparation of the scheme involves two stages [2, pp. 76–78; 13, pp. 5–59].

At the first stage, transport correspondence between individual transport microdistricts (TMD) of the city is examined and data for calculation are collected. Correspondence surveys are organized by the transport authority of the administration with involvement of specialized design and technological organizations with participation of carriers.

The following were used as TMD: residential areas, entrance checkpoints of plants with a large number of workers, other places of mass attraction of passengers (railway stations, stadiums, theaters, shopping and administrative complexes, etc.). If the residential area is located along a highway that has a single transport connection with the rest of the urban development (highway-radius), then such an area was taken as one TMD. When allocating microdistricts, they proceeded from the distance from the periphery of TMD to its center (no more than 500 m in accordance with the normative pedestrian accessibility of the transport line). The TMDs territory should not intersect with natural and artificial barriers – rivers, ravines, fences, etc., if there is no convenient walking route for passengers through these barriers.

On the large-scale plan of the city, the boundaries and centers of TMD were plotted, and the shortest possible routes of travel between neighboring (adjacent) microdistricts were determined. For centers of nodal TMD that are associated with more than two other TMDs, the average time spent on transfer from one direction to another was determined by passengers.

According to the results of the survey in the need for transportation a table of transport correspondences between separate TMDs was designed. Attention was paid to their correct presentation. Typical errors were: specifying correspondence without taking into account the passenger's use of rapid transport; lack of registration of arrival with children in preschool institutions before the trip and after the trip to work; zonal evaluation without taking into account various obstacles; lack of accounting for daily trips of passengers to neighboring settlements on electric trains.

A list of routes required for inclusion in the TMD was compiled, without preliminary calculations for reasons of conservation of: existing tram and trolleybus lines (taking into account the previously incurred significant costs for construction of the track and contact network); some of the most cost-effective bus routes providing the city's traditional transport links and ring routes. The share of such routes from their total number was, according to the opinion of the authors, usually of 10–30 %.

The data were prepared: on the number of rolling stock units; the minimum allowable length of the route for reasons of ease of operation and productive use of vehicles; the maximum allowable range of traffic on routes for reasons of ensuring the operation rate of transport of not less than 0,8; the minimum allowable volume of passenger transportation on the route based on the accepted maximum interval of traffic and the minimum capacity of a rolling stock unit. In this case, individual restrictions or all of them could be ignored.

At the second, design stage, an RS version is formed on the computer that satisfies the objective function:

$$\sum_{i=1}^{m}\sum_{j=1}^{m}(t_{c_{ij}}+t_{n_{ij}})R_{ij}+\sum_{k=1}^{n}t_{o_k}\cdot P_k+\sum_{l=1}^{l_0}t_{o_l}\cdot P_l\to\min,$$

where i = 1, ..., m – reference numbers of TMDs of the beginning of movement of passengers; j = 1, ..., m – reference numbers of TMDs of the end of movement of passengers; $t_{c_{ij}}$ and $t_{n_{ij}}$ – time spent per passenger to travel and make an interchange when traveling between the i-th and j-th TMD; k = 1, ..., R – routes of UPT; t_{o_k} – time spent by one passenger waiting for boarding while traveling on route k; P_k – number of passengers using route k; l = 1, ..., l_o – combined sections of the route network, along which two or more routes pass; t_{o_l} – time spent by one passenger waiting for boarding when traveling within the combined area l; P_l – number of passengers traveling within the combined area l.

Predefined routes are included in the scheme; the length of the routes is within certain limits; on each route, the interval of traffic is no more than a specified, the volume of traffic is not less than a specified one; there are no prohibited routes and route end points in prohibited TMD.

In formation of a rational TMD, the interactive mode of program operation is used. The solution option was promptly presented to the group of experts for evaluation and adjustment, taking into account additional requirements and informal constraints. By deliberately changing tasks, the experts sought a route scheme in which a compromise was reached between the requirements of the quality of passenger transport service, the economic interests of the carrier and the available resource possibilities.

RS, received after adjustments, was put on the city plan, tying it to certain streets and traffic patterns at intersections and squares.

The route scheme was revised in two cases:

• with current local changes caused by the emergence in the city of new residential areas, industrial organizations, UPT carriers, new metro stations or other rapid transport, new stadiums, theaters, shopping malls, etc.;

• with periodic radical reforming of RS, which was recommended to be held every 5–10 years [2, p. 71; 17, p. 210]. In reality radical reform was carried out not more than each 20–25 years.

4. Methods and rules

A problem that is quite independent and important for planning of transport activities is the study and forecasting of demand for transportation. For routed transportation, the demand for it is expressed in inter-district correspondence (the number of passengers traveling at a certain time between each pair of transport TMD, taking into account the directions of travel). These correspondences reflect the network mobility of the

population. On route hauls and stopping points, passenger traffic is studied through studying of movement of people through points of the transport network (hauls en route, arrival to the stopping point of the route and departure from it at the end of the trip). It should be noted that it is meaningless to talk about passenger traffic for taxi traffic, since in such cases there is only demand for transportation.

The methodology for studying and forecasting passenger flows for planning and development of transport systems is discussed in detail in [2, 15, 16]. Methods of obtaining data on passenger flows are based on the use of labor of the accountants, who perform many operations manually. It should be pointed out that the cost of obtaining information on passenger traffic, if we base on existing experience in solving the tasks of routing and technological transport organization, is equal to 95 % of the total cost of the calculations for organization of the route network and transportation within it.

Interdistrict correspondence serve as background information for formation of route schemes (network mobility of passengers). For planning the use of rolling stock, it is necessary to know the passenger traffic on the routes – route mobility of passengers.

Tasks of technological organization of passenger transportation indicated in Pic. 1 are solved on the basis of a repeatedly approved methodology, described in general form in [4, 17]. Similar tasks were contained in the previous regulatory technical document [18] developed at NIIAT on the instructions of the former Russian ministry of road transport [RSFSR Minavtotrans] and known to specialists under the working title «Order 200», as well as other industry guidelines.

In particular, SNiP 2.07.01-89 «Urban planning. Planning and development of urban and rural settlements» [19] was published. The specification of the requirements established by SNiP is carried out in regional (territorial) regulatory documents, taking into account local specifics and capabilities.

The projects of planning and development of urban and rural settlements stipulate to determine their prospects beyond the estimated time frame, including fundamental decisions on territorial development, functional zoning, planning structure, engineering and transport infrastructure, rational use of natural resources and environmental protection. An estimated period of up to 20 years is established, and a town planning forecast can cover a prospect of 30–40 years.

When designing urban and rural settlements, a unified system of transport and road network in conjunction with the planning structure of the settlement and the surrounding area should provide convenient, fast and safe transport links.

The rules stipulate the marginal standards of time spent by residents to move in one end of the settlement from the places of residence to the places of work (for 90 % of the population) depending on the population of the city:

Population of the city, thous. people	Time spent, min.
2000	45
1000	40
500	37
250	35
100 and less	30

For gigantic cities with a population of more than 2 million people, the standards for spending time for passenger traveling are established on the basis of an individual approach, taking into account local features of settlement, planning structure, level of development of rapid transport and other similar conditions. For residents of rural settlements, the time spent travel to job, as a rule, should not exceed half an hour.

In SNiP 2.07.01-89, the elements of arrangement and further development are regulated:

- *objects of external (main) passenger transport;*
- *road network of the settlement;*
- *facilities for storage and maintenance of vehicles;*
- *protection of the environment, including protection against harmful effects of transport on it.*

A separate detailed section of SNiP 2.07.01-89 is devoted to public passenger transport and pedestrian traffic. Standards for density of the route network, the prospective limiting occupancy of vehicles, the length of spans on routes, the time spent on interchanges and so on are established.

Currently, the updated version SP 42.13330.2011 of the previous set of rules is in force. The current regulations somewhat change the conditions for design of public transport. In future, it is proposed to calculate the occupancy rate of the passenger compartment on the basis of 4 pass./m^2 for the normal driving mode, and for rapid communications – on the basis of 3 pass./m^2 of free floor space of the cabin. We point out that such standards are exclusively town-planning and have no relation to rationing of organization of vehicles traffic on passenger transport routes (the latter are established only in transport legislation or by vehicle manufacturers).

The set of rules preserved the established norm of marginal distance of location of the public transport stopping point from the passenger's location which is 500 m, and also introduced some amendments for various local conditions and urban areas.

5. A plan has its own needs

The process of transport planning begins with determining the needs of the population for mobility, including the need for the use of vehicles.

The most general characteristic of the need for movement is the general mobility of the population – the number of travels per inhabitant per year. Travel over short distances is carried out mainly on foot. The share of travels by transport is determined by the coefficient of use of transport K_p, depending on the distance l and speed of movement v. For example, when l = 3,5 km and v = 6 km/h, and in the absence of results of a detailed study the coefficient K_p, on the basis of the available mean data, can be deemed to be equal to 0,47. Depending on the purpose of traveling, its share with the use of vehicles changes: labor and training transport traveling is typically not less than ¾ or more [4, p. 80]. The remaining trips are cultural, domestic and job-related ones.

The transport mobility of the population P_{tr} is measured by the number of trips per resident of the city per year:

$$P_{tr} = Q / N_{pop},$$

where Q – annual traffic volume on urban routes, thousand passengers; N_{pop}, – population of the city, thousand inhabitants.

In the absence of real data, it is recommended to use the enlarged standards for groups of cities [17, p. 161, 183]. The proportion of trips for various purposes varies depending on development and composition of the city-forming base, approximation of its objects to the places of residence. The need for travel varies regularly by periods of the day, reaching a maximum during peak hours.

Trips are characterized by direction, and therefore points of their beginning and end are allocated. The number of trips between a certain pair of points is transport correspondence. There are network (between microdistricts of the city) and route (between the

stopping points of a single route) transport correspondences. Network correspondence becomes the basis of the information base for transportation routing. Route correspondence is an informational basis for streamlining the corresponding routes.

General guidelines on definition of transport mobility, were developed in 1970 [20]. Since the publication of this manual and to the present, there have been no fundamental changes in the technological organization of passenger transportation. Only innovative technologies of obtaining travel information on the work of vehicles on the line and of monitoring data on traffic and passenger traffic, on introduction of new technical means appeared.

The methodology for examining passenger flows is discussed in detail in [15, 16]. For the purpose of streamlining statistical material on traffic and of planning the work of transport on the basis of standards for passenger mobility a guide was issued [21].

Former ministry of road transport once financed the conduct of dozens of studies to create a methodological basis for planning and technological organization of passenger transportation by various bus transportation modes. The greatest number of studies followed by organizational and methodological developments relate to buses used on urban routes and in the mode of route taxi. Passenger transportation by car-taxi was a separate scientific and methodological direction.

Route timetable for movement of bus transport is a basic planning document. When scheduling, it is necessary to solve a complex mathematical problem of conjugation of buses ready for release onto the line and schedules of drivers. To accomplish this, the methodology of allocation of buses by routes was used [22, pp. 6–23]. For the developers of timetables guidelines [23], relevant in present time, have been designed. Techniques embodied in these guidelines have been interactively implemented with the use of computer programs, the results being uodated and modified by experienced operators.

Rapid and express communication on bus routes at the same time increases the efficiency of the use of rolling stock, reduces the cost of transportation and provides a significant improvement in the quality of transport services for passengers. The fundamentals of planning and organizing rapid, express, semi-express and combined modes of bus traffic are described in [17, 24, 25].

The execution of the timetable has always been a problematic issue. Budget financing of carriers should be carried out only for voyages actually made in accordance with the schedule. Disruption of voyages has a significant impact on the quality of transport services for passengers, given that in Russia every fourth route is served by one or two buses. Therefore, to increase reliability of transport services, it is necessary to create and use a reserve of rolling stock.

The reorganization of the passenger transport system is associated with restructuring of a complex of public relations [3, 26]. When making calculations in the process of transport planning, the attention should be given to justification of the suggested method of valuation of time spent by passengers according to different transport solutions. The valuation allows you to set the travel time as the most important indicator of the quality of transport services and the cost of the project. The work [27] contains a description of domestic and foreign experience in determining valuation and discusses the methodological basis for substantiating this normative indicator for transport planning purposes.

Conclusion. *The analysis shows the methodological advisability to develop a guide on transport planning, which would set forth methods of solving problems of routing and technological organization of passenger transportation on regular routes of urban motor and urban electric transport that are adapted to new requirements. The guide should include the possibility of using modern software for modeling mobility and passenger transportation, as well as information obtained from georeferencing tools and the use of IT solutions.*

The principal requirements for the future guide are:

- *using the concept of sustainable development of transport systems and facilities;*
- *ensuring transport accessibility of various territories and objects visited by potential passengers;*
- *integration of urban planning, transport, environmental, social and other types of legislation in order to fulfill the regulatory requirements governing specified indicators of the quality of passenger transport service;*
- *implementation of capacity of modern «smart cities»;*
- *application of technical innovations in the field of transport engineering;*
- *an integrated approach to the use of the advantages of different modes of transport based on the concept of logistics of passenger traffic.*

To implement transport planning, it is necessary to create a system for monitoring information necessary for organizing regular passenger transportation, as well as to improve staff qualifications, modernize the content of the educational process at specialized universities, and the syllabus of training programs for the employees of the industry.

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