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The Quality of Public Transport Services in Multimodal Commuting in a Megalopolis



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ABSTRACT

The paper examines methodological issues related to development of an effective mechanism for structural and parametric identification of segments (streams) within connected flows of pedestrians and passengers through complex, long routes of movement of individuals within the boundaries of a megalopolis. Such routes determine significant volumes of multimodal transportation, repeated during the working week during peak hours, so it is necessary to identify them for managerial decision-making by organisations involved in transport planning, public transport traffic administration and provision of public transportation services.

The key point of the study is to determine the logic of choosing a route through an integral assessment of its quality, which includes an assessment of the quality of not only travelling itself and of services available during transportation, but also of the quality of transport infrastructure facilities, as well as of street-and-road network facilities on real routes involved in movement of people across the urban agglomeration.

To specify complex routes, flows with general parameters for formation and selection of routes for specific groups of pedestrian and passengers, and to build models of their behaviour, the study proposes a new key object, that is a public transport user (PTU), as well as an algorithm for identifying such routes using data from cellular operators.

It is shown that the known tools for studying the structure of demand for travelling on public transport are rather ineffective. The results of a study of the quality of public transport perceived by users within Moscow urban agglomeration presented in the paper have revealed a shift in priorities in choosing a route option from more time and money saving to the best in terms of convenience and quality of public transport on the route.

The study suggests a modified model of interdependent activities that directly influence the assessment of the quality of public transport on the PTU route, as well as a model of the sensitivity of PTU to the quality of route options.

Keywords: public transport, mass transit, transportation logistics, combined routes, behavioural profiles, passenger flows.

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INTRODUCTION

In accordance with the basic principles of sustainable development, public transport (PT) demonstrates higher quality since it is «more environmentally friendly», manages a structured demand for transportation services and owns a developed mechanism for satisfying it, including rational transit (e.g., [1]).

Namely the problem of creating such a mechanism determines *the key objective* of this study.

It should be noted that the very concept of «public transport» is very relative. In most countries, it is interpreted as a specific type of passenger transportation that operates on the territory and within the boundaries of a populated locality and meets mandatory characteristics that comprise the invariability of the route of movement of vehicles along the lines of the transport network allocated for these purposes; regularity of vehicles arrivals and departures at/from stations/stops for passenger embarkation and disembarkation; publicity, i.e., awareness of people about methods of transporting passengers, amounts and forms of payment for travel[1][2],. In several European countries and in the United States, where movement of people using personal vehicles prevails, the requirement for PT traffic according to patterns permitted by local administrations and departments of transport is not so strict. In these cases, slight deviations of PT vehicles from the path on certain sections of the route are possible due to the difficult road situation, as well as to the requirements for passengers boarding and disembarking (while planned stops remain obligatory).

According to another interpretation of PT, it includes vehicles intended for simultaneous movement of a «sufficiently large» number of people [2], which introduces some uncertainty for understanding the object of this study.

Another characteristic of public transport is its «accessibility», which in some interpretations applies to the entire population, in others refers to «wide strata» of population or general public.

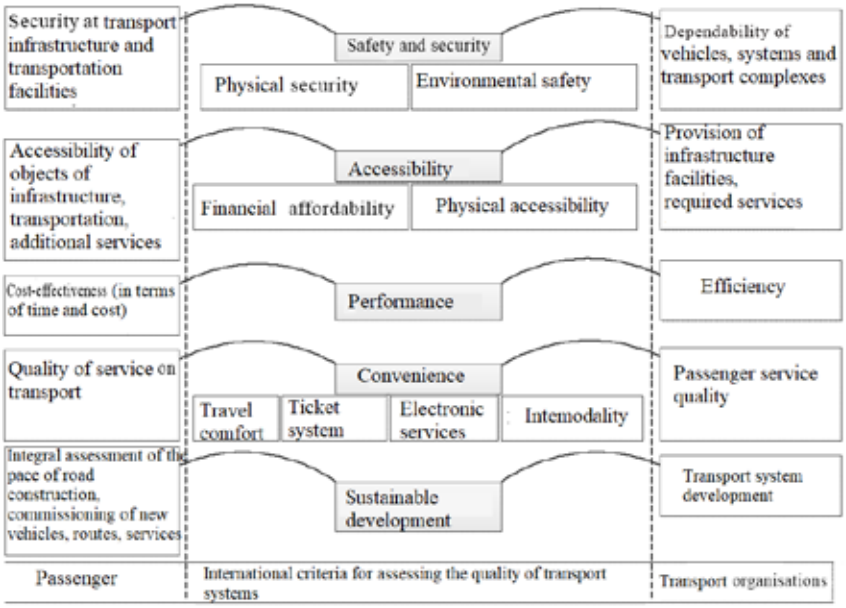
As for the physical accessibility of public transport, this requirement is unambiguous, while in terms of financial affordability in the second definition, such transport must provide price conditions for transportation of passengers with «low» incomes. In this context, the economic affordability of PT is not clearly defined either and thus is interpreted differently in different countries. In a few cases, the very principle of focusing on serving the population with low incomes is denied. Recently, a point of view has been gaining popularity according to which urban public transport should provide different services in terms of their range and quality, ensuring that the needs of different groups of people are met, including passengers who express readiness to pay a higher price for higher quality [3]. This position defines the existing differences in the standard sets of PT products and services adopted in different countries, which can be provided to people through allocation of specialised lines, partial operation of more comfortable vehicles on fixed routes as well as through provision of additional services.

For megalopolises, the requirements of consistency, regularity, public character, accessibility when organising «simultaneous» transportation of «large numbers» of passengers, in our opinion, are the most important. In this context, the article does not consider personal vehicles, taxis, including minibuses with fewer than 20 seats.

The public transport system of large urban agglomerations unites the transport systems of not only the city itself, but also of its suburbs and its commuter towns. PT systems of megalopolises with a high concentration of business buildings in the central areas of the city (e.g., Moscow) and of residential buildings around the circumference and in the adjacent suburbs and commuter towns are distinctive by active commuting of the population. The scale of large urban agglomerations, the high density of the transport network, which unites routes of various modes of urban transport in most megapolises, as well as the remoteness of residential facilities from scientific, educational, cultural, business and other centres of attraction of human flows, result in particular significance of complex itineraries (with more than one transfer), of long, combined routes which are in demand for the population and ensure commuting and are characteristic there-of. Such routes, according to our estimates, account for about 68 % in Moscow. The presence of many options for moving people to their destination across the megalopolis, for using various elements of street-and-road

[1] Collins English Dictionary (n.d.). [Electronic resource]: https://www.collinsdictionary.com/dictionary/english/public-transport.

[2] English Oxford Living Dictionaries (n.d.). [Electronic resource]: https://www. oxfordlearnersdictionaries.com/definition/english/public-transport?q=Public+transport.



Pic. 1. Model for a comprehensive assessment of the quality of transport (transport complexes and systems) [compiled by the authors].

infrastructure (on pedestrian sections of their itinerary) and elements of infrastructure of various types of public transport determines the need to assess the quality of such a route from the perspective of its end user, who is the main source of information on the perceived quality of public transport in general.

Insufficiency of fundamental developments in the studies on the logic of constructing and choosing a complex itinerary for various behavioural profiles of public transport users to identify within the general pedestrian and passenger flow profiled streams (segments) with characteristic parameters of their formation, as well as of studies on sensitivity of such segments on long, combined routes using modern digital technologies contributes to the relevance of the above research tasks.

MATERIALS AND METHODS

Among scientists and practitioners today, uniform criteria have been adopted for assessing the quality of the main «product» of public transport – «passenger transportation». They are reflected in the relevant standards, guidelines, handbooks of the International Association of Public Transport [UITP], UNECE[3], national handbooks (e.g[4].), etc., and are mostly based on the classic model of quality spiral.

The level of quality, in this case, usually determines the discrepancy between the achieved and expected quality of the transport service. In the USA and in several countries, it is calculated as the ratio of the actual level of quality to the expected level.

On the other hand, to evaluate public transport as a form of «organisation,» a set of criteria has become popular, which reflects the overall integrated assessment of the quality of transport, both from the customer's perspective and by transport organisations [4]. By transforming approaches to a comprehensive assessment of the quality of passenger transport from both customer's and transport organisations' perspective, we get a possibility to build a conceptual model for assessing the quality of public transport, shown in Pic. 1.

Since the overall assessment of the quality of public transport from the perspective of people mobility consists of assessments of effectiveness and quality (comfort) of transportation in a vehicle of each individual, as well as of their assessments of quality of elements of transport infrastructure (street-and-road, transport, route network) and services referring to their trips, then the quality of

[3] UNECE. A Handbook on Sustainable Urban Mobility and Spatial Planning – Promoting Active Mobility. United Nations Publication. 2020. [Electronic resource]: https://unece.org/transport/publications/handbook-sustainable-urban-mobility-and-spatial-planning. Last accessed 22.11.2023.

[4] A Handbook for Measuring Customer Satisfaction and Service Quality. Transportation Research Board. National Research Council [TRB]. Washington, D.C.: National Academy Press, 1999.

public transport as perceived by its user («perceived quality») will be identical to the quality of a route with a wide range of characteristics.

For combined, long routes with transfer hubs and walking sections, the performance indicator (total travel time), in our opinion, is no longer sufficient. The choice of a route (of better quality for an individual), as research results have shown [5], is influenced not only by the time in motion and waiting for the vehicle, the time of transfer to another transport route, but also by the quality of service while the passenger is in the vehicle and the pedestrian/passenger is at public transport infrastructure facilities along all the route from the place of departure to the place of destination. In this context, well-known methods for assessing the quality of a route [6] can be used only in terms of assessing its effectiveness, namely, «time en route».

Several researchers are trying to evaluate a transport service through the prism of its value for the end user. Some adhere to the traditional view and interpret the value of such a service through the opportunity to use time in a vehicle to their advantage [7; 8]. Others consider the value through accessibility [9], others – through perceived convenience, the quality of a comprehensive service [10]. Considering the quality of public transport on its customer's route in a broad sense, the value of the route option for PTU and the quality of public transport for PTU will be identical. Obviously, the value of the same route will differ for different people and different groups of users.

Traditional methods for determining the structure of demand for transport services, passenger preferences, convenience, accessibility and other important parameters and criteria for building and choosing a route, in most techniques, are based on marketing tools. In this case, the information is received based on the results of the surveys, which, according to experts, are effective only to evaluate the expected and desired quality of the route. At the same time, the real preference, the choice of the route option can be «seen» using modern digital technologies, the data of cellular operators and the method of identification of the individual's movement route in the territory of urban agglomeration proposed in [11].

RESULTS

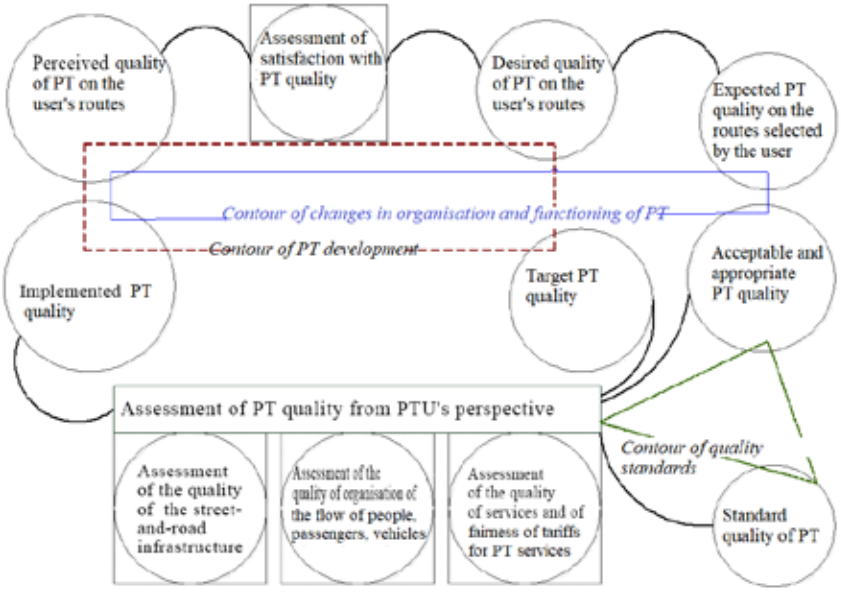
To specify such behavioural profiles and, accordingly, the streams within the interrelated flows of pedestrians and passengers, primarily identification of PTU is necessary. We propose to understand the public transport user of a megalopolis as a generalised, composite image of a person who changes over the course of time the status from an individual who makes a decision (search for information, analysis, evaluation and choice of an option) to a pedestrian and passenger en route. The introduction of this category into scientific discourse avoids problems of integration and coordination of data received from various sources of information, as well as of binding layers of the digital ecosystem of transport [12]. In this case, it becomes possible to conduct a multidimensional analysis of the results of sociological and marketing research conducted by various organisations and analytics received directly from carriers, cellular operators, organisations responsible for the operation and development of transport infrastructure.

Consideration of this facility in the complex scheme of organisation of public transport services for the population makes it possible to evaluate the quality of the «integrated product» of PT, namely the PTU route with a structured set of its characteristics during three phases of the evaluation process: desire (desired quality), expectation (expected quality) and reality (implemented quality). As a result, the classic quality spiral is modified and takes the form shown in Pic. 2.

As shown in Pic. 2 assessments of satisfaction with a public transport from customer's perspective can be obtained based on the results of comparing the values of the indicators of the «implemented» and «perceived and desired» quality, as well as of the «implemented» and «perceived and expected». In the first case, we are dealing with an ideal assessment, in the second with realistic one, which is formed considering the existing experience of PTU of using the analysed route. Moreover, factors that affect satisfaction and loyalty in the assessment of service do not differ significantly from those presented in the work [3].

The combined route of PTU does not always mean a change on the route of the type of transport, there are options of using one and the same type of transport, but of different routes along the lines/tracks/roads of this type of transport.

In PTU commuting, the final destination is an object of long-term stay (set by the researcher), and the origin one is the place on the residential area map. Another important condition for



Pic. 2. A model of interdependent types of activities affecting the assessment of the quality of transport services and public transport systems on the PTU route [compiled by the authors].

identifying the object of analysis and evaluation (referring to combined PTU routes) is a repetition of the route during the working days (during the time of the greatest loading on transport infrastructure). Accordingly, the proposed tools for specification of such routes are based on the principle of «repeatability».

To identify such routes and multimodal passenger transportation schemes, it is proposed to use the «models of network proximity» [11], to analyse and evaluate such routes it is suggested to apply methods of fuzzy clusterisation and the rate of user's satisfaction with public transport services [13].

In our opinion, the products of visual analysis of data are best suited as a research tool [14].

The fundamental difference of the proposed approach to the study and quality assessment of the full route of PTU is focusing on known assessment of the «level of service» of the passenger (LOS) [15], which indicates the level of quality of transport services and is used to classify traffic flows by organisations engaged in urban transport planning, namely on comprehensive quality assessment. If in a known concept the quality of transport systems is associated with its ability to ensure safe and reliable services to its passengers, then in the proposed concept, the assessment affects not only the systems of services provided to PTU, but also the state (quality) of the urban environment engaged on the user route that adds the value of additional service in the form of a variant of multimodal transportation by public transport.

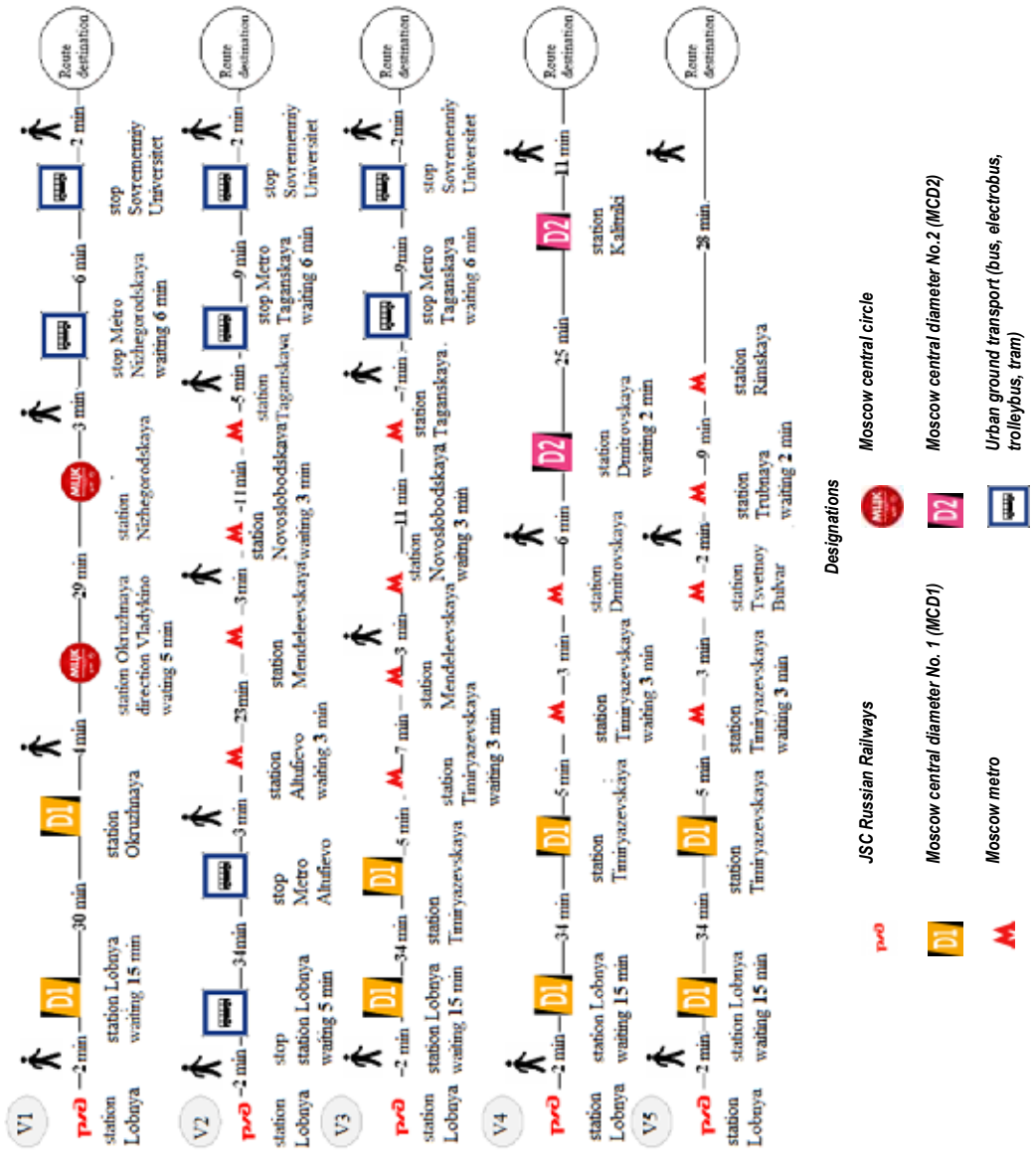
As an example, we considered the combined routes of Moscow Megalopolis, involving Moscow central diameters No. 1 (MCD1), No. 2 (MCD2) and the Noscow central circle (MCC) with walking sections of the PTU route, as well as Moscow metro and urban ground transport. These routes comprised options complicated for analysis and evaluation by PTU, consisting of no less than five alternative routes that had close values of the performance indicator. Main features of the studied combined routes of PTU are schematically shown in Pic. 3.

Table 1 presents the estimates of the considered route options. The values of the quality index reflected in Table 1 were obtained based on the results of studies conducted in 2020 on the issue of assessing the quality of transport infrastructure and transportation.

500 PTUs chosen randomly took part in the experiment. The assessment was carried out on a ten-point scale.

The results of the study confirmed our hypothesis that the choice of route is not always determined by the minimum travel time and cost of travel. 41 % of respondents preferred the fourth option, which has the highest quality index (nine points).

The economic assessment of performance of the set of possible routes that can be formed using MCD1, MCD2 is shown in Table 2.



Pic. 3. The structure of alternative options for the PTU route [compiled by the authors].

The columns in Table 2 indicate the departure stations. The lines indicate the arrival stations, at the intersection of the lines and columns there are the values of the effects for the corresponding routes (rubles per year), black cells mean the impossibility of constructing a route.

For economic assessment of effectiveness of the transport route, we used JSC Russian Railways 2020 data on passengers entering the railway stations indicated in Table 1 in the first half of the day, as well as methodological provisions [16], in which it is considered that every hour of time saved while waiting electric train, can be spent by the passenger on work, education or leisure. In this case, we assumed that the utility of a unit of time is the same in all three areas of its application. Thus, assessing the socio-economic effect, in our case, will come down to calculating the additional potential income caused by saving time [17].

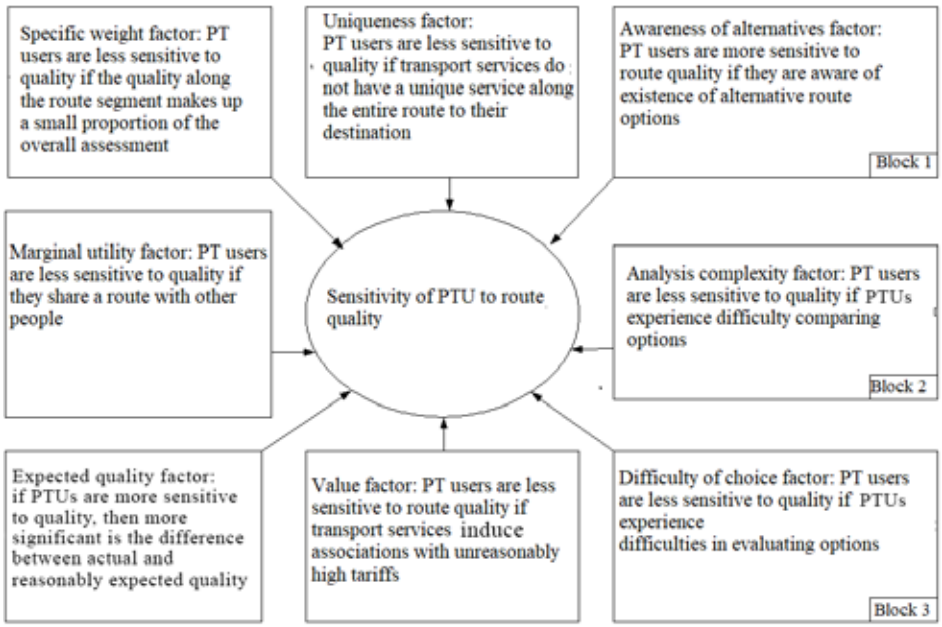
The results of our studies of quality of routes in Moscow agglomeration among passengers of suburban stations in the considered directions of travel showed that there was a shift in PTU

Table 1

Quantitative assessment of parameters of the routes under study

Assessment criteria	Numbers of alternative route options				
	V1	V2	V3	V4	V5
Performance (travel time, hours)	1,42	1,49	1,47	1,46	1,43
Route complexity (number of transfers)	2	3	3	2	2
Price/cost of service, rub.	MCD1 52/50 +MCC +bus 46/42	MCD152/50 +bus 46/42	MCD1 78/50 +metro +bus 46/42	MCD1 78/50 +metro +MCD2 46/42	MCD1 78/50 +metro
Quality index of PT on the route	8	6	7	9	7

Source: Compiled by the authors.



Pic. 4. A model for determining behavioural profiles of PTUs based on the priority «PT quality» [compiled by the authors].

priorities. There has been an increase in the number of PTU who give preference to options for complex, combined routes with the best characteristics of service, comfort and quality of transport infrastructure elements and route networks of the megalopolis: from 51 % in 2019 to 67 % in 2020 (provided the difference in travel time along the route does not exceed ten minutes). The survey covered 2000 people.

It is proposed that the specification of streams within the structure of passenger flow on long combined routes be carried out based on the parameters that influence the behaviour of PTUs of particular profiles presented in Pic. 4.

The difficulty of creating a mechanism for satisfying structured demand for public transport services that is adequate to real conditions is created by PTU who do not choose the traditional route («adherents») but do plan it and form it randomly. In this context, conducting research in terms of awareness, complexity of analysis and evaluation is a relevant task. Knowledge of the share of PTUs who respectively have information about alternative routes (Block 1, Pic. 4), have difficulties in planning a travel route, determining its structural characteristics and desired quality parameters (Block 2, Pic. 4), as well as those who have difficulties in determining criteria for a comprehensive assessment of public transport on the PTU route are necessary to build such behavioural models (Block 3, Pic. 4).

DISCUSSION

The results presented in this work lead us to a number of controversial issues and conclusions.

Matrix of PT performance values on combined PTU commuting routes (railway-metro pattern)

ANNUAL EFFECT	OTRADNOE	ODINTSOVO	BAKOVKA	TREKHGORKA	NEMCHINOVKA	SETUN	RABOCHIY POSELOK	KUNTSEVO 1	SLAVYANSKIY BULVAR	FILI	TESTOVSKAYA	BEGOVAYA	MOSKVA BELORUSSKAYA	MOSKVA SAVYOLOVSKAYA	TIMIRYAZEVSKAYA	OKRUZHNAYA	DEGUNINO	BESKUDNIKOVO	LIANOZOVO	MARK	NOVODACHNAYA	DOLGOPRUDNAYA
OTRADNOE		-115 869	299 148	-31 133	1 098 863	1 703 657	1 063 398	-305 375	0	-1 331 955	50 844	580 340	-680 055	2 841 399	239 649	88 159	334 872	378 235	469 342	16 755	11 888	239 363
ODINTSOVO	-136 444		-4 648	8 421	-7 146	-12 598	389 740	-1 371 994	13 211 648	-87 895	-244 552	86 686	-7 748 783	2 776 959	229 639	25 222	134 860	297 008	338 066	7 134	17 009	201 636
BAKOVKA	350 512	-42 539		-4 965	69 957	57 006	109 043	-249 953	1 517 165	344 189	-75 176	125 215	-384 218	358 077	24 771	6 545	26 745	34 906	39 965	0	1 376	23 617
TREKHGORKA	-24 365	-4 953	-204		1 131	119 076	30 297	-489 116	3 674 799	1 596 004	-138 793	908 938	1 004 592	500 066	33 107	4 204	42 213	58 754	62 477	6 614	160	73 259
NEMCHINOVKA	640 776	5 664	77 370	2 645		-5 199	8 872	-179 606	758 632	235 297	3 027	31 506	-265 530	74 456	10 721	1 630	6 905	12 738	13 919	0	4 478	18 654
SETUN	1 573 478	58 502	67 874	112 055	-4 270		15 756	1 095 537	14 968 659	19 817 588	-623 280	5 133 229	12 575 299	3 589 589	524 412	429 630	464 073	726 741	693 199	110 864	1 950	238 187
RABOCHIY POSELOK	961 614	366 178	73 666	40 559	10 575	731		140 055	2 553 619	2 565 540	-970 851	-51 693	2 202 528	1 640 120	251 440	163 199	197 893	359 626	278 850	54 479	4 995	74 602
KUNTSEVO 1	-196 545	-1 088 338	-142 760	-387 808	-59 760	735 040	174 143		-320 136	-6 777 164	-788 169	18 367 964	1 107 030	6 332 823	606 203	1 557 098	598 257	886 402	745 541	168 465	29 363	137 165
SLAVYANSKIY BULVAR	0	3 044 868	421 782	836 081	217 630	3 918 985	746 572	-269 511		29 374 311	7 421 274	55 274 601	15 591 290	21 163 257	5 620 257	4 539 993	2 506 931	3 239 811	2 685 762	632 606	122 341	307 923
FILI	-1 221 500	-2 105 461	207 750	987 276	79 015	9 509 443	4 190 407	-10 789 128	27 752 639	0	-903 134	27 933 060	4 799 858	8 047 054	2 073 230	396 279	1 424 555	2 010 598	1 728 114	402 676	77 683	690 527
TESTOVSKAYA	-18 951	596 186	146 161	90 086	6 336	538 888	499 674	-799 406	6 890 531	-1 436 824		14 686 180	20 491 229	7 650 490	2 476 948	-1 660	1 331 274	2 613 123	2 347 499	745 087	134 317	366 641
BEGOVAYA	3 039 611	4 222 829	674 389	2 354 473	89 203	4 218 897	2 414 851	14 763 610	45 688 616	23 646 103	23 091 711		19 451 283	46 868 057	10 330 956	1 989 781	4 412 499	5 670 406	4 494 937	1 346 074	421 281	1 094 448
MOSKVA BELORUSSKAYA	-599 921	-7 520 205	-286 763	-142 958	-345 020	5 491 279	4 405 263	943 012	17 020 225	4 538 388	18 852 258	21 354 233		0	-791 600	6 259 448	6 274 625	7 342 359	4 422 309	1 901 230	730 739	5 806 504
MOSKVA SAVYOLOVSKAYA	12 056 301	12 961 026	1 755 799	2 140 223	243 553	9 121 305	8 431 949	5 926 389	21 434 135	8 218 817	6 255 859	43 626 174	408 539		4 563 363	1 272 224	102 494	203 608	62 115	-447 941	-190 178	-975 018
TIMIRYAZEVSKAYA	881 068	1 022 465	103 044	66 951	19 084	1 733 640	1 753 025	693 991	6 517 178	2 454 988	1 209 483	10 931 775	-975 580	3 386 088		4 938 893	4 664 547	2 865 024	3 490 161	1 105 673	138 181	1 130 597
OKRUZHNAYA	89 622	46 438	5 691	2 600	1 629	284 283	330 829	1 473 930	4 945 655	740 830	-6 919	3 160 673	2 961 555	2 595 861	2 591 768		77 050	639 653	1 710 209	779 294	217 592	1 196 194
DEGUNINO	502 331	238 036	54 377	77 555	6 636	583 081	404 376	467 340	2 635 224	1 446 206	208 991	2 655 319	5 013 801	526 949	3 861 686	52 127		74 802	913 828	66 583	6 275	259 321
BESKUDNIKOVO	490 417	422 735	46 998	62 574	13 979	836 734	670 864	889 066	3 538 582	2 323 038	584 661	3 398 333	5 988 000	518 641	2 743 853	786 000	42 446		95 351	78 049	8 711	319 071
LIANOZOVO	614 183	556 792	42 828	86 720	22 652	823 078	572 761	670 538	2 757 988	1 688 373	332 085	2 120 520	3 859 790	227 031	3 321 164	1 574 824	836 409	63 869		25 090	62 374	1 019 128
MARK	39 042	31 614	3 677	6 065	784	179 222	80 413	167 383	751 824	474 488	118 168	749 132	1 764 612	-56 001	1 480 304	811 515	103 919	104 459	-1 868		-3 196	119 822
NOVODACHNAYA	18 646	12 797	0	8 912	3 565	65	15 160	7 350	36 651	19 606	3 405	74 002	86 673	-190 264	-45 961	115 644	-3 251	-7 612	41 384	797		17 877
DOLGOPRUDNAYA	338 004	309 332	23 227	85 183	4 395	295 043	140 227	140 306	364 045	740 308	112 144	643 783	1 120 541	-335 898	1 667 810	1 428 096	237 267	409 434	755 669	144 796	30 029	

Source: Compiled by the authors

• Considering the global trend to digitalisation of all spheres and areas of activity, we can assume the promising character of conducting in-depth research on real preferences, choices and implementation of customers' routes, as well as of building standard behavioural models of consumers of PT services. The developed models and algorithms for identifying profiled segments of passenger flows based on data from cellular operators make it possible to assert the possibility of using digital traces of PTU movements in the analysis and assessment of preferences and of acceptable PT quality characteristics.

• Not all users can correctly formulate their preferences. Research results show that in the decision-making process, the final choice is not always made in favour of a route option that has been built according to the parameters and criteria initially set by an individual. Conclusion can be made that survey methods are not so effective for improving traffic management systems and transport services for the population. The implemented routes provide a more accurate picture of preferences and attitudes towards PT quality.

• Not all PTUs choose a rational route of movement even after a real trip. Conclusion can be made that identification of a rational flow of passengers on a combined transport route, assessment of its capacity and sensitivity to price, service and organisational measures will make it possible to develop an effective mechanism for controlling movement of individual segments of flows of people in a megalopolis, as well as to identify bottlenecks in the system of traffic control and transport services.

• New services should include offers of routes for various profiles of PTUs with better «qualitative» characteristics of PT infrastructure elements within the permissible ranges of extra travel time and travel costs, which would consider the desire and ability of PTUs to independently conduct multi-parameter analysis and multi-criteria assessment of route options with the best characteristics for them.

CONCLUSIONS

The results of our research show the large share of multimodal transport along combined PTU routes using railway transport and urban public transport within commuting patterns of population migration. At the same time, there are reserves for optimising the load on certain sections of the transport network of a megalopolis by changing the direction of movement of passenger streams, identified by the behavioural profiles of the PTUs.

To form a behavioural profile of PTUs, it is proposed to use the principle of preference not only according to the known parameters of the route (type of transport, permissible number of transfers, maximum waiting time for a vehicle, time spent for walking sections, etc.), but also according to the quality parameters of public transport infrastructure elements engaged along the route.

The specification of profiled passenger streams within passenger flow is carried out based on a network proximity model and comprehensive assessment of quality of the route, which refers not only to its structure and performance from the point of view of saving time and money, but also to its convenience and «modernity».

We also identified a trend in Moscow for a change in the preferences of PTUs in the process of choosing a route option, from the initially planned more time-saving route to a route option with better quality indicators, but a longer travel time (with approximately equal total fare cost).

Analysis and assessment of sensitivity of connected flows of pedestrians and passengers within the boundaries of long combined routes to changes in the quality parameters of public transport infrastructure elements gives ground for offering the population a new service [18], which is a product of logistics of multimodal passenger transportation and mean route options for specific behavioural profiles of PTUs.

The introduction of the concept of «public transport user» with a variable status allows us to solve the problem of inconsistency of decisions in a multi-agent system, combine appropriate analytics in a multi-layer transport ecosystem, link quality assessments of the street-and-road network, route network, vehicles, transportation along the route and services from the perspective of a specific individual or a specific group of people within one behavioural profile.

Studies on the choice of public transport routes and assessment of their quality by people who owns a personal vehicle are also becoming interesting in the regions and countries with high rate of passenger cars per 1000 inhabitants, particularly in the USA and in the EU (respectively estimated as more than 850 and 560 in 2022).

Understanding the logic of forming a route and choosing an option for movement of people

across a megalopolis has a direct impact on congestion of individual sections of transport lines and the performance of public transport, allows developing reasonable plans for the necessary changes in transport systems considering the features of the current and predicted behaviour of users of transport services in specific region. This also applies to public transport development programs, which identify priority objects for transport construction and reconstruction of transport lines and nodes. In this context, more in-depth research is relevant, which will be based on the use of modern machine learning technologies in real time for a complex agent-based model of decision making in cities [19].

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