Contemporary Transport System of Kazan and Perm: Comparative Analysis

S A Merkushev¹, S R Khusnutdinova², A V Popov³

¹Department of Social and Economic Geography, Perm State University, Bukireva str., 15, Perm, 614990, Russia
²Institute of management, economics and finance, Kazan Federal University, Kremlevskaya str, 18, Kazan, 420008, Russia
³Faculty of Geography, Perm State University, Bukireva str., 15, Perm, 614990, Russia

E-mail: hsvr@yandex.ru

Abstract. Transport infrastructure is an important element of urban infrastructure, which affects the expansion of employment opportunities, accessibility and comfort of the urbiculture, and "failures" in the organization of the transport system, the choice of urban mode of transport may negatively affect the territorial-functional structure city, its sustainable development and lead to "alienation" of suburban areas, which is especially important in the agglomeration development of cities with a million population. In recent decades subway system, urban railways, street and high-speed tram, light rail, not only quickly develop basing on new technology, but more closely interact with each other and other species. One of the most important factors in the effectiveness of the combined system is cooperation between many city actors. Perm and Kazan have prerequisites for strengthening the integration of existing rail transport systems. However, there is a high probability that as a result of ill-considered management decisions, these chances, as well as the opportunities for a cardinal improvement in the transport situation, may be missed, which already leads to an aggravation of urban transport problems in the medium term. The completion of the large tram ring in Kazan is justified in terms of reducing the loss of the consumer due to the increase in travel time, the untapped potential of the tram network will decrease slightly. In Perm, the introduction of a combined rail transport system is advisable, both from the point of view of increasing the reliability of the tram network operation, and from the point of view of overcoming consumer losses due to an increase in their stay en route. The argument given in favor of the development of modern types of rail transport in two millionaires is undoubtedly regarded as one of the components of the rationale for the development of the mentioned types of transport in these cities, which should be the result of further interdisciplinary scientific research.

1. Introduction

The modern specificity of the development of millionaire cities, among other things, is the rapid change in their territorial and functional structure. At the same time, public transport in most cases is not a factor contributing to its optimization, but itself is being transformed more slowly than other spheres of city life. Nevertheless, all cities accumulate the latest experience of positive and negative
transformations in the transport sector, which requires study, comparison, comprehension and reformatting in recommendations on management decisions.

Transport infrastructure is considered as an important element of urban infrastructure, primarily affecting the expansion of employment opportunities, accessibility and comfort of urban lifestyle. And the "failures" in the organization of the transport system, the choice of the urban mode of transport may adversely affect the territorial-functional structure of the city, its sustainable development and lead to "alienation" of suburban areas, which is especially important in the agglomeration development of cities. Studies of such a plan are carried out on examples of cities in Australia and Europe [1].

2. Relevance
In scientific literature, attention is paid to the issue of the city's tram transport system from various points of view: accessibility for low-mobility groups; interconnection of the tram system and public spaces; the reintroduction of tramway transport in the cities of Europe, partially or completely refusing it; greater environmental friendliness compared to bus transport and the desire to ensure sustainable urban development; interrelation and mutual influence of the transport system, the cost of housing (rent), employment and access to urban services; expansion of opportunities for pedestrians, bicycles and communication with the general transport system; history of the formation of the urban transport system and its economic fundamentals [2-4, 5, 6-8, 9].

An important theme for cities in countries with economies in transition is to ensure the comfort of movement in urban transport, incl. trams, as a necessary condition for improving its competitive advantages compared to personal vehicles, creating huge problems for growing cities. A similar study was carried out using the example of Bucharest [10]. Research points to the commonality of urban transport problems for most developed countries, and examples of specific cities are exploring certain proposals for improving the urban transport system.

In recent decades, metro systems, urban railways, street and high-speed trams, light rail transport not only develop rapidly on a new technological basis, but are increasingly interacting with each other and other species. And if at the initial stage it consisted in the formation and perfection of the functioning of the system of transfer hubs [11], later it showed in the creation of systems of combined rail transport [12, 13, 14], called "tram-train". V.R. Vuchik notes that the use of such systems in the future can lead to a significant increase in passenger traffic (on average from 30% to 60%) on existing sections of the railway [15]. One of the most important factors in the effectiveness of the combined system is cooperation between many actors - transit operators, railways and city authorities [16].

It is important to note that the experience of the development of many successfully functioning urban transportation systems shows that often the opportunities for combining emerged at different stages of their development were ignored in making managerial decisions, that is, the chance to make systems more universal, economical and at the same time attractive for passengers was missed.

3. Formulation of the problem
Perm and Kazan are chosen for comparison precisely because there are prerequisites for strengthening the integration of existing rail transport systems, but at the same time it is likely that as a result of ill-considered management decisions, these chances, as well as the possibilities for a cardinal improvement in the transport situation, may be missed, which in the medium term will lead to an aggravation of the transport problems of cities.

In the article, the authors' proposals for the creation (development) of rail transport modes at certain sites are compared with the variants of accepted (negotiated) management decisions and inertial development in two positions: the efficiency of using the potential of the rail transport network and possible consumer losses due to the increase in time in the way, calculated on the basis of the algorithm proposed in the methodological materials on the assessment of the regulatory impact [17]. The comparison is made taking into account the overall context of the development of public transport systems of the two cities.
4. **Theoretical part**

The degree of efficiency of using the potential of the rail transport system (in this case, the tram) is estimated using the unused potential factor, which was calculated using the formula (1)

\[
Q = 100 - \left(\frac{\sum K_j \times 100}{L}\right),
\]

where \(Q\) - coefficient of unused potential, %;
where \(K_j\) is the "reduced length" of the jth edge of the network, km;
\(L\) - actual length of the network, km.

"The reduced length" was calculated by the formula (2):

\[
K_j = L_j \times P_j,
\]

where \(K_j\) is the "reduced length" of the jth edge of the network (actual length, corrected for qualitative characteristics), km;
\(L_j\) - actual length of the jth edge of the network, km;
\(P_j\) - complex indicator characterizing the qualitative state of the jth edge of the network, the fraction of units. The method of its determination has been considered in detail earlier [18]. If the value of each particular indicator corresponds to a reference one, then \(P_j = 1\), and \(K_j = L_j\).

Losses of the consumer due to the increase in travel time were calculated using the formula (3).

\[
M_j = (T_j - T_{min}) \times N_{med} \times 730,
\]

where \(M_j\) is the loss of one consumer of the transport service due to the increase in travel time for the year (for daily trips there and back) on the jth version of the trip, rub.
\(T_j\) - actual travel time for the jth version of the trip, minutes;
\(T_{min}\) - travel time according to the variant providing the shortest travel time, min;
\(N_{med}\) - the cost of one minute of the moving customer (calculated on the basis of the average wage in the region, adjusted for a coefficient of 0.75).

5. **Results**

In the structure of public transport, the share of trams in both Perm and Kazan has been steadily declining in recent decades. For the Kazan network, according to 2016, it was 7%. And was the lowest figure among all types of urban transport in Kazan (excluding city electric trains). According to the latest data for 2017, a street tram in Perm carries 12% of the total number of passengers transported, a lower figure only for the trolleybus - 5.5% (electric trains are also not taken into account).

Weak positions of the city tram of both cities are largely related to the current state of their networks. But if in Perm the main reason is the initially weak development of the tram network, which in recent years has been accompanied by a deterioration in the quality of the track infrastructure, which in 2017 led to a decrease in the speed of tramway trains, in Kazan - these are large-scale destructive processes the last two decades.

As a result, one of the most developed networks of street trams, based on three cycles by the classification of S. Tarkhov [19], turned into a network-tree, very poorly presented in the historical core, which is completely contrary to the global trend. The unused capacity ratio is currently 51.59%.

The coefficient of unused potential in Perm is 50.3%. As already noted, the network is used inefficiently primarily due to the unsatisfactory state of the track infrastructure. The most significant losses fall on the main cycle.

At the same time, it is possible that management decisions will not only change the situation, but will lead to better quality of passenger service. In Kazan, in our opinion, they are connected with taking measures to complete the big tram ring, which, of course, must be accompanied by the strengthening of its integration into the city's transport network. We considered two options for changing the coefficient of unused potential: when the rest of the segment was added using the technology of a conventional street tram and LRT technology. According to the first variant, the...
coefficient of unused potential will be reduced only to 51.09%, and on the second - to 49.54%. Such insignificant improvement of the situation is connected with large-scale losses of previous decades, which are difficult to fill, even using the most modern technologies. Nevertheless, the network will again have the first cycle, which may become a backbone for further network development, a convenient option will be created for a direct connection between the emerging transfer hub at the South Bus Terminal and Kazan-Passazhskaya station.

Speaking about Perm, we insist on the need to implement the idea of creating a combined rail transport system "tram-train". Similar recommendations were given and applied to some other cities in Russia [20-22]. It is proposed at the initial stage to organize the movement of combined rail transport between the Levshino and Perm-II railway stations, including at the site that is supposed to be destroyed in the near future [23], with the addition to the tram network within the projected transport and transfer hub at station Perm-II, and later in the district Motovilikha. As a result, the coefficient of unused potential of Perm will be reduced to 45.34%.

Next, we estimated the loss of time (loss of the consumer) because of the additional travel time that we expressed in terms of value, using data on the average wage by region according to the above methodology [24, 25]. In addition to the variant using the proposed combined system, when moving between the Levshino micro district and the Perm-II station, three other options were also taken into account (table 1).

| Types of transport   | trip | Way to a stop | Transfer | Summary, Tj | Tj - Tmin | Losses, Mj, rub. |
|----------------------|------|---------------|----------|-------------|----------|----------------|
| Electric train       | 40   | 5             | 45       | 5           | 7938,8   |
| Electric train + bus | 45   | 5             | 10       | 60          | 20       | 31755,0        |
| Bus + bus            | 80   | 8             | 88       | 48          | 76212,0  |
| Combined system      | 40   | 40            | 0        | 0           | 0        |

Thus, the option of replacing the movement with the help of a direct electric train on the site under consideration by a trip with a transfer at Perm-I station promoted by the authorities of the city and the region will result in an annual loss of time for one passenger (with a daily two-time use of the route), caused by irrational use of it, will increase in comparison with the existing version by 23.8 thousand rubles, using a combined system - they would decrease by 7.9 thousand rubles. This is another argument in favor of the decision to refuse the destruction of the site of the Gornozavodskaya railroad in Perm. Similar calculations were carried out for the section of Molodezhnaya - Perm-II (part of the above route). According to them, the additional losses of the consumer when moving with a transfer at the Perm-I station will increase in comparison with the existing version of the use of an electric train without a specified transplant by 17.5 thousand rubles.

In Kazan any option of creating a direct tram connection between two mentioned stations provides a reduction in the loss of the consumer, but the variant with the completion of the tramway ring using LRT technology is much more preferable.
Table 2. Comparative evaluation of consumer losses while using different variants of movement along the route "South Bus Station - Kazan-Passenger" in Kazan.

| Types of transport                              | time expenditure, min | Losses, Mj, rub. |
|-------------------------------------------------|-----------------------|------------------|
| Tram (existing segment)                         | trip 72, Way to a stop 3, Transf er 75, Summ ary, Tj 43 | 68273,3          |
| Tram (existing segment) + metro + trolleybus    | trip 24, Way to a stop 3, Transf er 10, Summ ary, Tj 37, Tj - Tmin 5 | 7938,8           |
| Tram (a new section of the ring)                | trip 33, Way to a stop 3, Transf er 36, Summ ary, Tj 4 | 6351,0           |
| Tram (a new section of the ring by technology, close to LRT) | trip 29, Way to a stop 3, Transf er 32, Summ ary, Tj 0, Tj - Tmin 0 | 0,0              |
| Bus                                             | trip 45, Way to a stop 8, Transf er 50, Summ ary, Tj 18 | 28579,5          |

6. Conclusion
Thus, the proposed management solution for the completion of a large tram ring in Kazan is reasonably justified in terms of reducing the loss of the consumer due to the increase in travel time, the untapped potential of the tram network will diminish slightly. In Perm, the introduction of a combined rail transport system is advisable, both from the point of view of improving the reliability of the tram network operation (reducing its unused capacity) and the point of view of overcoming consumer losses due to an increase in their stay en route.

This argument for the development of modern types of rail transport in two millionaires is, of course, considered by us only as one of the components of the justification for the development of these types of transport in these cities, which should be the result of a serious scientific study of a team of scientists belonging to different branches of science.

7. References
[1] Craven J, Horan E, Goulding R 2014 Population growth and infrastructure development in Melbourne *WIT Transactions on Ecology and the Environment, 9th International Conference on Urban Regeneration and Sustainability, SC 2014*; Siena; Italy; 23-25 September 2014 vol 191 pp 509-520
[2] Macdonald A, Coxo S 2011 Towards a more accessible tram system in Melbourne - Challenges for infrastructure design *ATRF 2011 34th Australasian Transport Research Forum 2011* 34th Australasian Transport Research Forum, ATRF 2011; Hilton HotelAdelaide; Australia; 28 September 2011
[3] Hirano K, Kitao Y 2009 A study on connectivity and accessibility between tram stops and public facilities *WIT Transactions on the Built Environment 15th International Conference on Urban Transport and the Environment, Urban Transport 2009*; Bologna; Italy; 22-24 June 2009 vol 107 pp 247-264
[4] Lois González R C, Otón M P, Wolff J-P 2013 The tramway between transport policy and tool for urban rehabilitation in certain European countries: Germany, Spain, France and Switzerland *Annales de Geographie* vol 123 694 pp 619-643
[5] Koloś A, Taczanowski J 2016 The feasibility of introducing light rail systems in medium-sized towns in Central Europe *Journal of Transport Geography* vol 54 pp 400-413
[6] Capasso A, Giannini G, Lamedica R 2014 Eco-friendly urban transport systems Comparison between energy demands of the trolleybus and tramsystems *Ingegneria Ferroviaria* vol 69 4 pp 329-347
[7] Burke T, Stone J, Glackin S, Scheurer J 2014 Transport disadvantage and low-income rental housing AHURI Positioning Paper vol 157 pp 1-62
[8] Naegeli L, Orth H, Weidmann U 2013 High-quality public transport and promotion of nonmotorized transport - Compromise or complement Transportation Research Record Issue 2350 pp 26-36
[9] Costa A, Fernandes R 2012 Urban public transport in Europe: Technology diffusion and market organisation Transportation Research Part A: Policy and Practice vol 46 2 pp 269-284
[10] Rădulescu V, Străinescu I, Moroianu L, Tudor E, Goia C, Bozaş F, Lupu V, Rădulescu B, Tănase M 2013 The need to improve transport conditions in the big cities of Romania WIT Transactions on the Built Environment 19th International Conference on Urban Transport and the Environment, UT 2013; Kos; Greece; 29-31 May 2013 vol 130 pp 125-135
[11] Rodrigue J, Comtois C, Slack B 2013 The Geography of Transport Systems 3rd edition (New York: Routledge) p 410
[12] Batiss F 2005 Combined systems of public rail transport 2000 World Railways 8 Retrieved from http://www.css-mps.ru/zdm/08-2000/00909.html
[13] Rayskin B M 2009 Tram-train company Alstom in Kassel World Railways 12 pp 21-28
[14] Hibbert L 2010 Trains get streetwise Professional Engineering vol 23 11
[15] Vuchic R V 2007 Urban Transit Systems and Technology (Hoboken: John Wiley & Sons) p 602
[16] Naegeli L, Weidmann U, Nash A 2012 Checklist for successful application of tram-train systems in Europe Transportation Research Record 2275 pp 39-48
[17] Collection of methodological materials on the assessment of regulatory impact 2011 Moscow (2016, Sepember 15) Retrieved from http://economy.gov.ru/miniec/acti-vity/sections/ria/
[18] Merkushev S A, Popov A V 2017 Tram networks of the Ural regional centers in a changing urban environment Geographical bulletin 3 42 pp 31–42
[19] Tarkhov S A 2005 Evolutionary morphology of transport networks (Smolensk-M:-Universum) p 384
[20] Epishkina K M 2010 Estimation of public efficiency of rail transport of megalopolis Region: Economics and Sociology vol 1 pp 255–72
[21] Ermak S 2014 Gaining meaning Expert-Ural 40 617 pp 12–18
[22] Plakhotich S A, Chemodanova K E 2010 New technologies of transport service of the population in industrial-urban agglomeration Bulletin of the Ural State University of Railway Transport 2 6 pp 14–21
[23] Shestakov A 2017 Our projects are real Rossiyskaya Gazeta-Nedelya-Perm Krai 7385 219 Retrieved from https://www.rr.ru/2017/09/28/reg-pfo/reshetnikov-rasskazal-o-krupnyh-infrastrukturnyh-proektah-v-prikame.html
[24] The average monthly nominal wage accrued in the Republic of Tatarstan for 2016 Retrieved from https://goo.gl/ic6YAr
[25] The average monthly nominal wage accrued in the Perm Region for 2016 Retrieved from https://goo.gl/wyrrz4