Transport hubs as experimental ground for new construction materials

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Abstract. The research purpose is to clarify the role, significance and problems inherent in transport hubs in the implementation of engineering solutions using new construction materials. The traditional scheme of commutation of passenger traffic between different modes of transport allows building physical models. However, the efficiency of materials in structures and the study of their operational properties are additional tasks for the calculation in new conditions. Historically, many large cities are characterized by a lag in the development of transport infrastructure in comparison with the growth rates of cities. The material and technical supply of construction inevitably faces the problem of the depletion of materials from their operational properties. Massive daily movement of the population to places of job and high operational loads reveal disadvantages primarily in terms of the traditional materials. The way out of this situation is the development of transport interchange hubs, while the use of traditional constructive and technological solutions causes additional difficulties for transport companies and businesses. The presentation of the key elements of the transport infrastructure as a testing ground for testing the properties of new materials such as high-alloy steels, composite materials, superplasticized concretes allows solving the problems of construction engineering in a new way.

The constructed transport hubs rarely comply with the loading standards, which is caused by the incorrect approach to their design: the existing construction rules are not comparable with the functional needs of new type facilities. For the assessment, such factors as material consumption, creation of regulatory conditions, quality and safety of materials, reduction in construction time, stability of functioning and others are used. The risks associated with the creation of transport interchange hub (TIH) are noted. The development of transport hubs in a megalopolis can be implemented during simultaneous improvement of the quality of applied construction materials and satisfaction of the commercial interest of investors. In addition to the direct technological effects, there are accompanying operational consequences in various areas of urban life.

1. Introduction

The purpose of conducted research is to analyze the interaction of the investment and the social spheres in cities based on the study of investment policy in transport construction area.

The methodology is based on dual system of views on the social-economic model [1]. On the one hand there is a use of factor analysis of different processes – construction, exploitation of transport...
objects, enterprises activity. On the other hand, the authors [2] approached social economic of a city as a synergetic system, creating additional effects thanks to interaction of separate elements.

This issue is covered by researches of many authors - A.I Popov (1998), A.A. Gavrilenkov (2011), A.V. Zvyagintsev (2018), L.A. Melnik (2018), Alfonso Valenzuela (2013), Irena Mocanu, Paul-Razvan Serban (2015).

Big cities in modern society acquired new qualities, that complicated systems have – multi-level management, lack of availability of resources, structural properties. Several decades ago there were two basic ways of a city development – either according to a centralized plan (from the centre to outskirts) or stochastic development of outskirts with their integration into cities. Nowadays all the cities in the countries of former USSR find new ways of growth in their development based on a combination of interests of the government, business and society [3]. The key part of the scheme of development is transport infrastructure, created by different types of transport (main, city and private). The success of transport system defines the quality of living standards and economic development rate. That is why the issue of investment management in transport construction is getting basic in the system of the social-economic development of the city.

During the process of the study of transport construction development the following tasks were stated and described:

1. Connection between gross figures of investment activity and macroeconomic indicators of economic and social development [4]
2. Social performance assessment of current construction projects in the passenger transport sphere, introduction of the project classification and substantiation of their selection criterion.
3. Building of social effect models accompanying urban development, determination of the proportion of the effect in technological development of construction and transport industries.

According to the authors, the above mentioned tasks suggest consideration of the important problem of calculation accuracy of investment needs. As the comparative analysis shows, this indicator in Russian investment complex is less 2 – 3 times than in American and European ones [5].

The interest towards the economic assessment of urban growth in Russia is increasing annually. The uncontrolled increase in the population in urban agglomerations can lead to negative consequences for the state and society, as it is noted in the work [6]. The authors made attempts to create scientific approaches to determine the limits for a city by the criterion of the equipment of its transport infrastructure by analogy with the methods proposed in the work [7]. The evolution of this idea over time should lead to the emergence of new scientific assessment tools. In addition, the useful consequences of these studies will be in the field of legislation, in the development of urban planning policies and urban development plans [8].

2. Materials and methods
According to the research work [8], one of the main problems in the development of urban areas is the inconsistency of the transport component with the rest of the components of any investment project. Thus, for Moscow urban agglomeration, the parameters of transport accessibility of a residential or industrial facility have no less significant impact on the return on investment than land lease rates. At the same time, the differentiation of this influence and its accounting in the investment budget of the project are significant. Other modern researchers come to similar conclusions [9]. For example, for housing construction on the scale of a micro-district at a distance of more than 30 kilometers from the administrative boundaries of the city, the costs of the provision of local transport infrastructure (in-yard passages, exits to the existing street-road network, urban passenger transport facilities and parking lots) comprise to 10-15% of the volume investment.

For the same type of construction within a 30-kilometer zone, the share of costs for transport infrastructure is reduced to 5-10%, and within the city it does not exceed a few percent. This is due to the increase in the value of land, as well as a high saturation of local roads. In such conditions, the problem of the provision of the population with a local transport infrastructure is solved quite successfully, which is confirmed in the work [10]. Such a conclusion could become in-depth only with
the traditional local distribution of the population in relation to the objects of employment: when the majority of workers at the enterprise live in a settlement or town for workers.

The complexity of the determination of large construction projects costs is explained by multifunctionality of the objects in specific cities conditions. There is an imbalance between the growth of demand for transport services and the carrying capacity of the city passenger transport and the capacity of road system. According to the population census data the Moscow population rose over to more than 12 million in 2010. At the same time the speed of traffic flows in the city decreases and as a consequence the duration of the population movement rises. Due to this productive time decreases and economic development of the city is getting slow and as a result investment flows are decreasing. However, the city is supposed to be developed improving living standards of its habitants and getting economic capacity better. It causes new standard requirements for all spheres of the city life, including the passenger transportation.

With the modern structure of the housing and labor market, specialists deal with significant daily movements of several tens of kilometers in different directions using various types of transport. This is typical for the modern stage of development of society [11]. This requires the development of not a local, but a unified infrastructure of suburban and urban passenger transport, as presented in the work [12]. The strategy for the development of passenger transport that existed in the twentieth century had an adequate supply of passenger traffic, but the population was determined by a target of 6 million people with sufficient employment in the suburbs. The sharp population growth that has taken place in recent decades, labor migration and job losses in small settlements have determined the need to strengthen the existing directions of passenger traffic. A completely similar situation is currently emerging in the countries of Asia [13, 14] and Europe [15, 16].

At the same time, some disadvantages were revealed such transfer hubs between railway stations, stations of underground and street passenger transport. If the throughput of suburban railways has enormous potential due to the creation of additional tracks, organization of clock traffic, introduction of new rolling stock (including two-story rolling stock), and increasing traffic speeds, then the connection between the station and the city is still organized according to the old, centuries-used scheme i.e. through the universal station square.

This brings to nothing the efforts of the relevant departments of the railways that are implementing investment projects in the field of passenger transportation. The actual efficiency of investments is also decreasing, since the significant time spent on transferring reduces the competitiveness of suburban public transport in favor of personal.

In order to get rid of bottlenecks in public transport system, the state budget remains the main source of investment. The participation of business and private capital in this area is limited only by the part of deductions from investment projects centralized in the budget in the form of rent, targeted fees and taxes. The second most important aspect is the participation of the transport operators themselves. However, even the railway industry does not have the opportunity to invest on its own because the limited investment budget and the actual dependence of any transport project on the interests of other participants play its role [17]. To determine the possibilities of engagement of various budgets in the implementation of the project for the construction of a network of transport interchange hubs (TIH), it is necessary to consider the management of economic and legal risks in this segment of investment sphere.

The main reason for the lack of investment initiatives in the development of THI is the lack of comprehensive legal and economic mechanisms for interaction between public-private investors within the framework of the agreement of public-private partnership (PPP). This raises questions about the way to manage this type of project. Today, TIHS are considered only for transferring passengers from ground passenger transport to high-speed off-street (metro, railroad, etc.), parking vehicles, providing related services and regulation of ground transport routes, in other words, for extended social functions, as noted in the work [18]. The safety aspect in the development of transport acts as a prerequisite that affects the design and cost [19].
In a scientific point context, TIH is a nodal infrastructure element, as opposed to linear objects. In large countries, the concept of infrastructure security has always meant the development of linear facilities. In the city, an interchange hub is extremely important and occupies a significant share in local traveling and has a significant impact on the natural and social environment [20].

3. Results

The studies show that in the most loaded nodes, where modern design solutions are applied, the density of passenger traffic reaches its limit values - up to 8-10 people / m², in less loaded nodes during peak hours the maximum density is 3-6 people / m². Only two TIHs out of 37 in Moscow meet the specified requirements. The operation of other transfer hubs does not meet the specified requirements as there is no optimal scheme for the movement of transport and passengers, intercepting parking lots, waiting pavilions, covered passages and information on the movement of ground transport. Almost all transport hubs in Moscow have a deficit in the length of the loading-unloading line by about 30–70%. The analysis, carried out through the examples of Moscow railway stations, showed the discrepancy between the construction codes and the commercial performance of the operators of suburban passenger transportation [5].

Thus, the growth of the general passenger traffic for all directions of TIH does not guarantee the provision of the increase in revenue for suburban traffic. Therefore, the participation of railways in investment projects for the implementation of TIHs is based on the risks determined by the imperfection of the used methodology. Having spent financial resources on the integration of station complexes into TIHs, there is a possibility not to get the result on passenger traffic in the zone of particular economic interests.

The social efficiency of construction is reasoned by the factors of the improvement of the transport accessibility of urban facilities. In this research on the determination of the economic efficiency of the development of TIH system, the following factors were determined and quantified:

1. The formation of a single system of transport hubs and new modern bus stations in the city and suburbs in order to increase the comfort and attractiveness of the use of transport system, which reduces the risk of underutilization of the transport line. The current state and problems of the transport industry in Moscow are characterized by the following parameters: Moscow in terms of population density (100.2 people / ha) is 1.5–2 times higher than similar indicators of the largest megacities in the world. The density of the road network is 3.3 km / km², which is 2–4 times lower than similar indicators in the world’s largest megacities. The volume of metro traffic is 1.5–2 times higher than those of the largest megacities in the world. The share of public transport in the total traffic (metro, railways and surface urban passenger transport) is about 74%.

The forecast of the changes in traffic volumes was performed, in accordance with which it was planned to increase the volume of traffic by public transport by 40%. At the same time, the maximum growth - one and a half times was predicted precisely on the railway.

2. The creation of regulatory conditions to take passengers and rolling stock of suburban, intercity and international traffic. The planning structure of mass passenger transport networks is characterized by the geometric features of the construction of communications in the city as a whole (for communications connecting the planning zones of the city with each other and with the suburban area) and in individual planning zones, the density and straightness of communications and the branching of the route network.

3. The improvement of the quality and safety of transport services, reducing the time for transferring at large transfer hubs will entail additional jobs. The quality of passenger service provided by the rolling stock of urban transport is checked on the basis of the calculation of the standard number of vehicles \( W_t \) on the network of this type of transport:

\[
W_t = \frac{120 L_c \mu_z}{V_m i}
\]

where \( i \) – standard traffic interval on passenger transport networks, min.
The following is taken \( i \leq 5 \text{ min} \) – to connect the main residential areas with the city center and the largest industrial zones, \( i \leq 10 \text{ min} \) – for other networks;

\[ V_m \] – route speed of this type of transport;

\[ z \] – coefficient of reliability to ensure the normative interval of movement, equal to 1.6;

\[ L_e \] – length of the network of lines of this type of transport, km;

\[ \mu \] – route factor, taken in the range of 1.5–4.

For TIH, this formula is of particular importance as the need for mutual coordination of transportation schedules for all types of transport will require changes in route coefficients, primarily for street public transport.

4. The elimination of unauthorized points of arrival and departure of buses. Such points, although insignificantly, have a negative effect on the economic development of transport.

5. Reduction of the time of communication between the city and the region.

The purpose of TIH is determined by the following tasks:

- to provide a safe and comfortable transfer of passengers from stopping points at the Moscow Railway Station to stopping points of other types of transport;
- to minimize the time spent on the transfer;
- to provide pedestrian communication of the stopping point with the adjacent territory, including ensuring transit.

6. The increase of the attractiveness of public transport. Transport hubs should consist of technological facilities that ensure the transit of passenger traffic from terminals to other facilities, including facilities of other types of transport.

7. The reduction of the load on the main road network due to the formation of a system of intercepting parking lots as part of transport hubs.

8. The provision of the conditions for the sustainable functioning of ground passenger transport systems through the implementation of special measures at the approaches to the nodes. The principles of TIH reconstruction are determined by the time spent on travel to the place of work for 90% of working citizens (60 minutes). However, this figure does not take into account the traffic flow from nearby cities, as for settlements in other large countries (the USA and China).

The reconstruction of transport hubs should be carried out taking into account their role in the system of transport services in Moscow, based on the following principles: provision of comfort and convenience of passengers, functionality in the placement of node elements and the complexity of the formation of nodes.

Nowadays there are two main ways of reconstruction of transport interchange hubs: placement in the hubs of multi-storey interchange complexes (as in the USA and Japan) and the implementation of local plane measures (as in busy cities in China). Taking into account the significant cost of multi-storey transport hubs, as the first stage, it is advisable to implement a set of local measures prior to the construction of large stationary facilities. In order to implement this project, it is necessary to analyze the risks that would affect the economic efficiency, which is important during the implementation of the project in the format of public-private partnership (PPP) with the prevalence of private investor investments.

It is necessary to note that in addition to positive effects, the project of TIH also carries a number of potential risks and negative consequences, such as:

1. Risk of underloading. The discrepancy between real traffic and projected indicators can lead to the decrease in the expected socio-economic effects and at the same time negatively affect the financial component of the project. The underloading factor is calculated by the formula: \[ C_{ul} = \text{Tariff} \times L_s \times \text{Length of the section} \times N, \] where \( \text{Tariff} \) - the adjusted level of nominal tariffs (RUB / vehicle-km); \( P_s \) - losses during collection of fares (number of cars, pairs of trains) (per day); \( \text{Section length, km} \); \( N \) - days in a year;

2. Risk of public resistance. The deterioration of the environmental situation and low awareness of the population about the purpose of the construction of a transport facility can cause discontent among people with the start of construction.
4. Conclusion
The basic conclusion of the authors is the quantitative determination of the investment process impact on social sphere of any city. It is determined that the biggest correlation has factors dependent on the quality of the pricing system. The results of the research are significant for the process of the pricing improvement in construction and urban planning regulation.

The main conclusion of this research is that the project of TIH can actually have a significant positive impact on the process of the use of new construction materials, without the reduction of the economic effect for railway operators. The direct beneficiaries from the construction and operation of TIH will be shopping centers, parks, hotels and business centers [8]. From a socio-economic point of view, new jobs will be created for the population of TIH-based region.

The direct beneficiaries of the project will be construction companies and private investors among the enterprises at the construction stage and due to the multiplier effects, economic benefits will be reflected in almost all sectors of the economy of Moscow. A separate effect directly related to the emergence of new transport services will be a reduction in the costs of transport companies, which ultimately will have a positive effect for most trade and industrial organizations due to the decrease in the cost of transport component.

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