Main measures to reduce the environmental burden in the operation of transport hubs of large urban agglomerations

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Abstract. Over the past 10 years, transport interchange hubs (TIH) in Russia have turned from projects with a strictly transit purpose into key elements of urban infrastructure modernization, increasingly attracting people's attention and acquiring additional functions. It is worth noting that in the living conditions of a modern metropolis, mobility, speed and ease of movement are the most important criteria for the development of transport infrastructure, and projects to create a TIH, meeting these requirements, give a new impetus to the formation of public spaces where people can receive the necessary services and services without leaving the area of residence. These factors require timely adaptation to the existing situation and the search for new solutions, one of which may be the integration of real estate into the TIH and adjacent territories, which will allow projects to be implemented on more investment-attractive land plots, within walking distance from the metro, MCC, public transport stops. It is assumed that office and shopping centers built in the adjacent territories of the TIH will have a higher demand due to passenger traffic passing through the shopping areas, reducing the time of office users on the road and the advantageous territorial location of the property, which will positively affect the growth of prices for renting and selling these objects and, as a result, on profitability and efficiency of development projects.

Keywords: development of transport hubs projects, environmental safety in the development of transport hubs and adjacent territories, passenger traffic, land for the construction of transport hubs, implementation of investment projects within transport hubs.

1 Introduction

A significant problem in the development of TIH projects and adjacent territories is the reduction in the number of vacant land plots for development within the city. The dynamics of changes in the volume of vacant sites in Moscow according to the Federal Service for State Registration and Cartography "Information on the availability and distribution of land..."
in the Russian Federation (by subjects of the Russian Federation)" for the period 01.01.2016-01.01.2023 [1] is shown in Figure 1.

Fig. 1. Schedule of dependence of free land plots for development on the time period

The shortage of land resources becomes a negative factor that will progress over time if the existing territories are not rationally used and real estate objects are not integrated into the transport infrastructure, taking into account the necessary environmental safety measures. The consequences that a shortage of land plots may lead to in the future are: a slowdown in the pace of construction, an increase in the cost of projects, a narrowing of the real estate market only to large players, a decrease in competition, monopolization and stagnation of the entire industry [2].

With the improvement of transport accessibility within the city, which is achieved during the construction of TIH, the load on the existing transport system increases due to population growth, and hence the environmental burden. The factor of transport infrastructure development is also one of the main prerequisites for the emergence of investment and construction projects as part of the TIH [3].

The implementation of investment and construction projects as part of TIH is becoming a new necessity and is gaining popularity in Russia. The construction of such facilities makes it possible to obtain the most promising and investment-attractive land plots located in close proximity to the metro, ground transport stops, and the increasing passenger traffic passing through shopping areas will guarantee the return on investment to the investor. These factors and advantages are especially important for the commercial real estate sector, since it turned out to be the most sensitive to the unfavorable epidemiological and economic situation in the country. It is also worth noting that any real estate object should not only meet the requirements of regulatory documents in engineering and technical solutions, but also have a unique concept, meet modern trends, be liquid and cause minimal harm to the environment [4].

In accordance with the Decree of the Government of Moscow dated 06.09.2011 No. 413 "On the formation of transport interchange hubs in the city of Moscow" by the end of 2024, the number of implemented projects will cross the mark of 192 nodes with a planned final indicator of 273 stations [5]. In total, the urban development potential of the TIH is 9 million square meters. Today, the total passenger traffic passing through the existing TIH is 8.2 million people per day, and by 2024 the projected passenger traffic will increase to 16 million. The dynamics of TIH passenger traffic in Moscow is shown in Figure 2.


Fig. 2. Dynamics of passenger traffic of TPU in the city of Moscow

2 Materials and Methods

Given the high level of development of transport infrastructure, the dynamics of TPU construction, it should be noted that in order to stimulate the economy and attract additional investment in urban projects from the private sector, the Moscow Government has developed measures to support investors implementing new projects in Moscow. This support measure is the provision of the status of an investment priority project (IPP) for a period of up to 10 years with mandatory annual confirmation. The IPP status makes it possible to reduce the tax burden on projects implemented under public-private partnership agreements [6-8].

To date, the main part of the TIH is being built in Moscow, taking into account the prevailing urban planning conditions, the complexities of the engineering and geological structure of the city and negative environmental conditions in some areas [9, 10]. The implementation of such a set of projects can significantly affect environmental aspects, since the construction and operation of any TIH is associated with an increase in noise exposure, passenger traffic, gas emissions, etc., however, without them it is impossible to develop the city. In this regard, the most important task is to optimize the process, taking into account the minimization of negative impacts and additional careful study of environmental measures during the preparation, construction and further operation of transport hubs and adjacent territories. The following are the main measures that can reduce the environmental burden [11, 12]:

- development of measures for additional protection against vibration and noise during the construction and further operation of TIH and adjacent facilities;
- reduction of carbon dioxide emissions by transferring part of the facilities to underground space;
- development of measures for wastewater disposal and additional wastewater treatment;
- elaboration of measures to minimize the risks of groundwater penetration and landslide processes;
- development of measures for possible secondary use of soil, as well as its removal or storage.
● development of measures for the removal of household garbage during construction, as well as subsequent sanitary cleaning of the territory;
● improvement and rehabilitation of adjacent territories

The key problems of the implementation of investment and construction projects in the TIH and in the adjacent territories are presented in Figure 3.

![Diagram showing problems of implementing ICPs as part of TIH]

**Fig. 3.** Problems of ICP implementation in the territories adjacent to the TIH in Russia

The construction of TIH and real estate in the adjacent territories can become a more investment-profitable and attractive project in comparison with similar activities for the implementation of shopping and office centers, apartments or residential buildings, provided that the identified problems are solved. At the same time, it is necessary to analyze various conditions and reasons affecting the success of such projects [13].

Speaking about the factors affecting the potential socio-economic effect of investment and construction projects as part of TIH, it is necessary to highlight the following, presented in Table 1.

**Table 1.** Main factors affecting the socio-economic effect of the ICP in the adjacent territory of the TIH
The key problems of the implementation of investment and construction projects in the TIH and in the adjacent territories are presented in Figure 3.

Table 1. Main factors affecting the socio-economic effect of the ICP in the adjacent territory of the TIH

<table>
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<td>Location of the TIH</td>
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<td>7</td>
<td>Revision of the regulatory framework with the inclusion of the possibility of construction of residential real estate objects in the adjacent territory</td>
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Speaking about the factors affecting the potential socio-economic effect of investment and construction projects as part of TIH, it is necessary to highlight the following, presented in Table 1.

Speaking about residential real estate as part of TIH, it should be noted that the residential component, of course, increases the interest of investors in TIH projects, but it does not fit well with their concept, proclaiming the priority of workplaces over bedrooms. However, as foreign experience in the implementation of transport-oriented development projects shows, housing can and should be located both within and in the adjacent territories of the TIH. Such housing is not for a calm and measured lifestyle, it is for those people who primarily need a convenient transport location and minimization of logistical costs. At the same time, the infrastructure around such real estate objects will be at a very high level, and the risks of unfinished construction are minimal due to the priority and importance of transport facilities for the city. Together with the TIH, the entire district will grow and develop, and, accordingly, the prices of apartments in it, which will be beneficial for potential investors [14].

The creation of residential projects as part of the TIH will be especially relevant in the current economic situation. This step will allow attracting more private sector to transport-oriented development projects, since it is investments in residential real estate that are the most conservative way to preserve and increase capital even in difficult economic conditions [15]. Also, as history shows, during crises, it is possible to observe the redistribution of funds from financial markets to real estate. As an example of the impact of TIH on investment and construction projects, it is necessary to consider the dynamics of prices for apartments in residential complexes after the start of construction of this transport facility (Table 2).

Table 2. Price dynamics of residential complexes after the start of TIH construction
According to these indicators, it can be concluded that after the start of construction of the TPU, the value of the price of sq. m. increased by an average of 14.3%. Thus, the choice of a real estate object as part of a TPU is an important indicator characterizing both the economic and social effect of an investment and construction project in the adjacent territory.

It is necessary to note such an important factor as the passenger traffic of the TIH. Speaking of commercial real estate, it should be noted that passenger traffic can affect the share of the retail component in the total area of the TIH, and it can also affect the composition of tenants of premises. This indicator is characterized not only by a balance between the interests of private investors, whose priority is to increase the share of the commercial component in the TPU, but also by passengers, for whom convenience, comfort of travel, and time reduction are important.

The next important factor is the development of the concept of environmental safety and reducing the burden on the environment. Partially environmental problems that may arise during the operation of TIH can be solved by transferring some objects to the underground space and designing energy-efficient engineering networks and communications. Next, let's look at some of them.

### 3 Results

1. Reduced energy consumption.

   In Moscow and the region, the average depth of soil freezing is 1.2-1.5 m. The ground below this depth has an almost stable temperature throughout the year, thus, the design of facilities below this mark allows for more flexible heating systems, which significantly reduces energy consumption. The use of cold/hot air filtration systems and the operation of...
pipes with water movement located in the supporting structures of underground walls will not require additional heating/heating systems for underground spaces. The use of the "wall in the ground" technology will allow the use of pipes cooled in these walls to cool aboveground premises in the hot season (replacing traditional air conditioning systems). This is due to the fact that the average ground temperature is 10-12 degrees Celsius, and it will cool the water in the pipes.

2. The transfer of some objects to underground levels allows you to free up the aboveground space and carry out its improvement or additionally design a park or recreation area.

Huge megacities, such as Moscow, often suffer from the lack of green areas, without which it is impossible to create normal living conditions and an ecological climate. The transfer of premises will free up the necessary territories and improve the microclimate around the TIH.

3. Overall reduction of the negative impact of TIH on the environment.

The implementation of this task is possible by transferring most elements of the TIH to an underground space, for example, bus stops, railway tracks, etc., which is the most environmentally friendly option. In this case, it is additionally necessary to provide modern ventilation systems, taking into account the design and implementation of exhaust gas processing systems, which will also have a positive impact on the environmental condition of the area.

In order to improve the mechanism for implementing TIH projects, it is necessary to consider in detail the structure of this interaction taking into account PPP mechanisms in Russia. To date, in domestic practice, the implementation of investment and construction projects in the territories adjacent to the TIH is carried out, as a rule, according to the following most common models, presented in Figure 4.

Let's consider 2 models for the implementation of transport-oriented development projects: construction at the expense of the investor; creation of a project company SPV. Construction at the expense of the operator's own funds, which in Moscow is the company Mosinzhproekt JSC, will not be considered due to the lack of private investment in this model.

**Fig. 4. Models of implementation of TIH in Russia**
It is worth noting that the following contract scheme is used in the models under consideration, as shown in Figure 5.

According to the DBT (Design - Building - Transfer) scheme, the transport infrastructure facility involves the design, construction, commissioning by the private sector and the transfer of the finished facility to the city.

In order to implement the DBT scheme, we will consider the first model of interaction between the private and public sectors. This model is characterized by the sale of the right to conclude a lease agreement for a land plot, as well as the transfer of a land plot for construction purposes to lease for 10 years based on the results of open auctions, as a result of which the annual fee for the plot is determined. This model, as a rule, is used for investment and construction projects implemented on vacant land plots as part of a TIH.

According to the results of the implementation of the TIH construction project, the total area of the facility is transferred to the ownership of the investor, with the exception of the technological component, which is transferred to city ownership free of charge. To date, this method is inferior in popularity to the model of creating a project company, since an important factor in protecting the interests of investors is the creation of conditions under which the revenue received would be spent only for specialized purposes. The use of a newly created company as a private partner or concessionaire, which is not engaged in any areas of activity, except for the implementation of a PPP project, just allows investors to minimize their risks. In addition, lenders can be sure that they only assume the risks associated with a specific PPP project, and not the entire business

To implement the DBT scheme through the SPV (special purpose vehicle) "project company" model, the city forms a subsidiary of the same name with the name of a specific TIH station. The land plots and the right to implement the commercial component of the project on them are transferred to the project company. The organizer of the auction and the owner of the assets that will be offered to investors as a legal basis for the implementation of development projects is the operator. There are currently 3 main operators in Moscow: JSC "Mosinzhproekt", SUE "Moscow Metro", JSC "MKZHD".

Then investors are attracted, and a competition is held, as a result of which the winner is granted a share in a subsidiary, that is, in fact, the investor buys out a block of shares. The size of the investor's share is determined at the level of the city authorities, but, as practice shows, the private sector buys 100% of the share in the authorized capital and additionally provides for the obligation to more thoroughly study environmental aspects and measures to reduce the burden on the environment compared to a conventional project. The subject of bidding, unlike the first method of project implementation, is not the amount of the annual rent, as it happens when a land plot is put up for tender, but a block of shares of a specific SPV. With the help of the creation of the SPV project company, the city capitalizes the land plot an order of magnitude higher than if it simply put it up for auction, since in this case the owner of the plot is clear, surveying has been carried out, there is an urban planning plan of the land plot, the main technical and economic indicators and the functionality of
future development have been approved. This model is typical for investment and construction projects, the objects of which are combined with the technological part of the TIH.

4 Discussion

Taking into account the peculiarities of this model of implementation of transport-oriented development projects, it should be noted that in addition to buying out a share in the project company, the investor should also take into account the costs of rent, the implementation of the project itself and the additional study of environmental safety aspects. Do not forget that TIH involves the construction of social and cultural facilities, including elements of the social sphere – these are police stations, health facilities, catering facilities. These factors make such projects attractive for the city and the authorities from the point of view of budget savings, but at the same time create an even greater investment burden on the private sector. Taking into account the experience of implementing such projects through SPV in the UK, it is necessary to make changes to this scheme of interaction in Russia. The main changes are as follows:

- **Implementation of the payment of the concedent.** In other words, in order to attract private investment, the state must compensate investors for the costs of implementing the technological part of the TIH after the commissioning of the facility, which is demonstrated by the example of the UK experience in implementing similar projects in Chapter 1 of this work. At the same time, the term of the contract must be equal to at least the lease period of the land plot, that is, at least 10 years. This step will allow the public sector to evenly reimburse the costs of the construction of the technological part of the TIH, and the investor will be able to receive a guaranteed income.

- **Commitment to further study of environmental aspects (including energy efficiency, underground space use, etc.).**

- **Operation of the TIH by the investor.** After the commissioning of the facility, the TIH is transferred to the city, but its maintenance will be handled by the investor. The costs of design, construction and operation will be compensated by the payments of the concedent for 10 years. The first compensation receipt should be formed after the commissioning of the TIH. Thus, the DBT (design – building – transmission) scheme will be supplemented to DBTO (design – building – transmission – operation).

5 Conclusions

The issue of improving the environmental study of investment and construction projects at TIH and adjacent territories requires further research and studies, since the implementation of large development projects is associated with an increase in negative impacts on the environment. The success of implementing environmental measures directly depends on the effectiveness of the state's interaction with investors, because it is with joint efforts and respect for the interests of all parties that the sustainable development of the concept of transport hubs and adjacent territories in the context of harmonious interaction with the environment is possible.

Thus, in the course of this study, the prerequisites for the formation of transport-oriented development in Russia were studied taking into account environmental problems, factors
affecting the potential socio-economic effect were analyzed, mechanisms for improving the interaction of public-private partnership participants in the implementation of investment and construction projects as part of TIH were developed, measures to improve environmental safety were proposed similar projects.

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