Urban transportation planning in the linear city

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Abstract. The paper discusses the transportation system planning based on problems and requirements of urban transport system by linear city form. Planning form has an important impact on urban transport characteristics, and urban road network structure. The object under study is the transport infrastructure of Volgograd city (formerly called Tsaritsyn and Stalingrad), the largest industrial center in the South of Russia. The city stretches along the Volga River for almost 100 km. The authors identify the main promising directions for the development of transport infrastructure: development of high-speed transport modes, which will link remote areas of the city with its center; development of radial transport infrastructure directions and the complexity of urban plan morphology from a linear form to a more complex one; establishment of combined transport and engineering corridors; development of pre-railway areas.

1. Introduction

The appearance of public rail transport by the end of the 19th century and the development of roads throughout the subsequent period led to the emergence of a new direction in urban planning theory related to the study of linear structures.

In the 21st century, new studies has emerged in North America, Europe and Asia related to linear cities and urbo-corridor structures (1-4). In 2003, Russian architects proposed a project of a linear resettlement system called "Sibstream" that was supposed to link the entire territory of our country (I.G. Lezhava, M.V. Shubenkov, etc.) [5-6]. Thus, the theme of the transport development of linear structures is at the moment still acutely relevant [7-10].

The aim of the present article is to explore the possibilities for optimized transport infrastructure of linear cities.

Despite the large number of theoretical studies, the practical implementation of the concepts of "linear city" is very few. All the more valuable is the experience of the establishment of the city with a linear planning structure of Volgograd. This city, which was called Tsaritsyn (until 1925), then Stalingrad (until 1961) is one of the largest city centers in the South of Russia with a population of more than 1 million inhabitants. It has been mentioned in all the world's publications on the development of linear planning structures. The article outlines the results of the latest studies on the prospects for the development of transport infrastructure in Volgograd. The objects under study were not only transport routes and connections, but also a set of different transport modes and their characteristics (speed, volume of freight and passenger traffic, etc.).
2. Theoretical research base

Linear form of planning development has become the subject of theoretical research together with the emergence of high-speed transport. (A. Soria-i-Mata, R. Malcolmson, P. Eisenman, M. Graves etc.). At the same time, the linear form of growth has become not only a response to the challenges of transport infrastructure. It seems to become an opportunity to solve different problems of our time. Including forms of management and regulation of the rapid growth of urbanized entities in the search for open and flexible urban systems (Y. P. Bocharov [11], A. E. Gutnov [12], K. Doxiadis [8], I.G. Lezhava [6], Le Corbusier [13], etc.; forms of optimization of social processes of life (N.A. Milutin, L. Gilbertseimer, F. L. Wright, etc.); optimal spatial form of territorial economic development (G. Hotelling [14]).

In addition to the work of these scientists, the authors relied on research conducted by specialists who dealt with and deal with the development of large cities, metropolitan areas and urbanized areas.

3. Linear cities and factors of their development

Analysis of modern cities with a linear form of planning structure leads to the conclusion that there are relatively few large cities of this type.

Volgograd, Sochi, Khabarovsk (Russia), Krivoy Rog (Ukraine), Sarajevo (Bosnia and Herzegovina) should be highlighted among them. All these cities have a length of several tens of kilometers. For example, Krivoy Rog with a population of 630,000 inhabitants is one of the largest industrial centers and the longest city of Ukraine (66 km of length). The territory of Greater Sochi is the second largest in the world along the length of the sea. It stretched almost 150 kilometers.

Often, small towns have a linear form and it really confirms the conclusion about linear structure as an early stage in the planning development of the settlement. The simplest type of linear structure is a small settlement, based on a group of houses built along the road or coast. Another type of linear development in world practice is urbanized sprawl between separate cities, which leads to the emergence of giant grid megastructures (“corridor development”).

As many researchers emphasize, linear-strip structures turn out to be promising planning elements in the context of territorial growth of cities [11-15].

The main factors determining the linear nature of the planning structure of cities and settlements are [7]:

• natural factors acting as planning restrictions (water and terrain features)
• anthropogenic factors acting as city-forming factors (railroad, highway, communication corridor).

With a linear planning organization, urbanized areas are stretched along for tens of kilometers in a longitudinal direction with small parameters of transverse sizes. Longitudinal links in such cases acquire system-forming importance as the main element of the framework and require the use of several parallel high-speed connections and different transport modes. The main compositional axes of linear structures are longitudinal lines (highways of citywide importance) that run along the territory of the entire city.

4. Development of Volgograd transport infrastructure and problems of the current stage

The study of the evolution of transport infrastructure and development throughout the history of Volgograd (Tsaritsyn-Stalingrad) has made it possible to highlight the transport factors of linear development of the city.

The first factor is the presence of a large river and a river connection on the Volga. The river has historically defined and still determines the life of the city. The Volga was a reflection and quintessence of the natural situation at the birth of Tsaritsyn. Before the revolution, Tsaritsyn port had precedence of cargo turnover among other ports on the Volga in the following cargo types: forest, coal, metal, fish, gourds. Currently, Volgograd River Port is one of the largest and most important enterprises in the Volga Basin.

The second factor is the railway construction which became a prerequisite for the future formation of Tsaritsyn city plan. Built by 1862, the Volgo-Don Railway connected the “Volzhskaya” station in
Tsaritsyn with the “Donskaya” station in Kalach-on-the Don. From the beginning of the road operation and till 1913, the turnover of transshipment goods from the Volga to the Don and vice versa increased more than 100 times. The Volgograd railway node, which is one of the largest in Russia, is approached by five main lines providing access from the region to the external network of the country.

The railway forms a transport corridor along the entire structure of Volgograd, and it is largely the "backbone" of the city layout, organizing the territories that became part of the city in the 20th century.

In the process of analyzing the transport infrastructure, the authors created a model of inter-district passenger connections in Volgograd, which helped identify problems in planning the city’s transport network (Figure1).

![Figure 1. A model of inter-district passenger relations in Volgograd.](image)

Analysis of the development of the transport system of Volgograd has also shown negative results of linear development as follows:

- small connectivity of the urban organism, due to the lack of high-speed modes of transport and highways;
- low accessibility of the urban center for remote areas, which has not acquired the necessary capacity for the city-millionaire (there is no range of necessary facilities of service in terms of quantity and quality);
- weak intra-urban communications lead to the autonomy of the southern districts and the formation of a “city in the city”;

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difficulty in reconstructing the strip structures along the Volga. The inertia of the existence of a powerful strip of industrial enterprises both in the northern zone and on the southern edge of the city with a width of 0.5 to 2 km does not allow renovation and transformation of these territories.

5. Directions of optimized transport infrastructure of a linear city (Volgograd city as an example)

Based on the study, the authors suggest several directions on optimization of transport infrastructure of linear cities on the example of Volgograd.

The first direction is connected with the development of high-speed transport modes. In Volgograd, a high-speed tram functions as one of the transport mode. Due to the long length of Volgograd along the Volga in 1976, a government decree was adopted on the construction of a high-speed tram. The underground part of the high-speed tram line - tunnels and stations - was originally designed and built in accordance with the standards of a full-fledged metro. The high-speed tram system in Volgograd consists of 22 stations located on one line more than seventeen kilometers long.

The new mode of transport has shown its effectiveness very quickly. Soon the analogue of Volgograd high-speed tram appeared in the city of Krivoy Rog. Currently, in Rostov, the neighboring city with one million inhabitants in the South of Russia, the possibility of building a high-speed tram system instead of a metro is also being considered.

The second direction is due to the development of road transport. Six federal highways to neighboring regions and the Republic of Kalmykia depart from Volgograd. Intra-district, inter-district and inter-regional transport links are carried out on the roads. At the same time, transit traffic flows pass through the urban areas, as the regional center-Volgograd does not have a bypass road. In this regard, the construction of the bypass road (Southern and Northern Bypass) and the completion of the Third Longitudinal Highway is extremely important. Completion of the Third Longitudinal Highway will allow to organize nonstop traffic of transit transport bypassing the city. The Third Longitudinal highway will combine several federal highways and become the main object within the transport complex, which will include a bridge over the Volga, Volgo-Don shipping channel and international airport. Also, the implementation of the project will provide an opportunity to develop new residential complexes and will allow to develop the city not only in length, but in depth as well.

The third direction is connected with the development of the city's radial connections. This makes the linear form of the plan more complicated. It turns into a linear-branch form, indicating its biological analogy by its name, when from the main highway as from the tree trunk “branches” of local roads are spread (Figure 2). This form has its merits: flexibility and compositional possibility of harmonious combination with natural conditions.

![Figure 2. Evolution of a linear form of Volgograd into a linear-branch form.](image-url)
The development of the city should be associated with active development of transport corridors and concentration of centering functions near them [1].

The combination of different transport modes in the form of transport and engineering corridors in the longitudinal direction should strengthen the integrity of a linear city (Figure 3).

![Figure 3. Scheme of prospective development of Volgograd transport infrastructure.](image)

6. Conclusion
In the report to the President of the Russian Federation and the Government of the Russian Federation on "Russian Urban development and modern urbanization processes" prepared by the Russian Academy of Architecture and Construction Sciences it is emphasized that "the first place in the territorial and transport planning is the task of finding the optimal combination of different types of transport infrastructure" [15, p. 39]. Based on this statement, it can be said that in the development of master plans of linear cities it is necessary to solve issues on the development of all types of transport system simultaneously: river transport, rail transport, high-speed tram, road transport, air transport.

The authors identify the main promising directions for the development of transport infrastructure:
- development of high-speed transport modes, which will link remote areas of the city with the center;
- development of radial transport infrastructure directions and the complexity of the morphology of the urban plan from a linear form to a more complex one;
- establishment of combined transport and engineering corridors;
- development of pre-railway areas.
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