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INFLUENCE OF THE ELECTRIC TRANSPORT SYSTEMON THE DEVELOPMENT OF KRASNOYARSK CITY MORPJOLOGY. ANALYSIS USING OPEN BIG DATAAND GIS

Abstract: *Public electric transport has a number of advantages in the environment of a modern city. It is environmentally friendly, safe and comfortable, has a high speed and can carry a large number of passengers. Unfortunately little attention is paid to it in modern Krasnoyarsk. One of the reasons is the fear that new transport systems could change urban morphology greatly and will need wide reconstruction. Electric transport is the most rigid planning system. It is connected to electrical systems - wires and rails. The laying of electric transport lines requires a large number of allocated territories. Besides, electrictransport crosses an automobile road network. And intersections of roads lead to the formation of multifunctional nodes. In these nodes, relationships between different morphological structuresarise. Electric transport provokes the transport-oriented development of urban areas. In this regard, there are areas of transport-oriented development (TOD). There are three types of public electric vehicle in Krasnoyarsk currently: an intra-urban railway transport, a tram and a trolleybus. To interact is inefficient in the city's transport system. The study is devoted to the relationship between the electric transport and the urban morphological system, as well as the impact on transport-oriented development in the city of Krasnoyarsk. The development of the city's transport system will create increasing amounts of datacontinuously. Russia lags behind in the development of transport modeling based on big data. Problems of transport planning, the analysis, control and also introduction and use of new types of electrical transport on the basis of open systems of big databases as the skeleton for the urban morphology are relevant today. Conducting studies on comparing the assessment of the electric transport functioning, depending on the needs of the city's population, keeping traditional one or enhancing the urban morphology if needed in this regard becomes possible with the availability of an electronic transport model of the city.*
Keywords: *open big data, transport-oriented development, electric transport, transport model, transport planning*

Introduction

Urban transport systems are related directly to the development of the city morphology. Electric transport is the most rigid planning system among all types of urban public transport. Because, it is connected to electrical systems - wires and rails. It is territorially fixed. This feature of electric transport systems leads to significant changes in the city morphology. The laying of electric transport lines, in particular those designated, requires a large number of isolated areas, such as tram lines or railroad tracks of intercity rail transport. The infrastructure of electric transport requires significant areas for service areas of these systems. Electric transport crosses the city's automobile network. The intersections of electric transport with other modes of transport lead to the formation of multifunctional units. Relations of different morphological structures arise in these nodes. The transport interchange node stimulates a multifunctional service that leads to a mixed type of the development. It attracts large flows of people. This process of shaping leads to a change in the city structure, and also gives impetus to the development of other structures.

Electric transport provokes the transport-oriented development of urban areas. Districts of transport-oriented development (TOD) arise in connection with the transport-oriented development of the city. Electric transport stimulates the density of locating building close to the efficient transport in a transport-oriented district.

This study is devoted to the relationship between electric transport and urban morphology, as well as the impact on transport-oriented development in the city of Krasnoyarsk. The main issue considered in the article is what electric transport gives in the morphological development of the city.

The aim of the study is to analyze the electric transport system and its impact on Krasnoyarsk city morphology with the help of large open data and GIS technologies. The process of the electric transport systems' influence on the city morphology can be analyzed using transport modeling. The strategy of developing the system of the public electric transport in connection with other means of transport and multimodal knots is offered in relation to conditions of domestic town-planning practice.

Transportation modeling is a widespread method of the town-planning analysis today. It is directed to finding general regula rities in the development ofthe transport system sand structure of the city. Themulti-layer characteristics of morphology dependence on the transport systems can be studied and analysed by means of the big dug-out data and transport planning technologies. The result of the study is the transport model of the city based on large open data. The model takes the interrelation of the influence of electric transport systems on the morphological structure of the cityinto account.

Methodology

The study is based on what input data is most useful for reflecting the characteristics of urban morphology and how it is interconnected with the city's transport system.

The study is based on the following methodology:

1. Theoretical study.

The research methodology is based on a theoretical study of the change in the city structure in connection with the transport systems. This is due to the transport-oriented development of the city. The analysis of morphology changes takes the changes in the electric transport systems over timeinto account.

2. Statistical analysis of the city transport system. Analysis of the model input data.

Analysis of the transport infrastructure of the city of Krasnoyarsk is carried out depending on the development of the city morphology on the basis of open geodata. The availability of open geodata extends the possibilities for characterizing urban morphology. There are patterns and dependencies of the development of the city structure and electric transport revealed.

3. Transport modeling based on GIS and large open data (Model of the city).

Open data or geodata represent the physical structure of the constructed city model. The model consists of several spatial layers. Statistical analysis of the city transport modelis based on the input data analysis. These are the population density, length and time of passage, as well as data on the attendant maintenance of these lines. An interactive city transport map is a model that consists of the imposition of spatial layers by the clustering method. The model reflects the influence of the electric transport systems of the city of Krasnoyarsk on the morphology. It is possible to control transport and morphological processes at the city level using this model.

Four characteristic dependent layers are represented in the model:

1) Transportation

Morphology depends on the transport flow and its density. For example, the configuration of the building depends on the location of the transport-transfer nodes. The density of the road and road network is directly related to the size of the building blocks.

2) Topology of the city and barriers

For the introduction and operation of electric transport, as a fixed line, it is necessary to understand the city topology. The relief, barriers and porosity of the urban structure affect the transport accessibility in the urban areas

3) *Morphological structure of the city*

The density of city districts is an important and fundamental variable for the introduction and operation of electric transport. The number of seats for passengers can be analyzed by the ratio of the density of the surrounding areas use. The length of electric transport lines depends on the size of neighborhoods and districts.

4) *Functional content*

The concept of the model is based on the imposition of statistical and functional layers. This indicates the distribution scheme of the city's key functions in the transfer nodes. Functional filling along the fixed line provides a comprehensive relationship between the city morphology depending on the ratio of demand and supply of public electric transport. To create the optimal level of integration, it is important to provide denser areas through which non-motorized vehicles pass.

We can see how the city morphology depends on a rigid electric transport system when these layers are applied in the model.

Measurements and analysis

Urban transport, especially public transport, consumes a significant share of energy, and also generates emissions into the atmosphere. Transport technologies play a very important role in the formation of urban morphological structures. The transport system of the city is formed by various modes of transport. Today the world trend is the development of high-speed electric transport. Public electric transport has a number of advantages in the environment of a modern city. It is environmentally friendly, convenient, has high speed and bandwidth. But it is inflexible, territorially fixed. The system of municipal public electric transport is formed in two parts: high-speed extra-public transport and urban rail and trackless transport. These parts are interconnected by transport-transfer nodes. Two types of elements of the electric transport system are formed: nodal elements and linear sections.

In Russia, the most common public electric transport are intra-urban rail transport, trams and trolley buses. Intra-urban rail transport can be used as a comfortable vehicle in the city. Itoccupies a specialplaceinthe Russiancities as over 50% of the cities of Russia pass the Trans-Siberian Railway within the city structure. This type of transport has a higher speed and can carry a large number of passengers. But its development in the urban environment is quite difficult. The allocated territory for the withdrawal of railway infrastructure is needed for this type of transport. In these territories, according to the Russian legislation, construction of residential and public buildings is not allowed. Many scholars have studied the relationships between the urban form and transport energy consumption as a basis for proposals about sustainable urban forms. Based on six case studies in the United Kingdom and the Netherlands, Banister, Watson, and Wood (1997) found that factors such as density, employment and car ownership would affect urban transportation energy use. (Jian Zhou, 2012).

Railway infrastructure and intra-urban rail transport affect the city morphologysignificantly. First, the railway infrastructure that runs through the city forms an isolated transport line and ruptures the urban fabric. Secondly, the density of urban development varies considerably near the stations of intra-urban rail transport. In the Russian practice of urban development, the area of the railway infrastructure - the strip of the railroad - is of little use. Accordingly, these territories are being developed chaotically and haphazardly. The impact of the railway infrastructure on the city morphology, population density and employment density are studied by Kasraian et al (2016), Ewing et al (2001) and Cervero (2010) and Giuliano (2004).

The share of electric transport in Krasnoyarsk city is only 20%. At present, there are three types of public electric transport in Krasnoyarsk: inter-city railway transport, trams and trolleybuses. Electric transport of the city has a great potential for development. The linear-node system of the city is formed by interchange nodes, a railway, tram lines and motorways.

The existing railway ring connects all the territories and partially suburban areas of Krasnoyarsk city. The ring is completely isolated, compared to other modes of transport. Therefore, it is an obstacle to the further spatial development of the city. Over time, the railway line has been transformed into a structural-planning ring, around which a new urban development has been intensively formed. Intra-urban railway traffic has been functioning since 2008.As a result, today we have a railway ring. Most of the territories along the railway infrastructure are of little use, developing chaotically. They are occupied by unregistered garage cooperatives, parking lots and, fragmentarily, the private sector. There is a small number of connections through a fixed line of intra-urban rail transport, both transport and pedestrian. Subsequently, ruptures of urban fabric of the city are formed. The city is divided into the parts isolated from each other.

The tram runs along a dedicated line in the urban environment. The share of this transport in theRussian cities is 40%. The trams and trolleybuses are connected to rails and wires. They are fixed city transport lines. These types of electric transport are not related in Krasnoyarsk city. Tramway traffic was launched in 1935 in Krasnoyarsk. The right bank of the city was connected with the left one with a tram line. Afterwards, in 1994, trams traffic through the bridges of the city was stopped, the routes were modified and reduced. Accordingly, the morphology of the streets and districts, where the lines of trams and trolleybuses passed, also changed. Historically, the infrastructure of the trams is located in the middle of the streets in manyRussian cities. It consists of tram tracks, stops, electrical systems. Subsequently, it has been dismantled, and the morphology of the streets has changed. Lanes for private vehicles have expanded. This has led to the decrease of pedestrian areas.

InKrasnoyarsk citythereareonly 4 tramroutes. AllroutesrunonlyontherightbankoftheYenissey River. Thereisnoconnectiontotheleft-bankpart. Ontheleft-bankpart, only 4 trolleybusroutesrun. The morphological structure of the 2 banks is significantly different (Figure 1). First, it depends on the city topology. Krasnoyarsk city has several unique landscape units. Secondly, electric transport systems have a significant impact on the morphological structure of the city. For example, streets where tramway communications are laid have a greater width, compared to the others. These communications are located in the middle of the street. On the streets where tram lines pass there is higher density of street-road network and accompanying maintenance.

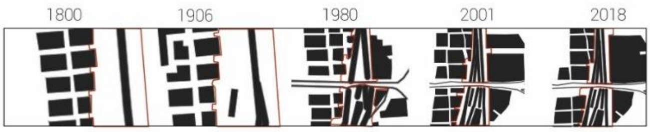

Figure1. Morphological changes in the central part of the city of Krasnoyarsk

The suppression of electric transport is provoked by transport-transfer units (TTU) in the city. Transport-oriented districts (TOD) are formed at the intersections of electric transport and other types of public transport. The "electric transport-TOD" connection is defined as a system where the nuclei distributed by various electric transport infrastructures are identified. This relationship contributes to the development of the city morphology and regional scales.

The process of the new TOD formation influences the development of the city morphology. Transit-oriented development is widely spread in recent years as the main vector of urban development. TOD is a flexible, mixed form of urban development.

The district of transport-oriented development in the world practice of urban development is considered to be a multifunctional city hub at the intersection of transport highways with the increased density of construction and functions, providing the possibility of unhindered change of transport. For such areas, a multimodal transport junction is typical. Transport-oriented areas are conceived as the core of the urban morphology development (Figure 2). The main link in the development of a transport-oriented region is the public transport infrastructure.Electric transport is the main element of the public transport sustainable development. In most cases, the fixed line of electric transport of the transport-oriented districts is a railway with interchangeable cores.

Morphological changes and the relationship between areas and public transport can be traced in these nuclei:

1. Nodes of different values are formed. Multifunctional units are formed at the intersections of electric transport routes and city highways, such astransfederal, regional, intracity routes, depending on the service territories.

2. Various zones are formed - business, warehousing, commercial ones. These areas are gradually displacing housing. Accordingly, the density of the building density changes in these zones. This affects the changes in the density of transport development.

The practice of applying TOD in different countries shows that such areas are a unique morphological form of urban development. TODs are the most attractive areas for urban transport planning transformations. The urban spatial structure has shifted from a nodal type to a multi-node one. It implies new forms of urban development and new economic ties. Gil et al (2012), in his study, uses a cluster analysis of blocks and streets to determine morphological urban typologies and their relationship to transport development. The potential of electric transport increases, if there is a possibility of city transport-oriented development. The introduction and development of electric transport is conceived as an adaptive system in which the city morphology is directly connected to the city's transport system. The development of the city's transport system will constantly increase the amount of data: the number of rolling stock, the density of stop points, the density of transport nodes. All data can be investigated and used to build a transport model based on the application of a software product using large data. Transportation modeling with large data is necessary both for the maintenance and development of transport systems in Krasnoyarsk, and in Russia as a whole. Town-planning analysis should take into account local features of the territory, the morphological structure of the city.

Transportation modeling is a common method of urban planning today. For example, the construction of a transport model depending on the land use of urban areas is carried out in the study by Ewing, R., and R. Cervero (2001). In this model, the following dependent variables are distinguished: the morphological structure of the city, the density of urban centers, land use, transport networks and urban design functions. The model shows the dependence of land use and density of buildings on the traffic flow density. Functions of urban design in this model have a minor effect on primary travel and a greater effect on secondary trips. But the model does not take the city topology and local features of the territory (landscape units, historical heritage, engineering communications) into account.

Statistical analysis of the input data has been carried out to build a model of the city of Krasnoyarsk. Comparisons and descriptive statistics, correlations have been used to study the relationship between the public electric transport systems and urban areas. The characteristics of the density of the electric transport traffic and the density of development are independent variables. Other characteristics, such as: the number of passengers, stopping points in one area, have been analyzed as a dependent variable. All variables are displayed in the model.

Figure 2. A transport-oriented district in Krasnoyarsk city

Description of the transport model

A single information database for analyzing the city's transport system does not exist in Russia today. There are some developments from the companies such as Yandex and Google, but they do not take the town-planning situation and the specifics of the transport in a certain cityinto account. The transport model is a software package that consists of information and calculation blocks. Information blocks are a single database of open data. It is intended for informaiton storage and processing. This information is necessary to analyze and plan the electric transport system. The calculation blocks realize the algorithms of the electric transport system influence on the city morphology. They are expressed in the following variables: density of the road network, urban density, FAR, OSR, traffic density.

Transportation modeling is carried out in the following form in the developed model:

- Cartographic analysis (Map of dependent layers)
- Definition of permanent variables of transport and morphology, their properties. They include technical specifications (traffic speed, number of stop points, time parameters)
- Visualization of the results by superimposing layers and variables by the method of "clustering" (clusters are groups in something similar or similar in properties of objects.) To visualize objects from different clusters, contrasting colors are used.Visualization of associations demonstrates the frequency with which tracers appear together in a set. The structure of the data organization is then determined (for example, where the electric transport systems most affect the city morphology). Clustering is performed by automatically finding the groups on which the analyzed objects should be divided. Clustering takes place step by step. On the basis of a distance matrix or a similarity matrix of features, the closest objects are combined.)

This model includes 4 stages:

1. Territory geospatial analysis. Analysis of spatial layers.

2. Statistical analysis. Determination of dependent variables of 4 spatial layers.

3. Visualization of the received data. Creation of an interactive model with the help of geoinformation systems. The obtained modelformed by superimposing layers on top of each other, reveals the dependence of the urban systems, analyzing the data.

4. Forecasting analytics. This model can be used to collect data further, to edit and improve it in order to submit information to the city government.

The analysis of the electric transport infrastructure of the city of Krasnoyarsk, depending on the city topology and the urban morphological structure, is based on open geodata. The availability of open geodata extends the possibilities for characterizing the city's transport-oriented development.

The spatial layers of the city of Krasnoyarsk have been determined for the analysis:

1) *Transportation*

Transport highways and the street-road network form the framework of the city. They form its planning structure. Electric transport communications are the most stable element of this structure that retains its functional significance even with global changes in the organization of urban transport and the vital activity of the population. The road network, the load level and traffic density depend on the planning network. Also, the size of residential areas and their configuration depend on the transport planning network.

2) Topology and barriers

The topological scheme, especially in historical cities, is created taking the natural conditions such as the terrain, the presence of watercourses and climateinto account. For example, in Krasnoyarsk city, a network of streets is located in the direction of prevailing winds in the winter season. This ensures the transfer of most of the snow through the city. The presence of such natural barriers as ravines, beams, streams, forest tracts are taken into account when determining the size of quarters and establishing their configuration - morphology. These natural boundaries are the boundaries of quarters in most cases. The electric transport line is laid taking the natural obstacles of the terraininto account. Continuity of the urban fabric is an important element in the design of public electric transport lines. It provides conditions for a comfortable transfer of users from one area to another and the growth of visitors' flows of objects of the associated commercial infrastructure.

3) Morphology

The main variable in the "morphology" layer is the building density. Urban density is the main method of differentiation because the demand for public electric transport increases with the increase of the population and commercial density. It depends on its service and price. The development of a certain type of public electric transport is influenced by social groups and jobs. This is an argument not only for urban density, but also for the nature of urban development, social groups that inhabit them or work there. The model uses different types of urban development, as the basis of the urban morphological system. Compactness is an important condition for the transport-oriented region developmen. The combination of a high density construction and the street-road network while maintaining the average number of storeys with mixed functional use of buildings and territories is the most effective condition for the development of the electric transport systems.

4) Function

The use of urban functions helps to emphasize the wider use of public electric transport in the land use of the city. The location of the city functions in transport-oriented areas increases the number of residents and jobs along electric transport lines. The urban structure depends on the processes of formation and transformation of urban areas.

The following dependencies have been determined when layers have been laid:

- The planning electric transport network influences the configuration of the building;
- The density of electric transport flows affects the building factor and the density of functions;
- The location of the transport interchange nodes affects the location of the functional development zones;

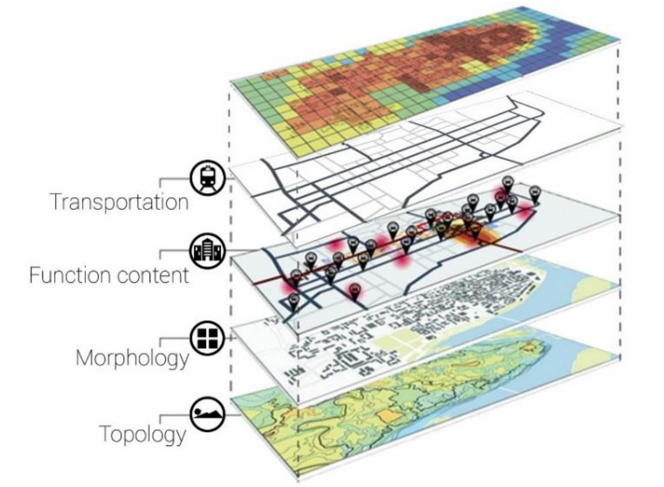

Figure 3. Transport model of Krasnoyarsk city

The result of the study is a multilayered information model based on open data and geographic information systems (GIS). A multilayered model of morphological characteristics is needed to manage the development and formation of urban development and transport systems. The information model allows collecting , analyzing and comparing different characteristics of urban morphology depending on the electric transport technologies (Figure 3).It allows analyzing the density of construction, the density of the street-road network, carrying capacity, urban mobility and the length of the road network.

Optimization of the model and proposals

The model supports the gradual development of the city's territories along the electric transport lines, the creation of dense building that is necessary for the effective use of engineering and transport infrastructures.

The application of transport models of cities and regions allows assessing the impact of the construction or modernization of federal transport facilities on the regional territory. In certain situations, the model can significantly improve the transport situation in the subject of the federation and the regional center.

The prospective nature of this approach is determined by the fact that its application allows us to calculate and forecast possible options for the development of the electric transport system of the city and the region. Also, this system helps to promptly plan and determine the basic performance indicators of the network, identify areas with insufficient or excessive transport infrastructure.

The interactive transport model of the city will contain information onthe urban public electric transport traffic, its general characteristics and types, modes of interaction with other modes of transport, prospects for its development.

Forecast models are designed to simulate the volume of transport work in networks with a known location of the city's public transport streams. These models can predict the consequences of changes in the transport network of the city that occur either in the process of changing transport demand, or in the process of changing the transport offer. Models of this type are used to support solutions in the field of city transport planning, analysis of the alternative development projects' consequences for the city transport network.

The model will help residents of the city visually see the condition of the city public electric transport, and the city authorities to monitor and timely prevent deterioration of its quality in online mode on reliable sources. Residents will be able to decide on the most profitable routes for them. All this will significantly improve the quality and importance of city electric transport.

Conclusion

The information model of the city's transport system is necessary for any city. It shows how the transport system will affect the city morphology.

This happens by mixing urban morphology and transport systems, determining the relationship between transport and mobility, areas and quarters along transit routes. The city and its structure are quantified and analyzed as independent variables. Morphology is described by urban densities, land use, distances to public transport, demographic data.

The model helps to understand the real situation of the city's transport-oriented development. First, it allows youto forecast at the stage of sketching that is planning. Secondly, taking all factors in the planning of the transport and pedestrian systeminto account, it is possible to save on transport services, to develop the shortest pedestrian routes, and energy costs. And finally, this information connection to the city allows monitoring the entire system.

This model can be used for further data collection, editing and improvement to submit information to the city government. In the described model, there is the possibility of modeling, changing the internal parameters of spatial layers. As a result, there are different scenarios for the development of transport-oriented development of the city. The model allows revealing the physical dependence of urban morphology and the introduction, functioning of new types of transport - electric transport. The main function of the model is calculation and analysis for the city transport planning.

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