Specific Features of Building Transport Infrastructure in Megacities

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Abstract. The paper analyzes specific features of the transport infrastructure building in modern megacities. Recently, the issues of transport infrastructure built in many megacities and cities associated with the comprehensive solution to urban and transport problems have become noticeably more relevant. This study uses a systemic approach that helped to show continuity, scale and social orientation of the transport infrastructure in megacities. The main problems and achievements in solving transport problems in large cities are identified. The issue of the role and importance of better transport infrastructure development in megacities is considered through the prism of complex and sometimes conflicting relations between transport and environment. The current transport infrastructure challenges and problems, new opportunities and benchmarks in achieving maximum efficiency of a particular mode of transport under different conditions are indicated. Special focus is placed on the possibilities of providing convenient and shortest travelling routes between all parts of the city, as well as between external transport routes. The content of the city transport network is described and characterized consisting of a set of streets and traffic routes served by various forms of city transport, underground, ground, above-ground transport lines connected with the street network in part or not connected with it at all, for example, city railways, overhead roads, metro, monorail roads.

1. Introduction

The megacity, as the largest form of settlement, formed as a result of merging neighboring urban agglomerations, is distinguished by the intensity of its traffic. Specific features of transport infrastructure development in many megacities and cities are associated with due regard for the complex solution of urban and transport problems [1]. Special focus is placed on the possibilities of providing convenient and shortest travelling routes between all parts of the city, as well as external transport routes [2]. The content of the city transport network is described and characterized consisting of a set of streets and traffic routes served by various forms of city transport, underground, ground, above-ground transport lines connected with the street network in part or not connected with it at all, for example, city railways, overhead roads, metro, monorail roads [3]. The main problems and achievements in solving transport problems in large cities are highly relevant. Problems and prospects of urban passenger transport development in a metropolis were investigated by A.V. Guzenko [4]. V.L. Glazychev [5] and V. Vuczyk [6] studied the problems of urbanism,
transport in cities that were convenient to live in. D. Gabarda [7] analyzed new transport systems in urban public transport, A.V. Colin [8] in his paper calculated the capacity and carrying capacity of transport lines in megacities when various types of urban passenger transport were operated. L.N. Kozlov, Yu.M. Urlichich, B.E. Tsiklis [9] updated conceptual approaches to the building and development of smart transport systems in Russia. V. Khatsenko [10] addressed the issues of development of high-speed tram transport, and D. Hess [11] focused on conflicts of objects as part of city transport urban beautification and the possibilities of an “environmentally friendly bus.” The influence of transport on the environment of a large city was comprehensively investigated by Yu.N. Bezborodov, S.A. Kovaleva, A.N. Sokolnikov, V.G. Shram [12].

2. Problem statement

Considering the totality of existing modern city problems, the role and importance of better transport infrastructure development in megacities is considered through the prism of complex and sometimes conflicting relations between transport and the environment. The current transport infrastructure challenges and problems, new opportunities and benchmarks in achieving maximum efficiency of a particular mode of transport under different conditions are indicated. Special focus is also placed on the possibilities of providing convenient and shortest travelling routes between all parts of the city and external transport routes. The content of the city transport network is described and characterized consisting of a set of streets and traffic routes served by various forms of city transport, underground, ground and above-ground transport lines connected with the street network in part or not connected with it at all.

As a result of total motorization of the population, road transport has become the main source of pollution of the environment in modern cities. Adjacent areas along streets and roads with heavy traffic suffer from increased air, soil, noise pollution [13]. This set of negative factors caused an urgent need to start developing and implementing measures for reducing the negative impact of road transport on the urban environment, to promote intensive development of environmentally friendly means of transport [14]. Among the least polluting modes of transport are trams, trolleybuses, metro, monorail, railway electric transport [15]. Electric cars, electric scooters, group and cabin electric transport are promising eco-friendly modes of transport. They differ in terms of carrying capacity, transport speed, maneuverability, construction costs, operating costs that affect the efficiency of the use of a particular mode of transport under different conditions.

The environment in a modern large city suffers greatly from large-scale motorization [16]. Heavy traffic and noise pollution negatively affect areas along streets and roads [17]. The above factors result in expedient development of measures that efficiently affect the current situation, namely, minimize the negative impact of transport on the environment ensuring the transport expansion without severe environmental damage. Among the existing least polluting modes of transport there are the metro, trams, monorail, electric and railway means of transport [18]. Electric cars, electric scooters, group and cabin electric transport are promising eco-friendly modes of transport that differ in terms of carrying capacity, transport speed, maneuverability, construction costs, operating costs that affect the efficiency of the use of a particular mode of transport under different conditions.

The trolley bus is characterized by high maneuverability, but its speed is relatively low with not more than 20 km per hour, considering that trolley bus stops should be arranged at quite a short distance. The maximum carrying capacity is not more than 10 thousand people per hour [19]. The tram has a higher carrying capacity, namely up to 18 thousand passengers per hour, but this mode of transport is considered less maneuverable. The speed in this case is the same 20 km/h. Tram lines slow down the traffic and this is the reason they are separated from the routes of other modes of street transport [20].

Special focus should be placed on high-speed models of trams with a maximum speed not more than 35 km/h. Here, the speed was improved by the increased distance between stops, which is no more than 1.5 km. Tracks for high-speed trams are laid in isolation [21]. These are small trains
consisting of 3-4 cars. The capacity of high-speed tram models can reach 20 thousand people per hour [22].

City railway is a street transport option relevant for megacities. Usually, the same tracks are used for trams as for passenger and freight trains. Thus, in an hour a city train goes through not more than 12 times, and this provides carrying capacity of up to 24 thousand people. If there is a need to increase this indicator, then additional tracks for parallel movement are built. This solution results in an increase in carrying capacity to 40 thousand passengers per hour. In certain situations, a decision is made to remove passenger and freight trains from railway lines in favor of suburban and inner-city passenger trains [23].

With a city population of more than 500 million people, the subway is a necessity. Depending on the economic development of cities, metro networks can differ in their complexity and number of branches. Metro together with suburban railway forms a single transport system. It also provides high-speed connectivity between the periphery and the center. In this system, the connecting link is provided by bus routes uniting city districts and metro stations. The stops are set at a distance of no more than 2 km from each other. If it is the city center, then the distance is reduced to 0.8 km. Metro shows quite high carrying capacity, in particular 60 thousand people per hour. The speed in this case is 45 km/h. At the same time, the metro is the most expensive project in terms of construction [24].

Out-of-street modes include monorail trains traveling on special beams located on supports, which can be suspended and mounted. This mode of transport is characterized by an effective carrying capacity of up to 25 thousand passengers per hour, and its speed is up to 50 km/hour. The capacity rates typical of a monorail train vary from 100 to 500 people. To ensure the operation of monorail transport, it is necessary to build a special road, which is rather cumbersome and disrupts urban skyline. High speed mode and safety should be considered as advantages of such a mode of transport [25].

Cabin modes of transport are equipped with cars accommodating 5–40 people and automatically moving along a special track. The car is driven by electric motors, the wheels are pneumatic. The systems of cabin transport are very diverse, the tracks can be laid on the ground, on flyovers, in shallow subways. The speed is 25–60 km/h, the carrying capacity reaches 5000 passengers per hour.

Group transport systems are the simplest off-street transport with independent tracks of a hat cross section, which can be laid on the surface of the ground, on flyovers, in tunnels. The rolling stock uses electric motors, the wheels are pneumatic, which makes it very attractive in urban conditions. Both single cars with cars 2–2.5 m wide and 2.5–3 m high, and trains with 2–3 cars can use these tracks. The speed reaches 25 km/h, the carrying capacity of the lines totals 5–15 thousand passengers per hour.

Moving pavements are becoming more widespread, used in large connection hubs, in exhibition areas, in pedestrian zones. They should be protected from precipitation. The maximum slope of the moving pavement is 15%, the width of the pavement band is 60–120 cm, the speed of movement is 5–15 km/h, the carrying capacity is 6–12 thousand.

Electric transport is considered as an alternative to cars polluting urban environment [26]. However, it is necessary to prepare for it in advance. In particular, the most advanced of the existing models of electric vehicles use 34 A current. The standard household network is not designed for such loads, so the introduction of private electric transport should be preceded by the formation of an appropriate energy infrastructure.

When transport infrastructure in many megacities is being improved, transit transport is removed from the urban area. For this purpose, bypass and district roads are built, intercepting transit traffic flows, directing them around cities. All this allows to concentrate transit and cargo traffic flows, optimize their speed regimes, thin the traffic in the central and middle zones of cities reducing the negative impact of transport on the urban environment [27].

One of the features of the development of transport infrastructure of megacities is better planning of urban street-road network. Reducing transit traffic in cities is facilitated by better planning arrangement of urban transport network. The radial ring pattern of the street network when traffic
flows are directed to and through the city center, can be significantly improved, for example, by laying chordal and cutting transport lines bypassing the center. Similarly, the so-called organic system for building a street network serves a similar purpose, with side streets moving sequentially away from a distribution street like tree branches, allowing for non-stop traffic.

To improve transport infrastructure in megacities, spatial separation of transport and pedestrian routes is carried out. Along main streets and roads, it is more appropriate to make special pedestrian boulevards and streets instead of sidewalks. On the pedestrian streets air is 50 – 70% less polluted than on transport ones, and noise pollution is 20 – 30% lower.

In megacities, a multilevel division of transport and pedestrian routes is used with the help of underground and above-ground spaces. There are also non-standard design proposals for separating transport and pedestrian routes, in particular, the isolation of vehicles by placing them in transparent pipes from which polluted air is sucked and cleaned. It is more feasible to spatially combine walking paths with urban water-green systems. In megacities, pedestrian safety is extremely important for local streets. To limit the speed of traffic there, various techniques are used: winding street configuration, artificial road bumps, speed limitations.

On transport and pedestrian streets, sidewalks are often separated from the roadway by strips of green spaces 3–12 m wide. Barriers should also be built to prevent pedestrians from crossing streets in undesignated places, and vehicles from entering pavements. To achieve these goals, dense thorny shrub is planted, stretched metal mesh and other means are used.

Active measures are being taken to advance the development of public transport in megacities. It is clear that the development of transport infrastructure must be ahead of the needs of cities, otherwise it is difficult to avoid multiplying transport problems. The development of public transport is a priority. Increased capacity of existing roads and streets and new transportation lines do not produce the expected results. A vicious circle occurs: more streets and roads—more cars—more traffic jams on streets and roads—again more streets and roads, etc. This is illustrated by the daily traffic jams in Houston, Detroit, Los Angeles, that is, where the most developed network of highways was built in the cities themselves and the surrounding suburbs. In Western Europe and the United States, there is already a clear understanding that the policy of adapting the city to the car which has dominated urban planning since the mid-20th century is doomed. It is obvious that without the establishment of a developed network of public transport, it is not possible to ensure the effective functioning of megacities. Therefore, the revival of public transport has become one of the important trends in the development of urban structures over the past 15 to 20 years.

Also, there is a revival of rail public transport, namely high-speed trams. It is planned to build long-distance high-speed tram lines connecting the city with the settlements of the growing multi-pole city. The construction of high-speed tram lines is much cheaper than that of a subway or monorail transport considering that a high-speed tram has similar carrying capacity and speed.

A bus subway is being constructed. In Brazil, the city of Curitiba with a population of 300,000 inhabitants has built an efficient system of high-speed public transport at the lowest cost. In the city, five main highways are divided into three parts: a two-way lane for express buses is in the middle while other transport moves on the sides. Getting on and off a bus takes place in special terminals, which can be entered only through turnstiles. Express buses depart every minute during peak hours. Spacious buses with wide doors for entry and exit, automatic control that allows traffic lights to be switched on and off from the bus giving them priority in traffic, carry three times as many passengers as traditionally organized city bus transport. At the same time, manual route planning and scheduling gave way to the software. Each high-speed bus line carries 20 thousand passengers per hour with a speed of 40 km per hour. It is important that the cost of construction and operation of such a transport system is 100 times lower than that of a traditional metro.

At the same time, when the megacity transport infrastructure building process is improved, individual public transport is developing, i.e. municipal car rental networks. Its user finds the position of a rental car closest to her on line, then, using the terminal installed in the car, the user logs in the
system and reaches the destination where she leaves the car. Next customer can then use it. You can choose from a number of vehicle types, such as a family minivan, office minicars, and more.

Smart transport systems are increasingly used for traffic management. A smart transport system is a smart car on a smart road. It uses satellite navigation devices, provides for information exchange between the vehicle and the traffic control hub based on traffic monitoring data, meteorological conditions, and the current state of the road network. A smart transport system ensures information exchange between the driver and the car: monitoring of the physical and mental state of the driver, early emergency warning, etc.; information exchange between the car and the manufacturer, service organizations, emergency response services on the roads; automatic information exchange between vehicles involved in traffic is carried out. In general, traffic flows are managed not only by smart traffic lights, signs and other elements of road equipment, but also by automated systems of information exchange between the vehicle and the road infrastructure, in particular automatic speed limiting, etc. [28].

3. Findings
Considering the operation of smart transport systems in Russia and abroad, the conducted research proves that they increase the carrying capacity of streets and roads by 15–50%, decrease the accident rate by 20–40% and the number of road accidents by 1.5–2 times. Better traffic flow management reduces fuel consumption and emissions by 10-20%, as well as road mortality.

Further deployment and development of underground transport infrastructure is also necessary, considering that this trend has been continuing for a long time, allowing to significantly simplify the distribution of traffic flows in the central part of the city. It is expedient to use underground and semi-underground parking lots near residential apartment buildings. Underground parking lots are widespread in the centers of megacities. When there is a lack of parking space, the parking problem is solved by using underground space to accommodate car parking lots. All modern multi-story public and residential complexes have underground parking lots. In urban historical districts, they are placed under squares, parks, boulevards without disrupting historical skylines [29].

4. Conclusion
Thus, the solution to existing transport problems in megacities lies in the integrated use of the emerging new technical possibilities. Better transport infrastructure in megacities is ensured continuously using developing technologies. Higher passenger speed and greater safety and comfort, without environmental damage remain a priority. When transport infrastructure of megacities is built, it is extremely important to consider the factors of environmental tension that affects almost all spheres of human activity. Transport ecology determines the extent of the impact on nature, nature protection strategies are developed. Each mode of transport has its advantages, it is important to minimize their environmental damage. Less emissions of polluting substances, development of alternative types of vehicles and fuel, means of transport remain a relevant challenge.

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