Sustainable Development of Local Street Road Network in Megalopolis

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ABSTRACT

The article emphasizes and substantiates the principles of sustainable development of the Street-Road Network (SRN) based on improving the quality of life of the urban population, and also it deals with the problems in the transport infrastructure of a megacity. The technique of diagnostic analysis of qualitative indicators of SRN functioning is observed. There have been determined the main approaches to the sustainable development of the SRN at the local level in the megacity. Its main indicator parameters are analyzed on the example of certain areas of the largest metropolis in the world – Moscow. Their technical and ecological state is assessed. The most effective management tools in the SRN system of the megalopolis at the local level are identified. The development concept of the priority direction of SRN in a stable regime is formulated on the basis of the system approach, the obtained results are aimed at ensuring the social, ecological and economic effect of its activities.

Keywords: Street road network, sustainable development, megalopolis, transport infrastructure, diagnostic analysis.

INTRODUCTION

The constant expansion of the borders of megacities, the growth of population (according to the UN forecasts more than 85% of the world population will be concentrated in cities by 2050), the rise of living standards assists the active growth of automobilization, including cities of Russia. So, according to the statistical data over period of 1993-2016 the significance of this indicator in the country and regions has increased almost 4 times (Kuzmich and Fedina 2008; Mayorov and Sevryugin 2015). In this regard, it can be noted that the increase in availability of owning a car leads to the requirements of new space, road congestion, numerous traffic jams, a shortage of parking spaces, pollution of the environment, causes many other economic, social and environmental problems.

In such a situation, the negative impact of increased transport flows on the urban environment is actively being discussed throughout the world, including such effects as air pollution and noise, damage to hydrological systems, impact on climate change and landscape degradation, local overheating effects etc. All this causes the attempts of some countries to reduce traffic flows, in particular, to restrict movement of private vehicles as the main source of natural environmental pollution.

At the same time, there is another position: it is not rational to reject scientific and technical achievements in the field of vehicles but the optimization of spatial planning in this area on the sustainable development principles is practical. This approach assumes, first of all, a strategic rescheduling of the local street traffic network in urban areas so that the negative impact of vehicles on environmental objects can be reduced. At the same time, the sustainable development concept focuses on satisfying the range of requirements of peoples' environmental and economic needs (including future generations), on involving the transport sector in the harmonization and evolutionary process.

In that context, the objectives of this study were the following: to explore the sustainable development principles of the SRN in the megalopolis; to investigate the basic approaches to the SRN sustainable development in the megacity area, including the environmental safety of the megalopolis SRN as the main factor of its sustainable development (World Cities Report 2016).

METHODOLOGY OF THE RESEARCH

The basic principles of the SRN sustainable development of a megalopolis.

The triune theory of sustainable (economic, social and environmental) development offers new approaches to the management of spatial development, namely, the commensurability of natural, social, productive and infrastructural potentials. In the National Security Strategy of the Russian Federation until 2020, these trends are declared as priority directions for Russian society development. The document, in particular, specifies that the transport infrastructure should increase protection of the population from natural and anthropogenic emergency situations. The diversity of problems connected with transport infrastructure varies depending on the characteristics of the megacity's area. In metropolitan cities, the most urgent issue is the traffic and road congestion problem, which depends on the urbanization process. In remote areas where the population density is lower, there is also another problem – the state of the transport infrastructure does not always allow for sufficient use of the road routes. (The decree of the Russian President "About the Strategy of national security of the Russian Federation till 2020").

Obviously, in order to implement a sustainable transport policy in a metropolis, it is necessary to ensure a normal level of functioning of one of the most problematic elements of the infrastructure – a street-road network system that includes a number of facilities: city mains, roads, streets, driveways, parking lots, sidewalks and urban amenities. Taking into account that the SRN of Moscow was formed mainly through the development of traditional routes, not focusing on the promising rapid growth of traffic flows, it was not ready to perceive today's level of automobilization.

The city authorities carry out separate measures to improve the situation in this area (catch parking lots, allocating special lanes for public transport, etc.), which, unfortunately, do not optimize the management of the city traffic in general (Mayorov and Sevryugin 2015).

To understand how to solve this problem, it makes sense to clarify the principles of sustainable SRN development in cities. In the documents of the European Conference of Transportation Departments (EKMT CEMT / CM) concerning the sustainable urban transport policy implementation, it is recognized that the "sustainability" criteria of urban transport activities in different countries may have specificity, which, however, often remains unclear.

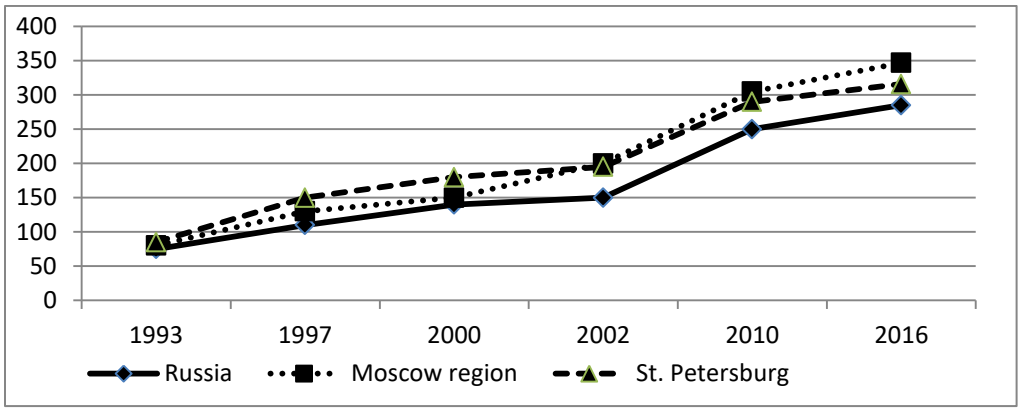
But there is complete agreement that the "sustainable" operation of the city's transport system is associated with improving the quality of life of the urban population, including transport accessibility to urban areas, high quality of transport services, minimizing damage to human health and the environment and inadmissibility of depletion of non-renewable natural

resources. (Traffic safety. European conference of Ministers of Transport 2006; Human Development Report 2016).

The index "quality of life" includes a number of indicator factors among which priorities are: public health, social life, material welfare, job security, gender equality etc. (Human Development Report 2016). The SRN should promote formation of these factors, activate the population, involve it into the city social life, providing workplaces and raising living standards of the population (Blecic and Cecchini 2017).

On the other hand, an increase of the life quality index of the urban population predetermines the sustainable development of the megacity road system. The constant growth of megacity population (according to the UN data, by 2030 the proportion of the urban population in the CIS will be 75%), as well as the growth of its borders leads to active ratio of vehicles to population in cities of Russia. Therefore, the stability of transport system development and operation, primarily, is determined by solving problems in the field of traffic organization. The analysis of statistical data shows over a period of 1993-2016 that vehicle-to-population ratio in Russian cities grew almost 4 times as 'figure 1' shows (Analytical agency AVTOSTAT).

Figure 1
DYNAMICS OF THE VEHICLE-TO-POPULATION RATIO IN RUSSIA (CARS/1000 PERSONS).



It should be noted that the growth in the volume of road transport and traffic occurs in conditions of a lag in the pace of development of road infrastructure. Thus, in Moscow, the annual growth of the automobile fleet is 4 times faster than the construction and reconstruction of the road network. This leads to congestion in the urban areas and major highways at the approaches to them, and, as a result, to a variety of different economic, social and environmental problems. It is obviously necessary to improve the methods and means of managing the SRN of megacities to eliminate such problems.

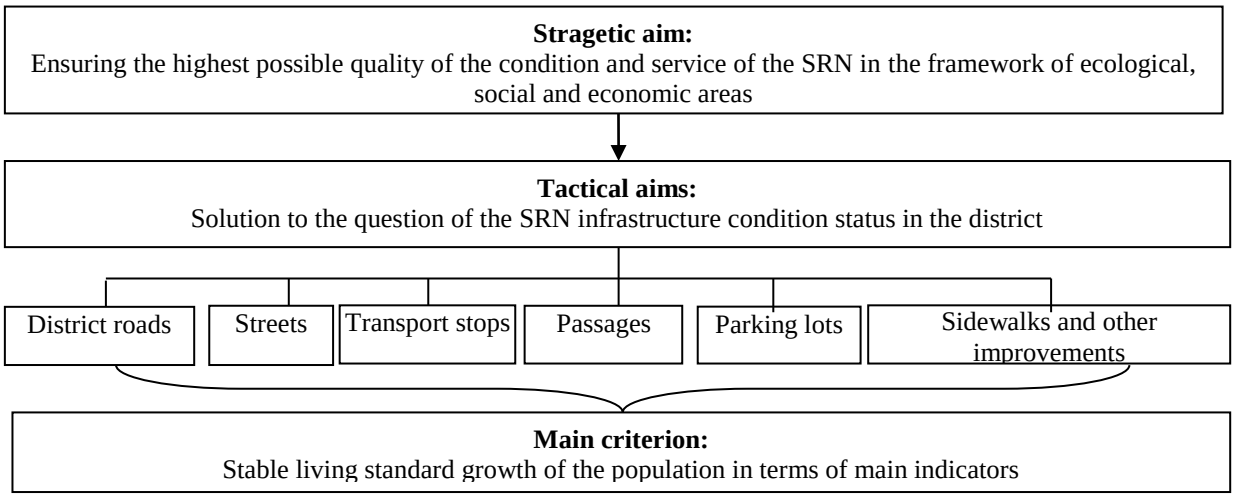
Approaches to the sustainable development of the SRN of a megacity at the local level.

The issue of improving the traffic infrastructure in megacities, particularly, the SRN is one of the most important problems in the world practice. In Russia, among the objectives of the Federal Program "Development of the Transport System of Russia in 2010-2020" are such areas as:

- development of transport infrastructure and reduction of transport costs in the economy;
- increase of accessibility of transport services for the population;
- increase the competitiveness of the transport sector in Russia;
- the national standard dated 01.04.2013 "About social adaptation services for disabled people", based on the UN Convention.

The development strategy of the district SRN in a megalopolis should be based on a program-targeted management theory that provides setting strategic and tactical goals, as well as the main criteria for their achievement, that is, the quantitative indicators which determine the measure or assessment of the goal achievement in comparison with alternative options for the system improvement. The strategic aim of the system under consideration is to ensure the high quality of the SRN condition and service in three directions – social, economic and environmental. Tactical objectives should include solution to the questions at the local level (the condition of local district roads, parking lots, traffic capacity, movement mobility, cleanness, etc.). The main criterion is the living standard of population in the district, which can be determined by a great deal of life quality indicators as 'figure 2' shows.

Figure 2
SCHEME OF GOALS AND CRITERIA FOR THE SRN MANAGEMENT OF A MOSCOW DISTRICT



Indicators of life quality of the population may be considered such factors as an increase of life expectancy, years; morbidity and mortality rate, %; population mobility growth, %; social life involvement, %; increase of population income level, %; hard-surface road area, m^2; environmental standards according to MPC (maximum permissible discharge) etc. The convenience of using the transport infrastructure was the main guideline in choosing the possible ways to improve the SRN.

THE RESULTS OF RESEARCH

It also should be noted that there are about 250 thousand disabled people of active working age who permanently live in Moscow, more than 60% of them are employed. The nearest plans are to bring this figure to 85%. Involvement of economically active people with disabilities in the labor and social spheres requires the widespread development of an appropriate infrastructure for safe and accessible transportation, including entrances of houses, adjacent areas, traffic intersections (traffic lights), all types of transport equipped with special devices and systems.

In this aspect, there were examined some Moscow districts, which were ranked according to the current situation in the public transport system in relation to the underground.

In Moscow, the share of the metropolitan is about 56% from the total public transport volume. About 7 million people descend into the underground daily, and on working days, it

exceeds 9 million. On average, more than half of the stations receive more than 50,000 people a day; each passenger's trip is about 14.5 km on average. Therefore, the SRN should provide accessibility for the public to the metro services.

Significant is the fact that the implementation of the Moscow Central Ring (MZK) project, which ended in September 2016 with the launch of 54 km of surface rail transport connected to all subway chords, significantly affected both the availability of metro for the population of almost all areas of the city, but also changed the load on most interchange stations, created the conditions for the development of large "docking" hubs of all types of land passenger transport, underground and railway. (Krozer 2017).

The daily traffic of the MCR (Moscow Central Ring) is about 350 thousand people. (30 million people for the first 4 months), availability of 31 transport-transfer hubs (TTH), including 17 metro stations and 10 changes for railway trains, significantly shortened the time of route, according to some data and directions - up to 3 times. (Official site of Moscow Metro).

The definition of the position in the rating of each district is based on the population size in it and the average distance to the metro stations. The areas of new Moscow (connected to the territory of Moscow from 1 July 2012, which increased its territory by 2.39 times) were not considered in this study because there is relatively small population (only 234 thousand people) and it is far from the metro stations in comparison with other districts of Moscow. There is given a conditional division of Moscow districts on the availability of metro by public in table 1 (Pavlova and Novikov, 2014).

Table 1
RANKING OF MOSCOW DISTRICTS REGARDING THE ACCESS TO THE METRO SERVICES

District	Population size, thousand people	Average distance to the metropolitan, m	Complexity measure*	Rank
CAD	742,689	589	0,00	1
NWAD	924,419	1743	1,00	2
SWAD	1366,282	1209	1,84	3
NEAD	1366,303	1525	2,78	4
SEAD	1294,660	1650	2,79	5
NAD	1114,607	2338	3,10	6
SAD	1703,892	1327	3,38	7
WAD	1275,970	2627	5,18	8
EAD	1459,051	2113	5,52	9

*The complexity measure was calculated as the ratio of the product between the different size of the population in a particular district and the Central Administrative District (CAO), and the difference between the average distance to the metro in a certain district from the average distance to the metro in the CAO to the population size in the least problematic district.

According to the research data, it was determined that the least problematic situation is in the Central Administrative District of Moscow (CAD), which has the lowest distance from the metropolitan and the smallest population size. It does not require the infrastructure network expansion (the construction of additional metro stations, roads, etc.). The calculated parameters, received in the result of research, revealed the most difficult situation in the Eastern

Administrative District of Moscow (EAD), where the maximum value of complexity measure is observed. In the study group of districts in the EAD, the average distance to the metro is not the greatest, but the population index in the district exceeds this figure in the SAD, which is more remote, by almost 60%. This determines the need for infrastructure development just in this district.

The infrastructure development of the lagging districts will reduce the transport routes congestion of the central district, through which a large motor vehicles flow is moving, for the absence of other ways to travel around the center. In such areas, increase of the ground transportation stops network and enhancing the diversity of the ground transportation routes will be rational measures, which will permit citizens to refuse from their personal vehicles and give preference to the public transport. During the analysis of the vehicle traffic, the results were obtained confirming transportation difficulties in the most problematic districts of Moscow.

It was revealed that the flow of vehicles in the WAD is much lower than in the EAD, where there is the highest level of traffic, both in the morning and in the evening. For the extended characterization of the area with the least favorable transport situation in the problematic district of the EAD, a detailed analysis of the data for each of the constituent microdistricts was carried out, which made it possible to identify their transport problems.
The results of the analysis are given in table 2.

Table 2
RANKING OF EAD MICRODISTRICTS IN THE COMPLEXITY OF TRANSPORT SITUATION

EAD micro district	Population size, thousand people	Number of bus stops	Number of bus routes	Distance to the metro, m	Complexity measure*	Rank
Izmaylovo Northern	81	47	126	100	1,4	1
Izmaylovo	110	114	316	800	2,4	2
Preobrazhenskoye	81	57	211	400	2,7	3
Perovo	135	128	429	1100	2,7	4
Sokolniki	55	104	258	1600	3,3	5
Sololinaya gora	85	87	268	1100	4,0	6
Novogireevo	95	72	262	1000	5,0	7
Veshnyaki	127	84	258	1600	9,4	8
Ivanovo	128	71	304	1600	9,5	9
Golyanovo	159	116	303	2200	10,0	10
Bogorodskoye	99	70	173	1800	14,7	11
Koshino-Ukhtomsky	17	43	105	4500	16,9	12
Izmaylovo East	75	40	95	1400	27,6	13
Metgorodok	37	36	79	3400	44,2	14
Novokosino	98	58	102	3400	56,3	15

* The complexity measure was calculated as the ratio of the cup product between the population size of the microdistrict and the average distance to the metro station to the cup product of the number of bus stops and the number of bus routes.

The Izmailovo North microdistrict is chosen as the conditional basic area on the results of the analysis, there are practically no transport difficulties. From the transport point of view, the definition of the least favorable regions (Izmailovo Vostochnoe, Metrogorodok, Novokosino) makes it advisable to develop the infrastructure in them, that is, the variability of bus routes, the

need for building bus stops, an additional metro station, and possible places for parking lots. In this aspect, new metro stations and commuter parking lots are being planned to open in accordance with Moscow programs of transport infrastructure development, as well as the construction of public transport stops, substitution of zebra crossing for aboveground or underground crosswalks, construction of interchanges, automated control of traffic lights, etc.

To solve problems of the SRN urban system, in our opinion, the following measures are to be taken to improve the transport situation:

– increase of the capacity and operational status of SRN;
– regulation of demand for road transport, affecting the welfare of the population;
– introduction of administrative and fiscal restrictions on the movement of road transportation;
– formation of an optimal parking policy;
– automated management of traffic flows;
– scientifically based increase in the number of metro stations using innovative technologies.

Elaboration of measures for the development of the SRN transport infrastructure will improve all three components of sustainable development: economic (reducing the time costs of workers and increasing their mobility), social (improving livelihoods and welfare); environmental (reduction of toxic emissions by personal vehicles).

To increase stability and improve the SRN system operation we considered the possibility of building multi-storey parking in one of the areas of concern in the EAD – Metrogorodok. The introduction of such an object will be a compact insulation of vehicles, will improve the comfort, will give the opportunity to receive additional revenues for the city and many other advantages.

For this purpose, there was made an analysis of the map of the adjacent territories in the area in relation to the nearby metro station and the availability of a free space was revealed, suggesting the introduction of a new transport facility. Expenses for the construction of multi-storey parking were calculated in the program of the Grand Estimate, based on the base prices of 2015 in terms of March 2016 and are presented in table 3.

Table 3
EXPENDITURES FOR THE CONSTRUCTION OF MULTI-STOREY PARKING IN THE MICRODISTRICT METROGORODOK

Main stages	Expenditures, thous. rubl.
1.Preparation of construction site	3784,52
2.Construction of a parking carcass	213283
3.Interior decoration of the building, interfloor construction	164709,3
4. Installation of traffic signs	2483,52
Total:	384260,3

It was assumed that this kind of facility would provide comfort and improve the quality of road transport services, as well as it would allow to get additional profit by means of the diversification of income (renting of premises, car wash equipment, etc.). The effectiveness of the proposed activity was confirmed by a system of economic indicators that reflects the cost-benefit ratio On the results of calculations, all the obtained indicators confirm economic attractiveness of the activity: low labor input of the product – 0.207, a normal level of capital output – 1.04 and a capital intensity – 0.96, energy intensity – 0.17, and a high level of profitability – 0.46.

Social benefits from the construction of multi-storey parking include a number of benefits: residents of the district will save personal time, save fuel expenses, increase mobility, gain additional jobs, improve welfare, road accidents will be reduced, etc. The calculated data show that potential customers of the proposed parking will save 30 minutes each day. This time saving has a value estimate: 1000 parking users will save 8625.9 thousand rubles. It also can be noted that 1000 car owners using parking services on working days will save 641.5 thousand liters of gasoline and 31.1 thousand liters of diesel fuel per year. Savings with an average price for gasoline and diesel fuel (2017) will amount about 23357, 2 and 1164, 7 thousand rubles.

Thus, the solution of the local traffic problem of the district SRN can be used to address the transport infrastructure of other metropolitan areas in the context of the sustainable development of the entire city.

DISCUSSION

The improvement of economic and social indicators within the framework of sustainable development policy should be harmonized with the creation of environmental safety conditions for its components (auto- and pedestrian roads, vehicles, stops, car parking, etc.). It is known, that vehicles have technogenic impact on virtually all components of the biosphere: atmosphere, water and land resources, flora, fauna and human. Cars are noted to cause atmospheric pollution by chemical compounds contained in waste automotive gases in the cities up to 80% (Babashamsi and Yusoff 2016).

Based on the analysis, the Izmailovo Severnoye microdistrict is chosen as a conditional basic area, where there are practically no transport difficulties. From the transport point of view, the definition of the least favorable regions (Izmailovo Vostochnoe, Metrogorodok, Novokosino) makes it advisable to develop the infrastructure in them, that is, the variability of bus routes, to build bus stops, an additional metro station, and the possibility of organizing places for automobile parking lots.

The main cause of chemical pollution is incomplete and non-uniform combustion of fuel. The presence of harmful substances in exhaust gases depends on the type of fuel, on the composition of additives and combustible-lubricating materials (fuel), on the engine operating mode, its technical condition and the car's movement, etc. (Larionov and Ryabyshenkov 2015).

It should be noted that air saturating exhaust gases together with other negative factors promote a synergistic effect and thereby contribute to the deterioration of the environmental status of SRN.

According to the data of the studies (Pavlova and Novikov 2014; Larionov and Ryabyshenkov 2015), the greatest amount of toxic substances is released when the engine operating modes change, namely during the stop and start-up, as well as during idle operation, which is typical and usual for SRN situations. So, with a decrease in the speed of the car from 60 to 30 km/h, the carbon monoxide emissions increase 2.2 times as compared to its concentration in the exhaust gases at a speed of 70-75 km/h, which is the minimum. Therefore, about 50% of motor transport emissions within the city are located on low-speed roads, and the maximum concentration of toxic substances occurs at intersections, near traffic lights, in traffic jams, etc.

The complexity of the ecological disturbance is also characterized by the consumption of air oxygen by motor transport. So, if a person consumes air up to 15.5 $м^3$ per day, then a modern car consumes about 12 m3 of air for burning 1 kg of gasoline. That is, in megacities, the use of oxygen by automobile transport is ten times greater than that consumed by all people living in them.

Along with the environmental contamination by harmful chemical emissions of motor

vehicle traffic, one should also note its physical effect on the atmosphere in the form of anthropogenic physical fields (increased noise, infrasound, vibration, electromagnetic radiation). Road transport is the main source of acoustic disturbance of the natural environment - in cities up to 75-90%.

The complex influence of many factors of the operation of vehicles on the environment can lead to significant deviations from its ecological balance. In this case, special damage is caused by emergency situations, accompanied by the entry of dangerous cargo of chemical and radioactive origin, combustible materials into the environment. This contributes to the penetration of the latter into the soil layers, to surface and groundwater, to plant uptake, as well as further migration, accumulation, poisoning and destruction of biological objects of natural ecosystems. Environmentalists say that with the trend of an annual increase in the number of cars, especially in large cities, where the traffic density exceeds 1000 per 1 km^2, the natural environment can be considered destroyed.

To develop measures to minimize the impact of vehicle traffic factors, it is useful to study the experience of the leading industrial countries of the world. In Japan, for example, protective strips of trees and shrubs are planted along the motorways, soundproof shields or walls are constructed within the residential blocks at a distance of 10-20m from the road edge, the construction of road surfaces is modernized, deep walking tunnels are laid. In addition, residential buildings located near highways are protected from noise by special finishing soundproof materials, they use vibration-absorbing foundations in the construction, etc. In another ecological-economic program "City of the Future" for megacities of France, the key element is the underground structures of a new type, the so-called ecoframes: automobile and other types of roads, collectors of engineering communications connecting the central part of the city with the areas of the periphery are supposed to be located below ground surface. It is proposed to create parks, squares in the exclusion zone of road areas, etc.

It becomes obvious that in restrained urban conditions, the construction of new arterial roads on the surface becomes economically inexpedient. At the same time, the development of infrastructure services should be aimed at reducing the concentration of pollutants that enter the environment from road transport, including street traffic.

CONCLUSIONS

There should be a step-by-step approach in building of a city transport policy on the principles of sustainable development. It takes into account the achievement of the primary goals and objectives of management in the transport infrastructure at the level considered. These include the SRN, the problematic factors of which are road congestion, difficult search for parking spaces, lack of comforts, etc.

The choice of management tools in the system of SRN of a megacity at different levels should be based on the results of diagnostic analysis and evaluation of the main indicator values of the quality of the road transport complex functioning. The diagnostic method includes the ranking of the SRN on problem districts and areas; analysis of existing problems and selection of the metropolitan area with the poorer index; development of strategic ideas and activities to improve the SRN at various levels.

As an example, a detailed analysis of the microdistrict with the least favorable transport situation in the problematic district of Moscow (EAD) was made and it is possible to improve the transport situation by means of arrangement of the parking place. One of the possible first-priority measures for the management system is to introduce a multi-storey parking lot in one of

the Moscow's problem areas which will have socio-technical and economic advantages. The experience gained can be applied in other parts of the city.

The following activities will act to improve environmental safety in the SRN system: technological (use of new modes of transport, for example, electric vehicles); use of alternative environmentally friendly fuels (gas, biofuel); timely maintenance of cars; improvement of internal combustion engines; sanitary (recycling and neutralization of exhaust gases using catalysts, neutralizing agents, etc); planned, controlled (organization of safe passage of streets at different levels); administrative (withdrawal of transit transport, warehouse bases and terminals out of the city, increase of payment for emission of toxic components of exhaust gases into the environment, identification of lanes for passenger transport and high-speed roads of non-stop traffic, optimization of traffic in the metropolitan area, development of electric transport, implementation of innovative projects , aimed at the ecologization of transport infrastructures).

Such a total-system approach will allow to formulate the concept of development of the priority direction of the transport network, Street Road Network, in a sustainable mode, to propose ways to increase the efficiency of its functioning, having received a social and ecological effect in addition to economic benefits.

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