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ANALYSIS OF THE CITY TRANSPORT SYSTEM'S DEVELOPMENT STRATEGY DESIGN PRINCIPLES WITH ACCOUNT OF RISKS AND SPECIFIC FEATURES OF SPATIAL DEVELOPMENT

Summary. Transport system is the key indicator of sustainable spatial development, because if it is ineffective it can render the economy, the environment, and society vulnerable. Despite the large number of already existing research, the city transportation system's development strategy design is still a relevant objective, because the existing ways and strategies of the transport development may not always be applicable in certain circumstances. This article presents the possible ways of improvement of sustainability of the city transportation systems adapted in accordance with the peculiarities of Russian cities. It is stated that when working out a city transportation system's development strategy it is necessary to take into account all possible risks. According to the case study of Naberezhnye Chelny city, all vulnerabilities of the system that today are typical almost for all Russian cities were analyzed, classification of risks was made, and means of their control were suggested. Solutions proposed as a result of the SWOT-analysis can be used when developing transport strategies for other cities with similar specificity.

1. INTRODUCTION

During the debates about sustainable development, the participants of the United Nations Conference on sustainable development (Conference "Rio+20" [1]) noted that transportation and mobility are central to sustainable development as means to improve social equity, health, resilience of cities, urban-rural linkages, and productivity of rural areas. The transport sector is a major contributor to air pollution and climate emissions, and the impact is set to increase with an expected tripling of the global vehicle fleet. UNEP's work is aimed at decoupling increased mobility from increased emissions. UNEP is a partner in several leading global transport programs in areas such as fuel economy, small particulate pollution, and infrastructure development, implemented through public-private partnerships.

Sustainable transport systems' development is one of the Global Goals for Sustainable Development [2] and is the priority area of work of the Pan-European Program on Transport, Environment, and Health (the PEP) that is focused on safe, efficient, accessible, affordable, inclusive, green, and healthy mobility and transport. In the Paris Declaration, in addition to the four priority goals of the PEP the new priority goal was adopted. This goal is to integrate transport, health, and environmental objectives into urban and spatial planning policies by developing capacities and frameworks for integrated urban and spatial planning in order to reduce the impact of transport on health, the environment, and land use, increase energy efficiency, and support green and healthy mobility and transport as well as sustainable livelihoods [3]. The planning of urban and peri-urban centers according to mixed-use and smart growth design principles must be a part of a sustainable transport future. Urban development along these principles will serve to lower dependence on personal vehicles and support in the increased use of public transport systems and non-motorized transport for short distances and daily commutes [4].

Moreover, sustainable urban mobility is one of the 6 Action Clusters of Smart cities that are highlighted by the European Innovation Partnership on Smart Cities and Communities (EIP-SCC) [5]. It is stated in [6] that Smart cities need to be accessible and sustainable. Together with the intelligent use of energy and ICT, smart urban mobility is at the heart of efforts and public transport a key integrator.

International experience shows that, in case of the choice of transportation system's strategy development, it is necessary to consider particularities of each country or region: current transportation spatial structure of the city, level of motorization, prospects for socioeconomic development, climatic and natural conditions, and so on. The analysis of development ways of the city transportation systems shows that there are significant differences between them, despite the unity of the purposes and available experience. Therefore, when designing development strategies of transportation systems it is necessary to not only rely on successful examples and solutions but also predict whether they are applicable in certain circumstances and what are the risks and consequences that can be caused by unreasoned measures in the field of transport policy.

2. EXISTING METHODS AND EXAMPLES OF THE DEVELOPMENT STRATEGIES OF THE CITY TRANSPORTATION SYSTEMS

Successful municipal authorities begin with the design of long-term strategy and goals of the city's development, as well as the recognition of relations between multiple and contradictory tasks of transport policy, and then provide agreed decision of outer problems such as the road network development, traffic management, and increasing the efficiency of public transport [7].

The project of the World Business Council for Sustainable Development "Sustainable Mobility Project 2.0" categorized global cities into groups according to their mobility characteristics and nominated six cities as demonstrator cities to develop a roadmap for sustainable mobility together with the city government and related stakeholders. These cities include Hamburg (Germany), Lisbon (Portugal), Campinas (Brazil), Chengdu (China), Indore (India), and Bangkok (Thailand) [8]. Online mobility planning tool was developed using the successful experience of six demonstrator cities. It should help other cities to develop fact-based and integrated sustainable urban mobility plans based on 19 sustainable mobility indicators [9].

2.1. Particularities of city transportation systems' development in North America and Australia

Particularities of the USA transportation system's development can largely be linked to the implementation of Roosevelt's "New Deal" to overcome the Great Depression, when resources were redistributed from production toward infrastructure. In order to bring down unemployment, millions of Americans were directed to construction of dams, highways and railways, power lines, bridges, and other important sites. This allowed to facilitate logistic and transport tasks and gave an additional incentive for business. Development of infrastructure and automotive industry has led to a much higher level of motorization in the USA than in other countries. Besides that, the USA has made a great effort to adapt to high motorization level, and since the 1950s other modes of transport have practically ceased to be taken into account when planning new neighborhoods and suburbs in many American cities. At the same time, the density of traffic flow in metropolitan areas is higher than that in the middle and small towns because of the high population density. Therefore, the cities of the USA, despite their rectangular planning and wide streets, were the first developed ones and have faced the problems associated with the rapid growth of motorization. Besides, population shift from central urban areas to suburbs caused the urban sprawl, a decrease in population density and distribution of workplaces, and has contributed to motorization growth and negative environmental impact caused by dependence on vehicles. There is neither access to the public transport lines nor sidewalks in many areas of residential and business buildings in the American suburbs, and investments into walking and cycling facilities and services are limited.

Only in recent years some cities of North America [10-12] have begun to establish human-oriented concepts focused on the variety of people's access to services (which requires to take into consideration not only personal vehicles but also public transport, walking, and cycling connections). Such con-

cepts provide high standards of livable cities rather than cities oriented on vehicles [13]. For example, the concept of improving bus service in Canada [14] includes the following: (1) network planning and services; (2) branding, market research activities, and social marketing; (3) giving priority to public transport; (4) bus stops and stations designed to ensure their accessibility and the linkages to other transportation modes; (5) vehicle selection; (6) selection of the key intersections where signal priority systems would bring about significant travel time savings; and (7) walking and cycling infrastructure and service development. In Australia, the Public Transport Plan was developed in 2015 [15]. The proposed public transport system will be built conceptually as a grid of high-frequency lines, running independently and integrated at transfer points such as bus / train stations and terminals. Transfers between different services will become an increasingly prevalent experience for passengers, further building on one of the key strengths of the existing system. Transfer points also represent an access point for cyclists to utilize public transport for a part of their journey, and an increased provision for bicycle storage facilities is expected to increase the attractiveness of both the public transport and active transport networks.

2.2. Particularities of city transportation systems' development in Asia and South America

Development of Asian and South American countries is accompanied by urbanization processes along with high population density and a low level of its incomes. It is the main challenge in the process of transportation problem solving. Thus, the transportation system of China is no longer able to cope with growing transport flows that decrease mobility and cause serious environmental problems. Public transport and walking play a very important role in densely populated areas and in the cities where the main value is the space. At the same time, the negative environmental impact of vehicles is especially serious in such areas. Thus, the more public transport and walking are used in a particular city, the more variable and comfortable this city is in comparison with the suburbs. The higher the city's dependence on vehicles and the longer the population does not use alternative ways of traveling, the higher the probability of the decline in central urban areas [16].

Walking and cycling are the principal means of transportation in cities of developing countries. This is largely not by choice, but rather driven by the great amount of lower income groups. At the same time, walking and cycling in metropolitan areas that are characterized by long distances and high density of population cannot satisfy population's mobility demand. Metropolitan areas today urgently need a more sustainable, low-carbon transport systems. Therefore, the most effective strategy for Asian and South American countries is the development of high-speed mass public transport, such as Bus Rapid Transit (BRT), Light Rail Transit (LRT) [17-21], and e-vehicles. Moreover, the introduction of electric bicycles has made it possible to use cycling not only for health and leisure, but as a viable means of transport. Thus, in Manila, the Asian Development Bank is aiming to roll out 100,000 e-trikes to replace current fossil fuel versions, which is not only good for the environment and health but also increases take-home pay for drivers by around 15%. Hangzhou in China, which already has the world's largest bike-sharing scheme, has embraced the electric car. Many options require city-level investment in new infrastructure – for example, the city of Gumi in South Korea is currently piloting a scheme that embeds wireless charging for electric buses within the roads, helping to recharge vehicles on the move [22]. Thus, organizational measures and the use of more environment-friendly transport modes are the two priority areas of transport policy for the cities and megalopolises of developing countries.

2.3. Transportation systems of European countries. Sustainable mobility strategies

European cities and streets turned out to be less adapted to significant volumes of traffic compared with American cities. Generally, it is connected with their rather small squares and with historically developed strongly marked city center. The gap between the capacity of the road network and increasing traffic intensity in such monocentric cities, wherein the vast majority of jobs and commercial activities are concentrated in the city center, can often cause serious traffic congestions. Therefore, many European countries have adopted various strategic decisions based on the rejection of the conception

"city for vehicles". In 2011, the European Commission adopted a roadmap of 40 concrete initiatives for the next decade to build a competitive transport system that will increase mobility, remove major barriers in key areas, and fuel growth and employment. This roadmap is called "The 2011 Transport White Paper" and sets ambitious numerical targets for urban mobility by the year 2030: (1) halve the use of conventional fuelled vehicles, (2) move to zero road fatalities, and (3) carbon-free logistics [23, 24]. One of the ways to reach these goals is by optimizing the performance of multimodal transportation planning, both freight and passenger transportation. Multimodal transportation planning is complicated because modes differ in various ways, including their availability, speed, density, costs, limitations, and most appropriate uses. London can serve as a good example of integrated transport planning. Its overall public transport network is characterized by a well-established rail network complemented by an extensive bus network and a ferry network. These networks are integrated by multimodal stations designed for ease of interchange for high volumes of passengers. At major stations, purpose-built bus interchanges have been developed to be within walking distance of the railway and underground stations, often manned by bus station staff and furbished with real-time information systems [25, 26].

The new alternative approach to the transportation problem solving is the concept **"Avoid – Shift – Improve"**, which seeks to achieve significant GHG emission reductions, reduced energy consumption, less congestion, and the final objective, to create more livable cities [27, 28].

The **"Avoid"** strategy seeks to avoid unnecessary travel and reduce trip distances. Reducing the need for transport requires plans, policies, and programs that are essentially preventative [29]. The proposal of Timmy Dooley, Fianna Fáil Spokesperson on Transport, Tourism, and Sport [30], is an example of such preventative program. There are five measures outlined in the document that can redistribute traffic across a greater number of hours to reduce congestion on the major arterial routes during peak travel periods. One of the measures is to encourage flexitime work in order to enable employees to commute during off-peak hours.

The "**Shift"** strategy seeks to shift passengers toward a more sustainable transport mode. According to the Global Status Report on Road Safety 2015 [31], moving toward more sustainable modes of transport (such as cycling and public transport) has positive effects if associated road safety impacts have been well managed. These include increased physical activity, reduced emissions and noise levels, reduced congestion, and more pleasant cities. Moreover, measures to promote safe public transport and non-motorized means of transport are also in line with other global moves to fight obesity and reduce non-communicable diseases (such as heart disease and diabetes) [29]. In the documents of the PEP it is noted that there are inspiring examples of improving the quality of the urban environment and supporting a modal shift toward cycling and walking in combination with public transport. These positive changes include the investments of cities such as Paris and Barcelona in cycling infrastructure and city bikes and the introduction of congestion charges in London, Stockholm, and other cities [32]. Today, two-thirds of road users of many European cities (such as Oulu, Amsterdam, or Copenhagen) constitute cyclists [33-35]. In other words, most megalopolis citizens really can use a bicycle, not a car. However, not everyone can ride a bicycle every day, especially long-distance cycling. That is why bicycles should be considered not as a competitor, but rather as an addition to other modes of transport.

More than 100 countries adopted policy measures on investments in public transport at the national or subnational levels. In most countries with high-income, public transport is regulated properly and therefore it is significantly more secure compared with private vehicles. However, in many countries with low and middle income levels, whose economy is growing rapidly, the growth is not regulated, leading to increased road traffic injuries among its users. Governments should ensure the security, availability, and pricing acceptability of public transport systems. The examples of strategies for the development of public transport systems and their successful implementation are as follows: Public Transport Strategy, developed by the East Riding of Yorkshire Council (Great Britain) [36], Guidelines for Attractive Public Transport with a focus on BRT in Sweden [37], Dublin Transport Map (Ireland) [38], Public Transport – an Attractive Alternative (Finland) [39], and so on.

Thus, the use of personal cars for daily trips may be reduced provided the right transport links between all parts of the city are established by public transport, there are sufficient reasons for not own-

ing a vehicle (e.g. limited and costly parking), and local walking and cycling facilities and services are encouraged.

The **"Improve"** strategy is a technological approach that includes lightweighting, new engine and fuel technologies, improving fuel quality, using vehicles run on alternative fuels, developing vehicle emission standards, and transitioning to "intelligent transportation systems" that take advantage of information and communication technologies to improve transport management [40].

The combination of all these three strategies in one city is called The Smart City concept. This concept can be defined as a model of the city development, which creates a surplus of resources through the use of information and communication technologies combined with sustainable and environment-friendly multiple solutions. It emphasizes the need to improve the level of mobility and connectedness through collaboration and open source knowledge on all levels of the society [41]. European Commission has made an extensive range of research in the field of urban mobility. Information on many of these projects, as well as best practices, news stories, and training material, can be found on official site [42]. One such project, the European Innovation Partnership on Smart Cities and Communities [6], brings together cities, industry, and citizens to improve urban life through more sustainable integrated solutions. This includes applied innovation, better planning, a more participatory approach, higher energy efficiency, better transport solutions, intelligent use of Information and Communication Technologies (ICT), and so on. More cost-efficient mobility can be achieved by means of intelligent services that allow less driving, less congestion, less idle time, and optimized traffic services. At the same time, traffic has a key role in reducing emissions, as it corresponds to 25 % of the CO_2 emissions in Europe. To achieve this, the concept "Maas" was developed [43], which can contribute greatly to improved traffic safety and also has major economic and societal impacts. In Finland, the main themes of the ITS strategy is to steer the development of the MaaS concept, including the following aspects: (1) customer-oriented mobility and improved service level; (2) promoting the implementation of new transport policy; and (3) utilizing the possibilities of ICT in full [44]. As a part of the European REMOURBAN (REgeneration MOdel for accelerating the smart URBAN transformation) project, the city in Great Britain, Nottingham, has been chosen as a "Lighthouse" city, because it aims to show how an urban area can integrate infrastructure – mobility, energy, and ICT – to meet population demands against a backdrop of environmental challenges [45].

In most cases of successful implementation, however, it is not a single policy but rather a package of measures. Such "packages" are more likely to gain public acceptance, and they allow a mixture of policies that may be seen as disadvantageous to individual users, but promote overall welfare gains to society [29]. The "packaging" process requires a deep and holistic consideration of different approaches together with the qualitative analysis of probable risks and consequences.

3. RISK ANALYSIS OF NABEREZHNYE CHELNY'S TRANSPORTATION SYSTEM DEVELOPMENT STRATEGY REALIZATION

3.1. Ways to increase sustainability of transportation system in Russian cities

The main transport problems in Russia are the problems of accessibility of the remote areas, the condition and quality of the roads, and sometimes almost catastrophic transportation difficulties of the large cities. Russia is currently experiencing the same traffic problems as other developed countries. These problems are a low traffic capacity of the road network, its quality, and ineffective strategic planning of the territory development, especially in the large cities. Considering the fact that about 65% of the population in Russia lives in the middle and large cities (with a population of more than 50 thousand), it is necessary to look for effective strategies of the sustainable urban mobility development. However, most of the already existing strategies would not be as effective in Russia as they are in other countries. The reason is the differences in climatic and natural conditions, level of economic development, urban density, peculiarities in spatial planning, and so on.

Transport strategy of the Russian Federation until 2030 was developed in 2012 and updated in 2014 on account of the changes caused by the world and Russian economic crisis. The strategy contains a number of sustainable transport development priorities. In particular, it provides the following:

(1) development and implementation of the state regulation mechanisms to ensure motivation of the transition to vehicles run on environmental-friendly types of fuel, (2) increased use of hybrid and electric vehicles, materials, and technologies that minimize negative impacts on the environment, (3) ensures environmentally safe waste management of the transport sector, and (4) decreased level of transport power consumption compared with the level in developed countries.

Main ways to shift to sustainable transport, realized in Russia, are almost the same as in European countries (Figure 1). Non-motorized transport still has limited application in Russia. For example, adverse climatic and natural conditions are one of the most popular counter-argument about cycling [34]. However, cycling in Russia can be successfully used as a solution for the "last mile" problem.

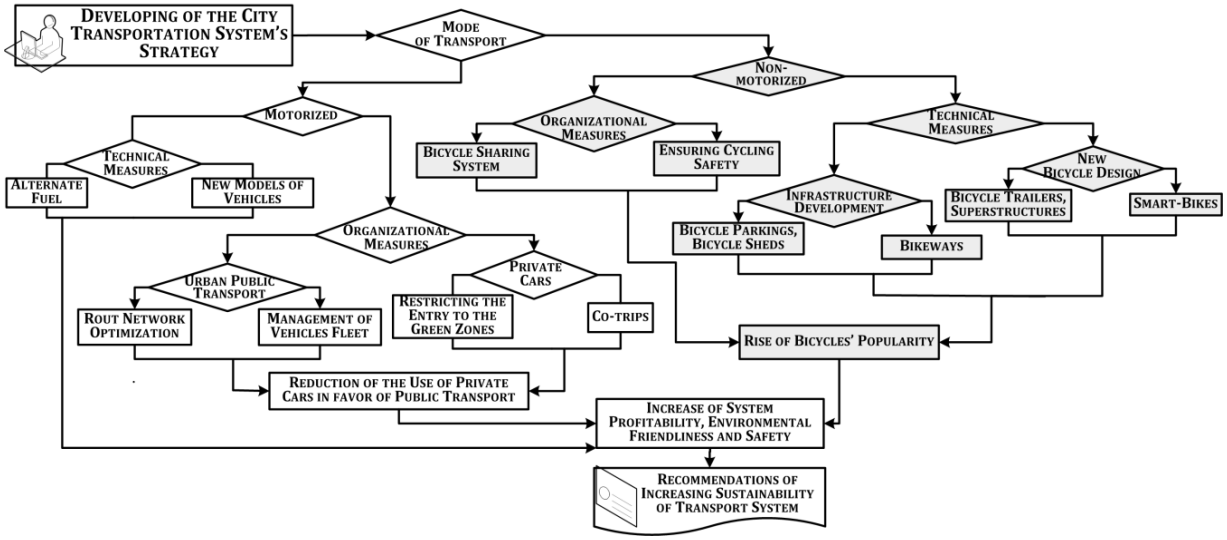

Fig. 1. Methods of increasing sustainability of the city transportation system

The spatial planning has a significant influence on transport situation in Russian cities.

Ideas to create "ideal cities" that were implemented when developing plans for regular cities were actively developed in Russia in XVIII-XIX cent. This unprecedented program allowed to seriously reconstruct Russian cities in a historically short period of time, from 1766 to 1831. 384 cities, in total, were designed, built from scratch or radically reconstructed during that period. The idea of regularity itself was understood as the ordering of the cities' chaotic building and its reduction to a clear regular system that is the most expressed as the coordinate rectangular grid with blocks of residential development. Therefore, the most common type of the regular city is a city with a rectangular urban form. One of the important qualities of Russian "ideal city" is to provide equal accessibility of the public areas and to create own centers in each separate part of the city and several sub-centers in the linear planning structures. City center always stood out and was located in the most easily reachable place, as a rule, either on the main city street, or at the intersection of the main streets, or at the most compositional significant place considering the landscape.

Spatial planning solutions of the city transportation systems can be reduced to conditional arrangement schemes: radial, radial and ring, rectangular or chess, triangular, rectangular and diagonal, and combined or free-pattern town planning. In the process of urban development, city area's expansion, and its structure's complication, the initial structure is changing by inclusion of new elements of other schemes. The main Russian peculiarity is the existence of essentially different spatial-planning organization of the city: the rectangular scheme is widespread in relatively young cities. This scheme is characterized by proportional distribution of transport loading on highways, duplicated communications, and the lack of the shortest connections in diagonal directions. The rectangular-diagonal scheme of the cities eliminates the disadvantage of the rectangular layout. There are combinations of schemes for various districts in large cities.

The old cities, which were originally built as fortresses with a strongly marked center (e.g., Moscow, Nizhny Novgorod, and Kazan), face problems similar to problems of old European cities. The cities extended along banks of the rivers or along the seashores (e.g., Murom, Volgograd, and Na-

berezhnye Chelny) are characterized by the absence of a clearly defined city center, the large number of intersections of the longitudinal and cross streets, and the imposition of routes.

3.2. Perspective directions of Naberezhnye Chelny's transportation system development

Naberezhnye Chelny – one of the youngest Russian cities – is a major railway, motor transport, and aviation hub known on the Kama river port. Linear structure open type with the "classic" functional zoning was laid according to planning organization of the city with a parallel location of industrial and residential areas and suburban recreation zones. Longitudinal highways that connect the residential areas of the city comprise a transport-planning frame of the city that gives rise to the planning scheme of its road network to rectangular. The main "diameter" of the city is a longitudinal thoroughfare, which includes M. Jalil avenue, Naberezhnochelninsky avenue, and Mira avenue [46]. One more feature of the cities of similar planning is the proportional distribution of the population throughout the residential area, and there are kindergartens, schools, and shops in each residential district (complex). It was made in order to minimize the number of trips to schools and shops. Because of the fact that a significant part of all trips during peak hours is the trips to (from) work, the separation of industrial and residential areas causes the problems on the longitudinal and cross streets' intersections. Public transport represents 14 tram routes, more than 25 bus routes, and taxi; the taxi includes the so-called Social taxi carrying several passengers. Naberezhnochelninsky tram is one of the latest new tram systems in the USSR and Russia, which is close to the light rail. It was created to provide a large passenger flow between the residential areas of the city and a vast industrial complex KAMAZ and other large enterprises. One of the very few in post-Soviet Russia, a tram system of the city, has increased in the 1990s and 2000s, and has plans for further development, including both new construction sites in the city and creating inter-city light rail line to the Yelabuga, a project which was developed during the Soviet period.

Expansion of the tram route network and its combination with the existing bus route network can help in reducing the traffic load of road network. Trams in Naberezhnye Chelny today are the second popular mode of public transport after the buses. By the end of the 2000s, private buses of small capacity practically replaced the municipal buses. Excessively increased number of small-capacity buses led to environmental problems, increased traffic load on city roads, and reduced passenger safety. In 2009, the city launched the reform of the city bus system. Its aim was to displace small-capacity buses and to restore the bus fleet and the route network. In 2013, city carriers have bought 100 new buses of large capacity that run on gas fuel: 84 buses for urban transportation and 16 for suburban transportation. In 2015, optimization of urban bus transport was made: 136 new buses of large capacity that run on gas fuel NEFAZ-5299 were bought. All shuttle buses are equipped with GLONASS devices.

The purpose of strategic planning is to develop methods of ensuring sustainability based on the balance between transport demand and transport supply using the most effective and safe transport modes. The strategy of social and economic development (Strategy of SED) of Naberezhnye Chelny city until 2030 [47] is directed at increasing the city transportation system's sustainability. Strategy implementation should ensure the establishment of the system of comfortable and environment-friendly rapid public transport and encouragement of logistics companies to shift to "green" transport. From our point of view, the existing Strategy pays insufficient attention to non-motorized modes of transport as well as to multimodal transportation development.

For example, construction of the walking and cycling facilities is planned only along the riverwalk – that is, as a recreational area, not as an element of the city transport infrastructure. At the same time, in the case when the destination point is situated on the longitudinal avenue that is parallel to the point of departure (in connection with the above-described peculiarities of urban planning) and there is the lack of the lateral routes of public transport in the city, the "last mile" problem exists. Bicycle sharing systems have frequently been qualified as a way to solve the "last mile" problem and connect users to public transit networks. Sophisticated, modern, new, city bike-sharing programs serve the last mile best by making fast door-to-door connections easy. The set of both technical and scientific decisions is devoted to the solution of this problem.

3.3. Risk management

The operation of any complicated system is always closely connected to the risks. It is especially actual for transportation systems. The complexity of transportation systems' risk analysis is due to the fact that an accident potentially may happen in any part of the route and the same events may lead to absolutely different consequences [48]. As the implementation of the Strategy of SED of Naberezhnye Chelny city requires investments for infrastructure changes in the street-road network as well as for the replacement of the existing vehicle fleet with a more environment-friendly one, this is connected to risks. Therefore, each management decision for the existing transportation system's optimization should also be considered from the perspectives of risk management. We have carried out a risk analysis.

In most of the investigations [49-52] connected with risk assessment, the risk management process is divided into 4 stages:

1. Risk identification: The classification and recognition of the potential risks connected to uncertainty of decision-making situations in transportation systems' management.
2. Risk assessment: The assignment of probabilities to risk-bearing events in the system and identifying the consequences of those risk events defined in the first step. To reach this goal, previous years' statistics and experience are used.
3. Risk reduction: It is determined depending on the probability and potential weight of risks' consequences. In general, the methods of risk control are risk taking, risk mitigation, risk avoidance, and risk transfer.
4. Risk monitoring: It includes risk tracking and fixing the changes in the system for timely response and assessment of efficiency of the risk minimization measures.

Risk, as a physical category, should be rated through two-dimensional set of indicators: the measure of uncertainty of the negative result occurrence (risk probability) and the measure of consequences or damage.

To determine this, 10 experts (employees of the Transport Division of Naberezhnye Chelny and private carriers, working in the sphere of public transport not less than 5 years) were suggested to estimate the probability of every risk in the following manner: 1 – a very low probability; 2 – a low probability; 3 – risk is probable; 4 – a high probability; and 5 – a very high probability. A risk assessment of potential damage was carried out in accordance with the following meaning of consequences: 1 – without consequences; 2 – with small consequences; 3 – with great consequences; 4 – with critical consequences; and 5 – with catastrophic consequences.

Thereafter, the values obtained for each risk were multiplied and included in table 1, and the risk matrix based on these results was built (fig. 2). The risks specified in table 1 are typical not only for Naberezhnye Chelny city but also for the majority of Russian cities. Therefore, the proposed solutions can be extended also to other cities. There are a lot of risk assessment methods – for example, risk radar, risk chart, SWOT-analysis, Delphi technique, and Decision Making Tree [53]. Risk matrix is presented in figure 2. Figures in the center of each square signify the risk level, and figures in the low right corner signify the number of the risk.

3.4. SWOT–analysis of Naberezhnye Chelny's public transport system's development strategy

At the first stage, the factors influencing the implementation of development strategy of Naberezhnye Chelny's public transport system were identified (fig. 3).

An assessment matrix of internal and external factors is formed using expert method. Thereafter, to determine strengths, weaknesses, opportunities, and threats, the matrix of the factors' interaction is compiled. The results are given in final SWOT-matrix (tab. 2). Final SWOT–matrix contains sums of windowed estimates. The choice of the most significant quadrant from the point of view of the strategy is based on the maximum absolute value of quantitative assessments. The result of SWOT-analysis is contained in the matrix of strategic events (fig. 4): **SO** – events that are needed to be conducted to use strengths for increasing opportunities; **WO** – events that are needed to be conducted to overcome weaknesses using submitted opportunities; **ST** – events that use strengths in order to prevent threats; and **WT** – events that minimize weaknesses to prevent threats.

Table 1

Assessment of the risk violation of transportation system's sustainability

№	Risk	Probability estimate	Consequences	Risk level	Ways of influences
Technical equipment and infrastructure					
1	The disrepair of transportation infrastructure (roads, etc.)	3	3	**9**	Timely repair of transportation infrastructure
2	Use of low-quality spare parts and	2	4	**8**	Concluding a treaty with reliable contractors
3	Vehicle breakdown	2	4	**8**	Subjecting vehicles to a regular maintenance; writing off
4	Insufficient development of cycling infrastructure	5	2	**10**	Designing a strategic plan of cycling infrastructure development
5	Unavailability of new bike designs	4	2	**6**	Development of new economically available bike designs
Process					
6	Breach of a bus timetable	5	3	**15**	Implementation of the bus timetable control mechanism
7	The lack of information among the population about the new routes	3	2	**6**	Development of the special websites and applications; notifications in media
8	The route network does not cover all areas of the city	3	3	**9**	The use of modern IT-technologies in new route network development
9	Passengers prefer small-capacity buses	3	5	**15**	Raising public loyalty to more sustainable large-capacity buses by 1) strict observance of the bus timetable; 2) propaganda
10	Errors in predicting the transport needs of the population	3	3	**9**	The use of modern IT-technologies in predicting transport demand
Personnel					
11	The driver has not passed a medical examination pre-trip	2	4	**8**	Setting the ignition disabler with breathalyzer
12	The human factor (feeling sick, the blahs, emotions)	3	4	**12**	Implementation of the driver's fatigue control systems and tachographs
IT-technologies					
13	Malfunctions of information and telecommunication systems	2	3	**6**	Implementation of backup systems for the emergency cases
Safety					
14	Drivers competing for passengers	4	4	**16**	Development of such a scheme of payment for labor of drivers that depends on the strict observance of the bus timetable and of driving regulations
15	Traffic offence	4	4	**16**	
Nature and ecology					
16	Bad weather conditions	2	4	**8**	Protection and clearing roads and bikeways from snow drifts
17	The negative impact on the environment	4	3	**12**	Raising public loyalty to more sustainable large capacity buses; reduction of vehicles' overmileage; avoidance of public transport routes passing through the overloaded road network areas

Analysis of the prospects of cycling transport's development strategy was carried out similarly. The results are shown in tab. 3 and fig.5-6.

4. CONCLUSION

One of the key challenges that countries and cities face is the complexity of city transportation system as well as the need to identify and implement holistic solutions, tailored to local needs. When developing a long-term strategy of city transportation system's sustainable development the positive solutions implemented in other countries should be critically examined from the point of view of pos-

sibility and effectiveness of their realization in specific circumstances of a particular city. We have analyzed the possibility of implementation of the city transportation system's development strategy in Naberezhnye Chelny that is directed to increasing its sustainability under risk.

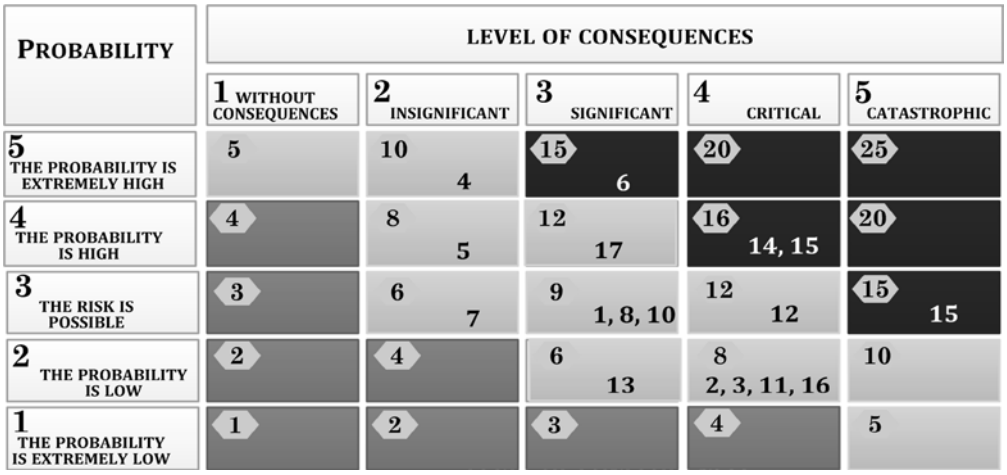

Fig. 2. Matrix of levels of risks

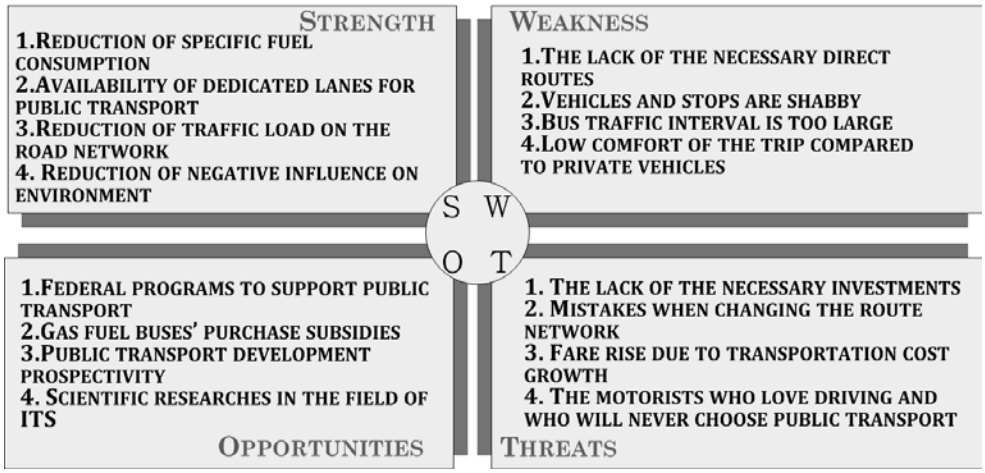

Fig. 3. Factors influencing the development of the city public transport

Table 2

Final SWOT-matrix of implementation of the public transport system's development strategy

		Strengths					Weaknesses				
		1	2	3	4	$\sum A_{ij}$	1	2	3	4	$\sum A_{ij}$
Opportunities	1	0	0	9,6	6,4	16	-2,88	-6,4	-6,4	0	-15,68
	2	0	0	12	16	28	-2,4	-6,4	-4,8	0	-13,6
	3	1,5	1,2	4,5	3	10,2	-4,5	-1,5	-6	-0,15	-12,15
	4	3,84	2,4	7,2	7,68	21,12	-7,2	0	-9,6	-1,2	-18
	$\sum A_{ij}$	5,34	3,6	33,3	33,08		-16,98	-14,3	-26,8	-1,35	
Threats	1	-1,2	0	-4,8	-4	-10	4,8	4	4	0	12,8
	2	-1,6	-1	-3	-2	-7,6	2,4	1	3,2	1	7,6
	3	0	-2,1	-3,15	0	-5,25	0	0	0	0	0
	4	-1	-1	-3	-1,2	-6,2	0	0	0	0	0
	$\sum A_{ij}$	-3,8	-4,1	-13,95	-7,2		7,2	5	7,2	1	

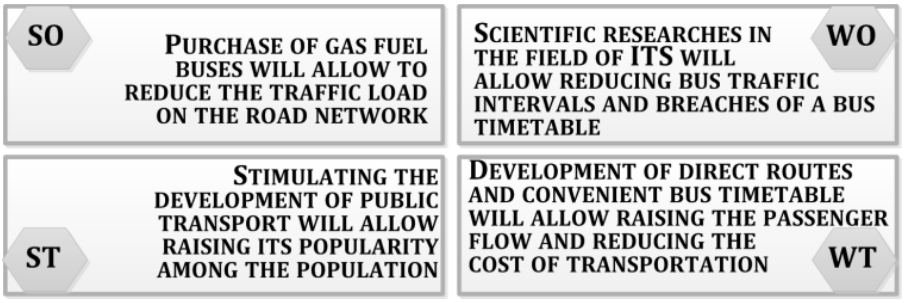

Fig. 4. Matrix of strategic events of the public transport system's development

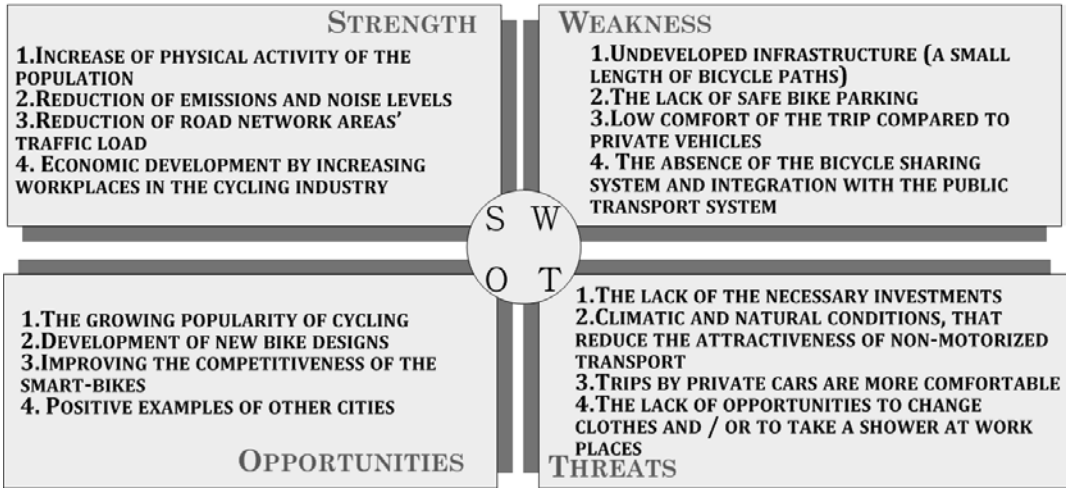

Fig. 5. Factors influencing the development of the cycling transport

Table 3

Final SWOT-matrix of implementation of the cycling transport development strategy

		Strengths					Weaknesses				
		1	2	3	4	$\sum A_{ij}$	1	2	3	4	$\sum A_{ij}$
Opportunities	1	10,8	7,2	7,2	1,08	26,28	-7,2	-1,8	-5,4	-3,6	-18
	2	1,89	1,26	2,52	1,05	6,72	0	0	0	0	0
	3	1,26	2,1	2,52	0,63	6,51	0	0	0	0	0
	4	0,75	0,5	0	0	1,25	-1	-0,15	-0,45	-0,3	-1,9
	$\sum A_{ij}$	14,7	11,06	12,24	2,76		-8,2	-1,95	-5,85	-3,9	
Threats	1	0	-1,44	-0,96	-2,4	-4,8	9,6	2,4	7,2	4,8	24
	2	0	-2,7	-3,24	-1,35	-7,29	5,4	0	6,48	2,7	14,58
	3	-1,44	-2,4	-9,6	-1,2	-14,64	9,6	1,2	3,6	0,96	15,36
	4	-0,9	-0,4	-1,2	-0,3	-2,8	0	0	0,9	0	0,9
	$\sum A_{ij}$	-2,34	-6,94	-15	-5,25		24,6	3,6	18,18	8,46	

That is why at all stages of strategic planning it is necessary to take into consideration the identification, classification, and development of accounting methods of risks' influence on the result. It should be borne in mind that the risks cannot be removed completely, as they arise in all areas of activities. In this regard, it is necessary to create self-regulating methods: recognition of risks, assessment of gravity of consequences owing to their emergence, ways of influence, development of strategy, and tactics of risk management.

Fig. 6. Matrix of strategic events of the cycling transport development

In this way, for decreasing negative influence of most dangerous risks connected to public and non-motorized transport investing, it is necessary to implement the complex of measures such as public transport route network optimization, organization of drivers' labor schedule, bicycle infrastructure development, and raising public loyalty to public and non-motorized transport, and especially to more sustainable large capacity buses.

Decisions that are unique for Naberezhnye Chelny could be used in case of strategic planning of other cities with the same peculiarities.

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