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SUSTAINABILITY OF CITIES AS SOCIO-TECHNOLOGICAL SYSTEMS

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Abstract

Issues of sustainable development are widely discussed in the scientific press, and their consideration is relevant. The purpose of the research is to study and analyze common problems of major cities in the world, to develop approaches to their solution. The research methodology's peculiarity is the factor analysis of data in a long-term period for some large cities and urban agglomerations. It has been found that the problems of most large cities and urban agglomerations in industrialized countries are associated with the rapid ageing of their infrastructure (energy, transport, utilities, waste disposal). These problems are quite general and comparable and confirmed by actual data. The article shows that cities can be considered as large and complex socio-technological systems consisting of two subsystems or levels. The material and physical subsystem is configured by the built urban environment and physical infrastructure. The social subsystem is configured by human activity and social interactions of people in the city. The problems of the material and physical subsystem can be solved with innovative technologies (digitalization, the intellectualization of cities) and significant investments. The problems of the social subsystem of cities are determined by their historical development, social structure, and demographics and require separate approaches for specific cities. A conceptual model of climate and other external factors on the city's water ecosystem is proposed.

Keywords: Innovative technologies, large cities, problems, sustainable development

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1. Introduction

Cities play a significant and often decisive role in the modern political, socio-economic life of each country individually and the world as a whole. Cities occupy about 2 % of The earth's land area but consume 3/4 of the world's resources. Half of the World's population now lives in cities. It is assumed that by 2050, the urban population will make up 70% of the world's population. For example, Russia can be considered a highly urbanized country, since already 73% of the country's population lives in cities and every sixth Russian life in a city with more than a million inhabitants.

Modern cities are complex socio-economic systems that function and develop in the context of increasing competition in world markets. One of the most important conditions for the competitiveness of urban socio-economic systems is the stability of urban infrastructure subsystems.

The main characteristic features of modern large cities and urban agglomerations are high-density high-rise buildings, a large amount of transport, the prevalence of built-up territory and territory under artificial surfaces (roads, squares, etc.) over green natural and artificially created spaces (parks, gardens, green zones).

The lack of analysis of industrial production factors and socio-technological sustainability models in urban planning and management concepts leads to disturbances in natural habitats, including a high concentration of sources of negative impact on the environment, an increase in non-recyclable waste and wastewater, and emissions to the atmosphere.

2. Problem Statement

The problem of sustainability of cities as socio-economic systems in the context of analyzing the problems of major urban infrastructures is very relevant in modern conditions. This is due not only to the sharply increased complexity of urban systems but also to the influence of factors of scientific and technological progress.

Such factors can include, in particular, factors of digitalization and intellectualization of management processes of modern socio-economic systems. The relevance of the analysis of urban sustainability problems is also due to the complex nature of technical and economic risks that accompany the functioning of critical urban infrastructures (Martin et al., 2018; Simon, 2018).

The direction of sustainable development has become the main goal of the socio-economic policy of a large number of both developed and developing countries and individual cities (Jooste et al., 2019) and (Camboim et al., 2019).

The problems of interaction between man and the natural environment have always concerned the best minds of mankind. However, it was only in the 21st century that the anthropogenic impact on nature reached such a scale that it allowed us to talk about the coming disaster. This conclusion was made in the work of members of the club of Rome “the Limits to Growth” in 1972. The term “sustainable development” was mentioned only in the report “Our common future” of the UN World Commission on environment and development (Commission Brundtland) in 1987. It was then interpreted as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This is the first time that environmental protection has been recognized internationally as an

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essential element of balanced growth and even human existence. The concept of sustainable development has gone a long way after the report of the World Commission to improve and clarify in the materials of further international forums: “Rio Declaration” (1992), “Agenda 21” (1992), “Millennium Declaration” (2000), “Rio + 20” conference (2012), “2030 agenda for sustainable development” (2015), “SDG Summit” (September 2019, Political declaration of the high-level political forum on sustainable development convened under the auspices of the General Assembly UN).

The “2030 Agenda for sustainable development” identified 17 sustainable development goals covering various aspects. Issues of sustainable development concerning cities are widely discussed in the scientific press. The starting point in this discussion is goal 11 “Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable”. Besides, several goals address issues related to the economy, certain aspects of environmental protection, and the social sphere. The concept of a sustainable city, as well as the concept of sustainable development in general, is based on the interaction of all these factors. In this regard, an urgent scientific task is to study certain factors that are essential for the functioning of critical urban infrastructures.

3. Research Questions

How problematic organizational and technological factors of urban infrastructures affect the sustainable functioning and development of cities. Analysis of their impact on the socio-economic sphere on the example of individual large cities.

4. Purpose of the Study

Propose a study of cities as socio-technological systems and their individual problems that are essential for the sustainable functioning of critical urban infrastructures.

5. Research Methods

In this study, the authors relied on General methods of analyzing system objects, including methods of system retrospective (historical) analysis. The peculiarity of the research methodology is the factor analysis of data in a long-term period of time for some of the large cities and urban agglomerations.

6. Findings

In our view, modern cities can be considered as large and complex socio-technological systems consisting of two subsystems or levels. The first subsystem – material and physical – includes the material urban environment built over a certain period time, including the city's economy, and the physical infrastructure that serves the city. The second subsystem – social – is configured by human activity and social interactions of people in the city during the period of its existence. Both subsystems are in a constant process of change.

We consider the socio-technological system as a complex and dynamic system, which can repeatedly face destructive impacts in the course of its life and development. The stability of such a

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system, as a concept, is associated with the ability to resist any destructive effects and, if not prevent them completely, then reduce the scale of this destructive impact. In this sense, the system's stability should also reflect its ability to recover over a certain period time. At the same time, the city's stability cannot be reduced only to the stability of the material and physical subsystem. The social subsystem plays an equally important role. In particular, the city's sustainability is impossible without the formation of social and environmental responsibility for its development among citizens. In our view, sustainable urban development is a process of economic, social and cultural change in which investment activities, scientific and technological development, political and managerial activities, the use of natural resources, social, educational and cultural development of citizens personalities are coordinated in a complex with each other and are aimed at the present and future satisfaction of the needs and aspirations of city residents. At the same time, the sustainable development of an individual city should not contradict the overall sustainable development on a national and global scale. Ultimately, it is about ensuring the quality of life of current and future generations of people in harmony with the environment. By combining the concept of sustainability with urban development, we link sustainability and the problems of the largest cities and urban agglomerations.

Analysis of scientific literature in recent years (since 2016) shows that most cities' problems are similar (Al-Azzawi, 2019; Angelidou, 2017; Ward et al., 2016). By the previously proposed definition of a city as a complex socio-technological system, in any city, its problems can be divided into two groups:

- technical or technological problems. In our view, the second definition more accurately reflects the essence of the problems. It includes machinery and equipment (machines and mechanisms) and processes involving this machinery and equipment. Technological issues permeate the entire city life. First of all, these are the problems of urban physical infrastructure (energy, transport, housing and communal services, etc.), the solution of which is connected with the development of the city and its stability. Infrastructure problems increase over time. The ageing of infrastructure is most pronounced in cities with a significant history and little population growth. On the other hand, rapidly growing cities in developing countries tend to have the little infrastructure, but growth opportunities;

- social problem. Social problems are also inherent in any city and are a conglomerate of various components (national, racial, cultural, environmental, labour, poverty, leisure, etc.). Social problems are most pronounced in large cities in developing countries. The scale and nature of these problems in different cities and the possibilities for solving them are different. Given the processes of urbanization, globalization and technological change, many cities are simultaneously addressing the challenges of competitiveness and sustainability. And it is not always possible to combine the solution of these problems at the same time. The largest cities with the best resources, finances, and management are ahead in this issue. Due to the limited space in the article, the completeness of the analysis of problems is limited to considering how individual problems prevent cities from becoming sustainable. At the same time, the main focus was on “smart cities” or cities that strive to become “smart”. In the scientific press, the concept of “smart cities”, their real implementation and functioning are widely discussed (Bosch et al., 2017; Cowley & Caprotti, 2019; De Falco, 2019; Noori et al., 2020) and (Mora et al., 2019).

Some authors (Capra, 2016; Fernandez-Anez et al., 2018; Joshi et al., 2016) and (Karvonen et al., 2020) believe that the “smartness” of the city and its stability depend mainly on the advanced

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technologies introduced into the life of cities, including information and communication technologies (ICT). There is no doubt that technology contributes greatly to economic, social, environmental and cultural progress in cities. However, often advanced technologies implemented in “smart” cities are aimed at profitability and efficiency, which is poorly related to sustainable development goals. Such technologies should be commercially profitable for their owners and fair and ethical towards people and the environment. For example, the widespread introduction of automation and robotics is a remarkable achievement that removes a significant number of employees from the technological process. Equipping robots with artificial intelligence, which is much discussed in recent times, will lead to the loss of some “mental professions” and a potentially significant unemployment level. In the 2019 review, The McKinsey Global Institute (MGI) forecasts changes, 2030: “The next wave of automation will affect professions across the country, displacing many functions of office support, catering, transport and logistics, and customer service. More than 38 million jobs occupied by young people (18-34 years old), workers over 50 years old, Hispanics and African-Americans can be automated. The challenge will be to address local inconsistencies and help employees acquire new skills”. The creators and owners of automated and robotic enterprises will be in a better economic position than those they left out of work. At the same time, robotization can have a strong impact on developing countries, where similar enterprises may close down as unnecessary, with the complete loss of many jobs and negative consequences for the state's economy. In other words, this has a direct negative impact on goal 8 of sustainable development (Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all).

Any innovation has its pros and cons. Thus, the positive aspects can be attributed to the competitive advantages that arise from a company or enterprise that implements an innovative solution. A positive factor is the accelerated growth of the economy and improving the quality of life of people. On the other hand, there are risk factors and uncertainties in both the economic and social spheres (negative impact on the environment, increased unemployment).

In our view, sustainable development in terms of the impact of innovative technological solutions on socio-technological systems should include:

- the assumption of the potential danger of innovation from three points of view (economic, social and environmental);

- a comprehensive review of innovations from a scientific point of view to identify the consequences (analysis and identification of real advantages over imaginary, momentary, even economic).

One of the most important and complex problems in solving the material and physical subsystem of cities is the transport problem.

The transport component of the city's infrastructure serves not only to connect individual districts of the city but also largely determines the quality of the socio-economic and technological structure of the city. The development of the transport system aimed at improving the efficiency of urban communications, in turn, contributes to solving the problems of demography and employment. Many complex problems of urban farms are often associated with transport problems. It can be argued that the prospects for the development of the city are determined by the effectiveness of the implementation of

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strategies for the development of its transport structures. In some cases, transport problems are large "historically inherited" and formed by the "previous" history of building and development of the city. The inability to expand roads and build crossings may be caused by outdated or erroneous decisions in the field of urban planning.

Traditionally, the urban transport system can include bus, cars and trucks, trolleybus, tram, metro, river tram, city train, cable car. Usually, cities have a heterogeneous structure of vehicles. In a number of cities, either car-bus service or electric transport dominates.

Despite the fact that any type of transport requires speed, comfort, safety, and environmental friendliness, these requirements are not always feasible for various reasons.

The problems of urban transport can be studied in various aspects. Such problems may include, for example, technical, economic, psychological, and organizational problems.

The problems of the transport system can be attributed to congestion, traffic jams, poor public transport (insufficient number, wear, discomfort, lack of priority for its movement), lack of crossings for pedestrians, problems of alternative transport (bicycles, scooters, electric cars, etc.). Personal cars, even electric cars, along with the infrastructure that serves them (garages, Parking lots, repair shops, etc.) occupy a much larger space in the city than public transport and especially bicycles.

It should be noted that transport problems are often complex and interrelated. However, according to the authors of the article, one of the most important problems associated with the operation of bus and road transport is the problem associated with harmful exhaust gases.

Vehicle emissions of pollutants, such as particulate matter and nitrogen dioxide (NO_2), CO and methane (CH_4), have a negative impact on the inhabitants of the urban ecosystem, causing irreparable damage to their health. Microparticles released into the air have a negative effect on blood vessels and not only increase the risk of blood clots and heart attacks but also negatively affect a person's cognitive abilities.

Air pollution from diesel and gasoline vapours negatively affects the cardiovascular and respiratory systems, causing real damage to the health of urban populations.

It is fair to assume that the health of the population is one of the most important factors in the growth of national welfare, and the adverse environmental situation in cities, largely due to the functioning of road transport, negatively affects the socio-economic indicators of the entire country. The ecology of the habitat also affects the demographic situation.

Indicators of mortality, birth rate, and migration of the working-age population are related to the level of environmental well-being and determine the levels of socio-economic stability and competitiveness of cities.

Many cities around the world are making efforts to solve environmental problems related to transport. To reduce air emissions, a number of countries, including the United Kingdom, Germany, France, and Australia, are implementing projects to convert urban passenger and freight transport to electric traction. However, it should be recognized that despite the development of tram networks, the gradual transfer of public transport to electric buses and an increase in the number of personal electric transport, the creation of a favourable and friendly urban environmental environment is a rather distant prospect.

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However, despite the fact that emissions from road transport in London have fallen less than expected, there has been a steady positive trend in the transport sector over the past two to three decades, according to reports.

Thus, in the transport sector of the EU Member States over the past 30 years, emissions of nitrogen oxides have significantly decreased by 40%, sulfur oxides by 66%, carbon monoxide and non-methane volatile organic compounds by about 87%. Particulate matter emissions were also reduced by about 40 %.

However, despite the positive trends with road and other modes of transport, aviation and shipping have seen an increase in emissions of nitrogen oxides and other harmful air pollutants.

A separate problem for urban transport is ensuring its adaptability to climate change, other negative natural and man-made impacts, and manifestations of terrorism. Unfortunately, in most cities, this issue is not yet given the necessary attention.

Water supply and Sewerage systems are among the segments of the physical infrastructure of cities that play an important role in human life and have a significant impact on the environment.

According to Goal 6. “Ensure availability and sustainable management of water and sanitation for all”. Over the past few decades, the international community has made some progress in providing drinking water and adequate sanitation. Hundreds of millions of people in cities still do not have access to clean drinking water and do not have adequate sanitation facilities.

At the present stage, urbanization has significantly increased water consumption for the household needs of the urban population. Anthropogenic influence has changed the composition of water in natural sources and its quality. The level of pollution of natural waters by sewage has increased significantly, primarily in developing countries. Consumer attitudes to drinking water sources over the decades have led to their catastrophic depletion. Protection of surface and underground water from pollution and wastewater treatment are the main concern for preserving the quality of drinking water and the entire water ecosystem of cities.

Developing models of even individual parts of the socio-technological structure of modern cities is a very difficult task. The modelling process should take into account various aspects of the functioning and development of the urban economy, which are affected by a large number of factors. Models should reflect not only the characteristics of individual elements and links of infrastructure subsystems but also the complex relationships between these links. When describing such relationships, it is necessary to reflect not only the statics but also the dynamics of financial, information and transport flows. For example, the sustainable functioning and development of systems that provide the city with water resources require the development of various types of models. These models can include dynamic models for planning water balances; models that take into account the influence of climate factors (including temperature instability); models that take into account the development of the social and industrial sphere of cities. As an example, the authors offer a conceptual model of the impact of climate and some other external factors on the city's water ecosystem (figure 1). Such a conceptual model can be expanded and supplemented by taking into account a number of external factors in a particular territory. For example, it is expected that global climate changes will lead to further melting of ice and expand opportunities for the

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development of navigation in the Northern sea route zone. In this regard, localities that provide infrastructure links to navigation will be developed.

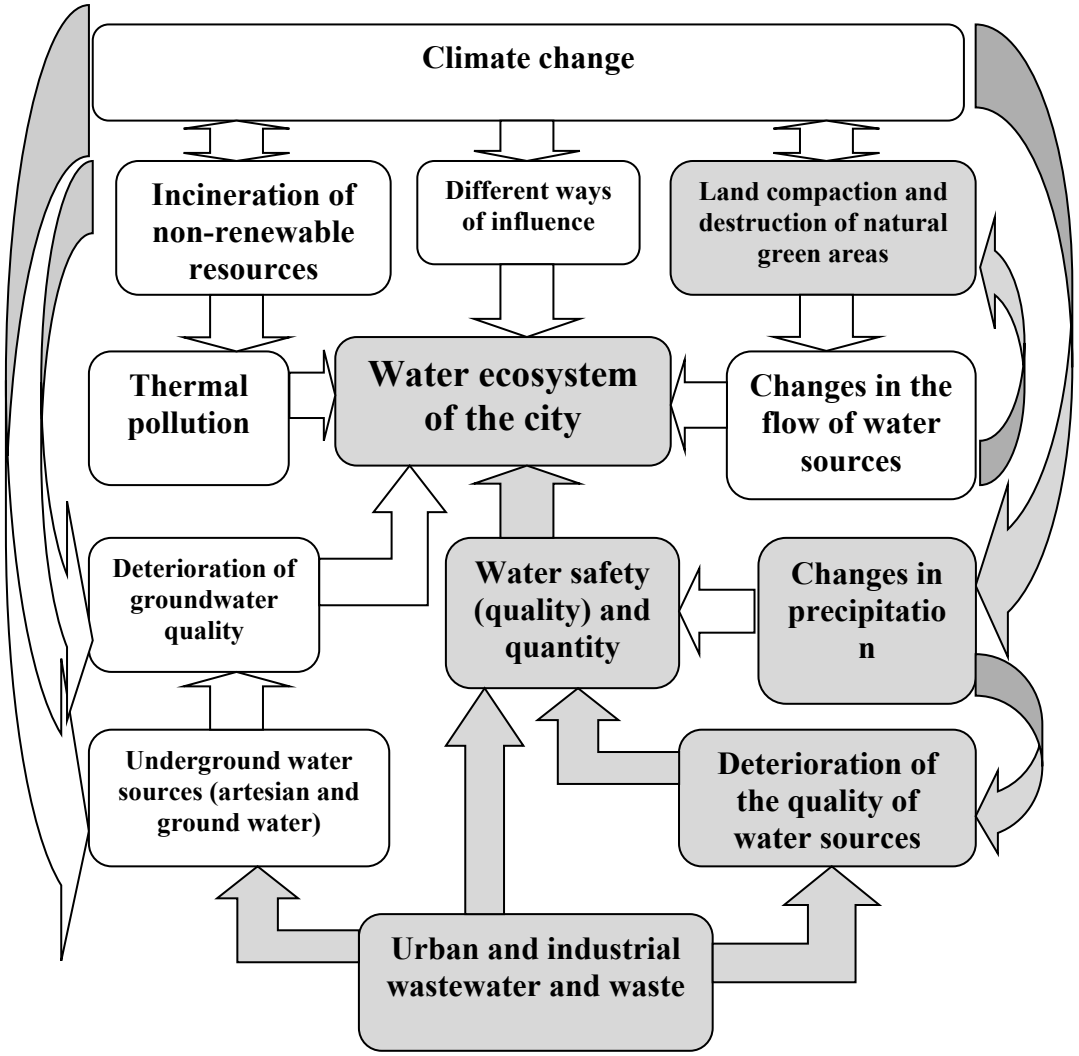

Figure 1. Model of the impact of external factors on the city's water ecosystem

In many cities, there is a decrease in the flow rate of water sources that were previously used. In this case, cities are forced to search for surface water sources at large distances from their borders, which leads to disruption of water ecosystems in these areas. Water delivery distances are tens of kilometres, which leads to significant financial and material costs and increases the cost of water. Sources of cleaner underground water often do not have the necessary supplies or are also located far from cities.

In a number of industries, water is still used once and after treatment, not always of high quality, is discharged into water sources. Thus, the possibility of its reuse is lost. The negative impact of untreated or insufficiently treated wastewater affects three aspects:

- negative impact on the environment;
- negative impact on people's health;
- negative consequences for the economy.

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A linear economic model based on the principle of “take, use, dump” should no longer be used with limited resources of clean water. We need to make greater use of recycling water supply systems at enterprises and introduce reuse of treated domestic waste water. This refers to the direction of the circular economy developed in individual countries. In this case, the goal is not only economic benefit, but also to reduce the impact on water bodies and restore natural resources. There should be options for processing and recycling waste water to extract valuable components or produce new products.

Sustainable water supply systems must, in accordance with the reliability category assigned to them, provide household and drinking water to the city's population and employees, provide water to enterprises for production, provide water for firefighting and, if necessary, for other needs (watering streets and green spaces, etc.). The reliability category must answer the questions: for what period of time is a break in the water supply system allowed; by what percentage is the water supply allowed to decrease to consumers and for how long. At the same time, the water supply system must provide water of the required quality, in the amount necessary for consumers and with the required pressure.

The water supply system must perform its functions within the limits defined by reliability, when external influences are exerted on it, except for the occurrence of emergency situations (earthquakes, terrorist acts, etc.). A stable system is characterized by the ability to return to its original state after the impact on it ceases. For a water supply system, the stability conditions may differ from those for other technical systems. The stability of water supply systems is relative. For example, is it possible to call a stable system in which the pressure decreases for a short period and water quality deteriorates, which leads to consumer dissatisfaction, but falls within the parameters of reliability? In this sense, local interference in the operation of the water supply system, such as repairing or replacing a section of the network, or improving technology of water treatment, is a violation of local stability. However, on the other hand, this is a development that will entail a new state of stability and reliability in the operation of the water supply system.

In 2020, the Covid-19 problem was added to the main urban problems, which took over the entire world. All previous global pandemics have affected cities in one way or another. First of all, medical systems were changing. Besides, infrastructure has changed, such as water supply and sanitation systems. Given the experience of the current epidemic, cities must become adaptable to various negative situations. Of course, first of all, this should concern the healthcare system, transport, trade and services. This also applies to other aspects of social life in such situations. Thus, urban improvement programs should include the creation of conditions for maintaining a social distance for pedestrians, as well as in public transport. It will be necessary to introduce new standards for the design of public spaces, taking into account security measures. For older people, provide for the organization of walks, so that they suffer less from restrictions on motor activity. New innovative solutions should be considered that will allow faster adaptation of the entire economic and social life of cities to the possible occurrence of similar situations, for example, the second wave of Covid-19. At the same time, city administrations need to involve more urban communities to find and discuss such solutions and take into account the opinion of residents. This will allow, based on their common opinion, to reduce the level of negative social manifestations (protests). In cities where a significant proportion of migrants, refugees and internally displaced persons

live, it is necessary to provide measures in advance to support them in such situations, including information support.

The experience of the pandemic has shown that new technologies, including digitalization, should play a special role in such situations. Despite the many negative aspects already mentioned above, the use of ICTs in such an environment is only increasing. For example, contactless payment technologies, contactless charging of gadgets, thermal imagers for temperature control, geolocation systems, online education, e-commerce.

But their effective use will require the implementation of certain measures:

- the wide reach of the Internet;
- the readiness of the population and all areas of the city to use ICT (training, computers, etc.);
- ensuring security when using digital technologies.

7. Conclusion

Analysis of the main problems of most cities allows us to assess their lack of development from an environmental point of view.

The development of many “smart cities” is based on a technological orientation, which is in contradiction with the environmental and social goals of sustainable development.

Approaches to the development of critical urban infrastructures based on innovative technologies should not lead to disturbances in urban ecosystems and the loss of their stability.

The most effective way to solve the problems of most cities is through integrated functional planning, which should ensure that the goals of sustainable development are taken into account as much as possible.

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