MUNICIPAL INFRASTRUCTURE MANAGEMENT USING SMART CITY TECHNOLOGIES

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Abstract
The study investigates the issue of managing the municipal infrastructure of cities by means of Smart City technologies on the example of the Russian Federation and proposes an adaptive approach to introduce the smart city policy in the country. The chosen topic is deemed relevant since yet no universal models for the implementation of SC ideas in Russia exist. The study presents the authors' vision of the SC strategies closely related to the concept of sustainable development. Besides, the paper provides the SWOT analysis of the developed vision and reviews approaches for determining the level of readiness of Russian cities for the implementation of smart services. By means of the survey method, the study uncovered the main directions and residents' preferences for the introduction of SC technologies in the cities of the Russian Federation. Apart from that, step-by-step recommendations for municipalities seeking to introduce smart initiatives were developed.
Keywords: municipal governance; municipal infrastructure; public administration; public utilities; smart city; sustainability.

1. INTRODUCTION

In this day and age, modern cities are widely regarded as drivers of economic growth. They remain significant for regional and national economies as they cover a considerable part of national economic

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activity, governance, trade, and transportation. The need for Smart Cities (SCs) has arisen in response to urbanization, the spread of environmental awareness, and rapid technological and innovative developments. These factors have necessitated a rethinking of urban management procedures and provoked the development of approaches to perform them successfully.

The SC concept is often referred to as a roadmap for the development of a city in the context of growing importance and prevalence of information and communication technologies (ICT); population mobility; increasing volumes of information; globalization; rising residents' requirements to living standards and to the level of transparency of city services, including city greening. In the context of municipal infrastructure management, the SC concept provides for the integrated use of ICT as well as engineering and transport technologies to improve the quality, efficiency, and intellectualization of city services' functioning and foster peer-to-peer dialogue between residents and authorities. It is strategically envisaged to increase the rating of universities and scientific institutions; attract and manage investments in research and development; develop high-tech start-ups; and introduce advanced technologies in public and private sectors of the economy to improve the comfort of life, services, and business activity (OECD, 2020).

The modern SC concept adheres to the following principles (Eremia et al., 2017):

- Improvement of residents' quality of life;
- Modernization and development of the technological infrastructure of the city;
- Use of technological solutions for effective city management;
- Compliance with standards of environmental friendliness, sustainable economic development, and social inclusion;
- Active residents' participation and engagement in city life.

The introduction of the SC initiatives makes it possible to ensure effective functioning of modern big cities (hereinafter this term will be used as a neutral notion without reference to the actual city size). Such a smart policy allows permanent remote participation of residents in city management through various e-government models (G2G, G2C, G2B). It promotes the introduction of automated control systems for managing parking, traffic, municipal services, a system for collecting fines, ordering tickets, and video surveillance (Matsumoto et al., 2019).

Today, considerable experience has been accumulated in the implementation of the SC concept by Amsterdam, Barcelona, Stockholm, Tel Aviv, Southampton, Dubai, Singapore (OECD, 2020). Thus, there is an increasing scientific interest in generalizing the gained experience with the aim of quick construction of effective intelligent systems of municipal governance worldwide. Exactly this systematization will be

presented in the present research on the example of Russian cities, whose market conditions are characterized by the absence of a unified model for the SC concept introduction.

2. LITERATURE REVIEW

Today, the SC concept is constantly improving and deepening. The European Commission describes a smart city as a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business (European Commission, 2018a). According to the Organization for Economic Co-operation and Development (OECD) (2020), smart cities are "initiatives or approaches that effectively leverage digitalization to boost residents' well-being and deliver more efficient, sustainable and inclusive urban services and environments as part of a collaborative, multi-stakeholder process" (OECD, 2020). At the same time, there are a significant number of different interpretations of this concept, common to which is the vision of a smart city as a component of the sustainability idea (OECD, 2020).

Cooperation of international organizations (International Organization for Standardization, International Electrotechnical Commission, International Telecommunication Union, Comité Européen de Normalization Électrotechnique, European Telecommunications Standards Institute, National Standards Body, and Standards Developing Organizations) made it possible to develop the following standards:

- ISO 37120:2014 —Sustainable development of communities – Indicators for city services and quality of life;
- ISO/TS 37151:2015 — Smart community infrastructures – Principles and requirements for performance metrics;
- UNE 178301:2015 — Smart Cities. Open Data;
- ISO/DIS 37101 — Sustainable development of communities – Management systems – Requirements with guidance for resilience and smartness;
- ISO/DTR 37121 — Inventory and review of existing indicators on sustainable development and resilience in cities;
- ISO/NP 37122 — Sustainable development in communities – Indicators for Smart Cities;
- ISO/WD 37120 Sustainable development of communities – Indicators for city services and quality of life;
- PNE 178106 — Smart Cities. Infrastructures. Universal accessibility;

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- PNE 178306 — Accessible mobility in Smart Cities;
- PNE 178501 — Management system of smart tourist destinations. Requirements (European Commission, 2015).

ISO standards are the most comprehensive among those related to SCs (Criteria of British Standards Institution, Smart Cities Mission, International Telecommunication Union, or United Nations Economic Commission for Europe), as they cover economy, people, governance, mobility, living, environment, water management, energy management, healthcare management, education, security, and building systems.

These standards form a basis for the implementation of the SC concept all around the world. In particular, in India, it is introduced through the use of Smart Grid Technology, cloud computing, web connections, alternative energy sources as well as rational use of biological resources, intellectualization of transport systems, smart health protection, water and gas distribution systems, waste logistics management, and smart video surveillance. In Singapore, the SC system provides for the availability of broadband nationwide access and infrastructure for collecting data on problem areas, transport interchanges, parking zones and transmission of this information to specialized analytical centers. Barcelona within the SC framework has built energy self-sufficient urban spaces, as well as introduced open data portals and a sensor system that guides drivers and bicycle riders to open parking spots.

Apart from this, the city carries out the coordination of volunteer projects and takes care of responsible waste management. SC policy of Santa Cruz, California, focuses mainly on ensuring public order (crime prevention by means of statistical data analysis and forecasting software), privacy, and autonomy. Launched in 2009 by the local government, the wide-known Amsterdam SC initiative currently includes 79 projects collaboratively developed by locals, government, and businesses. These are smart lighting, which allows controlling the brightness of street lights; smart traffic management, where traffic is monitored in real time via wireless peripheral devices and sensors and information about current travel time on certain roads is broadcasted to allow motorists to determine the best routes to take; energy monitoring system; smart parking; and smart public security system. As can be seen from the above, the SC concept provides for the city's sustainable economic development and a high level of residents' quality of life, primarily in such key areas as economy, environment, social activities, and governance. Benefits in these areas are provided through innovative and computer technologies, as well as resource optimization (Vienna University of Technology 2015).

The literature review shows that most researchers (Stratigea, 2012; Joss et al., 2019; Matsumoto et al., 2019; Brown et al., 2020; Karvonen et al., 2020; Timeus et al., 2020) focus their attention on innovative and computer technologies and the use of available resources to expand access to vital services with

minimal involvement of new resources. The idea of smartness in city development is achieved through the use of Big Data, Open Data, the Internet of Things (IoT), the 5th generation networks (5G), Wi-Fi, video surveillance, unified monitoring services, situational centers, and other elements of the knowledge-based economy (Joss et al. 2019). The OECD has summarized the main approaches to the classification of SCs (OECD 2020):

- By stage of urban growth (new cities, existing cities, and shrinking cities);
- By spatial cluster (smart economy, smart environment, smart governance, smart living, smart mobility, smart people) (Vienna University of Technology 2015);
- By type of smart urban innovation (technological innovation, with new practices and services; organizational innovation, which happens internally in public organizations; collaborative innovation, which combines efforts and resources based on the triple helix model (creating synergies among governments, universities and companies); and experimental innovation, through a resident-centric approach);
- By goal (SCs equipped with advanced infrastructure; platform-centered SCs; SCs for innovation space);
- By level of economic growth ("Developed economy + legacy city"; "Emerging economy + legacy city"; "Emerging economy + new city"; "Developed economy + new city").

The latter classification approach implies the implementation of specific SC management (Macomber, 2016). Thus, for the types "Developed economy + legacy city" and "Emerging economy + legacy city," SC technologies will need to deploy across existing physical infrastructure, such as roads and buildings, or embedded service businesses. Cities of the "Emerging economy + new city" type are characterized by high population growth; therefore, it is proposed for them to develop social infrastructure (parking, transport, local e-government). Cities in the category "Developed economy + new city" are mostly satellite ones located around existing metropolises, so that they need to focus on physical (buildings, roads, bridges) and social infrastructure. These strategies are applicable, for the most part, in the cities of Eastern and Central Europe (Kola-Bezka et al., 2016), and use the management model developed by the Vienna University of Technology (Vienna University of Technology 2015). This model provides a high level of standardization and determines the level of smartness based on the aggregation of six key characteristics of urban development: smart economy, smart mobility, smart environment, smart people, smart living, and smart government. Each of these characteristics is defined by a number of factors (90 in total), the value of which is converted into standardized units (from 0 to 1), thereby giving one the

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possibility to take into account the indicators' heterogeneity (Vienna University of Technology 2015). Nowadays, it is applied to cities of two categories:

1. Medium cities with 100 000 to 500 000 people and at least one university;
2. Large cities with 300 000 to 1 million people.

Nevertheless, this model leaves small towns and metropolitan cities unattended and, what is especially important, operates only with standardized indicators. Therefore, it cannot be applied to countries like Russia. The Russian Federation has developed its own standards concerning management, business, utilities, and the main SC indicators within the framework of the National Program "Digital Economy" (Kamolov & Kandalintseva, 2020; Ministry of Digital Development, Communications and Mass Media of the Russian Federation, 2020). The program's main directions are transport (automatic registration of traffic violations, vehicle weight and dimensions control, analysis of parking space availability, automated traffic control systems); security (video surveillance, threat monitoring, coordination, and interaction systems); healthcare; utilities; environment and e-government services. The implementation of projects within the framework of this program is carried out only in several big cities, led by Moscow, Kazan, and Skolkovo.

Despite a considerable amount of studies investigating models for smart technologies' implementation, several research gaps in this field exist:

- Most researchers concentrate on the technological aspects of the SC idea (the use of certain technologies), failing to conduct a thorough investigation of its social aspects (the attitude of urban residents to the concept implementation);
- Lack of a unified understanding of an SC, which results in a complicated investigation of the advantages and disadvantages of this concept (for example, by means of SWOT analysis);
- Insufficient attention to studies characterizing the experience of SCs in individual countries, and therefore little developed recommendations for future implementation of smart initiatives.

Problem statement

Today, considerable experience has already been accumulated in the implementation of SC technologies (mainly by the United States and the European Union countries, which is another evidence of the importance of ICT in the modern world) (Vidiasova et al., 2019). At the same time, the idea of an SC has only recently begun to be implemented in the Russian Federation in the form of local projects (Council for strategic development and priority projects of the Russian Federation, 2017). The standards developed in Russia lack a unified understanding of the SC concept. This may be explained by its novelty, absence

of a comprehensive plan for its implementation, and the fact that the developed standards predominantly concentrate on city management and prioritize preferences of not residents but authorities (Makarenko & Loginovskaya, 2019). Consideration of people's interests is the first and the most crucial stage of the SC concept implementation (Drozhzhinov et al., 2017). Even though understanding of this concept by residents of Russian cities has been discussed in several studies (Vidiasova et al., 2019), the regional features and managerial models for its realization are poorly disclosed.

The focus on the formation and implementation of SC policy in the Russian Federation stems from the fact that Russia has several million-plus cities located all across the country, whose residents, due to different mentality, may have a unique vision of this concept, its priorities, and ways for realization. Correspondingly, the aim of the study is to describe typical models for the implementation of the SC policy in big cities on the example of the Russian Federation. This objective can be achieved only after addressing the following tasks:

- Define how the residents of different Russia's big cities understand the SC concept and the methods for its realization;
- Determine the features of practical implementation of the SC policy, in particular, the inconsistencies between the declared and actual principles and ideas;
- Develop strategies for SC technologies' introduction in big cities of Russia.

3. MATERIALS AND METHODS

In order to accomplish the tasks assigned, the research process was divided into several stages. During the first stage, based on the studies conducted by representatives of various scholarly traditions (UNECE, 2015; Vienna University of Technology, 2015; Kola-Bezka et al., 2016; Meijer & Bolívar, 2016; EIP-SCC, 2018; Breslow, 2020; Karvonen et al., 2020), the key parameters characterizing the SC concept were analyzed. The obtained data became the foundation for the development of the authors' vision of the SC concept, relevant to the current state of the development of society and ICT in Russia. The second stage was devoted to a SWOT analysis of the vision formulated.

The third stage covered an examination of the readiness of Russian cities with a million-plus population to implement the SC technologies. The materials used at this stage were represented by data retrieved from the Federal State Statistics Service for 2019 and open data from the World Council on City Data (WCCD), based on the ISO 37120:2014 standard. Also, at this stage, the main smart cities of the world widely recognized as leading the way were identified and grouped into five clusters according to the k-means clustering algorithm, and the corresponding indicator values for each cluster were determined.

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Cluster analysis is one of the data mining methods and is designed to divide objects under study into homogeneous groups (clusters).

A distinctive feature of the k-means clustering method is that it is a distance-based algorithm. Its clusters are located at the greatest distances from each other. However, the authors believe that the disadvantage of this approach is the failure to assess each factor's influence. A similar analysis was performed for Russian super cities (with a population of over 3 million people), major cities (with a population of from 1 to 3 million people), large cities (with a population of from 250,000 to 1 million people), and large towns (with a population of from 100,000 to 250,000 people). This differentiation was based on the subdivision of the urban and the rural settlements by type provided by the Town-Planning Code of the Russian Federation.

In the fourth stage of the study, the peculiarities of smart solutions' practical application were determined. In particular, the gap between the declared principles and ideas and the actual specifics of the SC concept implementation in Russia was examined. Besides, in this research stage, an online survey of the Russian population was carried out to determine what exactly the residents of big cities understand by the SC concept, reveal its fundamental components, and unveil how people use the available SC benefits. The respondents' selection was performed by sending invitations via social networks (Facebook, VK) only to those who indicated one of Russia's big cities as a place of residence in their profiles. Despite its relative convenience, this approach imposes limitations on this study as there is a possibility that the real place of living does not coincide with the declared one. The survey was anonymous and voluntary. It was conducted in February 2020 among 197 people. The absolute majority of respondents was the population aged 18 to 40 (92%).

However, these data were also taken from the participants' profiles and may not coincide with real ones. What is notable, among all the invitations sent, the prevailing part of positive answers to participate was received from women (58%). Of those involved, 54% lived in Novosibirsk, Yekaterinburg, Kazan, Omsk, Rostov-on-Don, Ufa; 25% in the cities of St. Petersburg and Moscow; and the rest – in Krasnoyarsk, Voronezh, and Perm. Within the framework of the survey, each respondent could choose five priority options that, in his/her opinion, were most suitable for defining the SC concept. The proposed options included both specific smart technologies (for example, smart parking or smart lighting) and fundamental, broader categories of this concept (IT infrastructure, big data analytics). The survey itself was conducted through the use of Google Forms. During the examination process, the following data quality control was envisaged:

- Personal data obtained in the survey were compared with that in respondents' social profiles;

- Data were taken for a certain time period (further changes in social profiles were not investigated);
- Multiple registrations were identified;
- Data uniqueness was controlled.

The sampling error did not exceed 5%.

In the last stage, based on the information obtained, recommendations and specialized management models for the practical implementation of the SC technologies were developed.

4. RESULTS

Analysis of previous studies on this topic showed the wide use of the following categories of keywords that characterize the modern concept of SC (from more to less frequently used): ICT/Communication/Intelligence/Information, Infrastructure, Environment/Sustainability, People/Citizens/Society, Quality of life/Lifestyle, Governance/Management/Administration, Economy/Resources, and Mobility. Since the modern SC concept provides for development within the framework of sustainability, the following guidelines were taken into account when creating the authors' vision of the concept:

- Consideration of the main trends and promising development directions presented in the scientific literature;
- Consideration of the cultural, historical, socio-political, economic characteristics and traditions of a particular city territory;
- Emphasis on the principle of sustainable development to ensure a balance in solving economic, social, and environmental challenges through broad public participation in the development, discussion, and implementation of SC strategies (this provides for the effective interaction of government, business, public organizations, and scientific environment).

As it was already noted, the authors' vision of the modern concept of SC was based on the first stage results, according to which SC is an innovative system that uses open-source data, ICT, and other means to improve quality of life, efficiency and competitiveness of urban operation and services, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects. The proposed authors' vision made it possible to perform its SWOT analysis as part of the sustainability concept, which differs from the one carried out by OECD (2020). Their comparison is presented in Table 1.

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TABLE 1 - SMART CITY CONCEPT SWOT ANALYSIS: COMPARISON OF THE AUTHORS' AND OECD'S VISIONS (OECD 2020)

Authors' vision	OECD's vision
Strengths	
Availability of IT developments and possibility of their implementation; high level of digital literacy; improvement of mutual interaction between the government, business, and society; optimization of working time and processes; removing barriers while entering the digital market; availability of basic physical infrastructure; availability of financial capabilities to implement the concept; reallocation and optimization of resources.	Widespread digitalization; access to high-speed broadband; transformation of the ways policymakers engage with society; possibility to work remotely; reduction in public services' operating cost due to digitalization; resource-saving; attraction of skilled workers to the local labor market.
Weaknesses	
Lack of clear understanding of the SC concept and priorities in its implementation technology among city residents; absence of a strategy for introducing the smart tecnologies into urban management; high cost of particular projects' implementation and its long duration; lack of knowledge and qualifications for the development of new technologies and innovative solutions' application; lack of infrastructure and a unified approach to SC implementation at the state and local levels.	Weak capacity to use data in municipal policy-making; inconsistency in the actions of personnel or their insufficient qualification for managing and processing data; lack of regulatory frameworks favoring innovation and experimentation; risk of territorial divides related to the principle of access to innovation.
Opportunities	
Rapid development of start-up projects and entrepreneurship; implementation of projects within the sharing and circular economy business models; creation of new high-tech jobs; increase in budgetary allocations; improvement in living standards of the population; development and promotion of a people-centered management approach; integration of regions in the context of sharing and circular economies.	SC integration into regional and national structures; improvement in service provision and the living standards of the population; introduction of early warning systems for various natural hazards; city budget development with regard to its residents' opinions; dissemination of sharing and circular economy practices.
Threats	
Rise of cybercrime; increased demands to the government; fragmentation of the national digital model by establishing individual data centers, identification systems, or city strategies; process automation instead of smart initiatives' implementation; insufficient information security and possible threats to personal data protection.	Personal data disclosure; population inequality in terms of digital literacy; increase in the marginalization of individuals having no internet access; vesting interests of large companies at the expense of smaller firms; threatened consumer protection, taxation, labor contracts and competition; need for the companies to adapt to a new environment quickly.

The SWOT analysis proved that ensuring the sustainable development of a big city within the SC framework is a multilateral process. On the one hand, the sustainability of a big city directly depends on the sustainability of socio-economic systems of a higher level (region, state). On the other, the overall city's sustainability directly depends on all constituent elements of the city's socio-economic system (business entities, non-governmental institutions, numerous public or private organizations and associations).

With the aim of investigating whether Russian cities are ready to become smart, the study used indicators of ISO 37120:2014 standard (Sustainable development of communities — Indicators for city services and

quality of life), in particular, those of the "Economy" category. To make the outcomes more reliable, other big cities of the world where the SC concept was introduced were also analyzed (data were retrieved from the WCCD). They were divided into five clusters according to the following indicators: a city's unemployment rate; the assessed value of commercial and industrial properties as a percentage of total assessed value of all properties; the percentage of city population living in poverty; the percentage of persons in full-time employment; youth unemployment rate; the number of businesses per 100,000 population; and the number of new patents per 100,000 population per year. The values of indicators were calculated using the k-means clustering algorithm. Corresponding data are presented in Table 2.

TABLE 2 - CLUSTER ANALYSIS DATA FOR SMART CITIES OF THE WORLD (BASED ON DATA RETRIEVED FROM THE WCCD)

Cluster	Cities-representatives	Share in total	Indicators (mean of standardized values)						
			City' s unemployment rate	Assessed value of commercial and industrial properties as a percentage of total assessed value of all properties	Percentage of city population living in poverty	Percentage of persons in full-time employment	Youth unemployment rate	Number of businesses per 100,000 population	Number of new patents per 100,000 population per year
1	Amsterdam, London, Vaughan, Shawinigan, Riyadh, Saint-Augustin-de-Desmaures, San Diego, Cambridge, Eindhoven, Brisbane, Oakville, Sintra, Zwolle, Zwolle, The Hague, Tainan City.	45%	0.7	0.22	0.8	0.2	0.77	0.39	0.21
2	Los Angeles, Zagreb, Doral, Kielce	12%	0.65	0.6	0.8	0.3	0.75	0.72	0.15
3	Buenos Aires, Makkah, Boston, Toronto, Leon, Surrey, Koprivnica, Torreon	24%	0.68	0.3	0.42	0.31	0.74	0.71	0.11
4	Melbourne, Dubai, Makati	8.5%	0.87	0.82	0.7	0.7	0.51	0.41	0.11
5	Barcelona, Valencia, Porto	8.5%	0.16	0.2	0.58	0.3	0.22	0.78	0.12

Cluster analysis for Russian cities was also carried out, though it was based on data from the Federal State Statistics Service for 2019. Big cities of the Russian Federation were divided into three clusters according to the subdivision of urban and rural settlements provided by the Town-Planning Code of the Russian Federation (super and major cities, large cities, and large towns; data on medium and small

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towns were not considered). The analysis was performed according to the same indicators as the world cities (Table 3).

TABLE 3 - CLUSTER ANALYSIS DATA FOR SMART CITIES OF RUSSIA (BASED ON DATA RETRIEVED FROM THE FEDERAL STATE STATISTICS SERVICE)

Cluster	Cities-representatives	Share in total	Indicators (mean of standardized values)						
			City' s unemployment rate	Assessed value of commercial and industrial properties as a percentage of total assessed value of all properties	Percentage of city population living in poverty	Percentage of persons in full-time employment	Youth unemployment rate	Number of businesses per 100,000 population	Number of new patents per 100,000 population per year
1	Super and major cities (population more than 1 million)	10%	0.1	0.8	0.1	0.8	0.2	0.7	0.51
2	Large cities (population 250,000 – 1 million)	47%	0.21	0.5	0.15	0.5	0.2	0.4	0.2
3	Large towns (population 100,000 – 250,000)	23%	0.28	0.2	0.19	0.3	0.2	0.1	0.05

Given the obtained analysis results for Russia (Table 3), one can note that clusters are predominantly formed in terms of the number of residents. In other words, an increase in the urban population is associated with a decrease in the unemployment rate and an increase in property value, the number of businesses, and the number of new patents per 100 000 population per year. Thus, the standardized indicators of the ISO 37120:2014 standard are not relevant to the Russian Federation since they do not correspond to the country's market conditions and thus do not allow the measurement of its cities' readiness to introduce smart technologies. While considering the assessment methods based on indicators of the use of ICT and the internet (telecommunication networks, their basic infrastructure (wired and wireless broadband, IT technologies)), the authors noted that the presence of this infrastructure characterizes all the super and major cities of the country.

What is more, according to the Ministry of Digital Development, Communications and Mass Media of the Russian Federation, residents of super, major, and large cities, as well as those living in large towns, are characterized by a high level of digital literacy and regular use of digital technologies. As indicated in the passport of the Federal project "Personnel for the digital economy," the share of individuals with excellent digital literacy skills comprises more than 27%. Therefore, the analysis of Russian cities under these indicators will also be uninformative. The analysis revealed that the main barrier to the implementation of

the SC policy in the Russian Federation is the absence of proper infrastructure and non-compliance of existing infrastructure with world quality standards. Access to infrastructure depends on climatic conditions, remoteness from big cities, while access to information is closely connected to households' well-being in emerging markets. For the purpose of determining what exactly residents of Russia's big cities understand by the SC concept, an online survey of the Russian population was carried out. Thus, the most popular among the proposed answers were smart waste management (14.49%) and energy efficiency (13.04%). Next in the response rating were IT infrastructure, smart lighting, and smart resource management with almost the same results (about 10% each).

As for the use of the SC services implemented in Russia, 23% of respondents indicated that they have already taken advantage of information systems with real-time arrival schedules at bus stops. Not less popular were e-government (e-petitions) and e-transport services (e-tickets). At the same time, only 1% of surveyed declared to use the "safe city service" (video surveillance), and less than a third benefit from SC mobile applications (mostly those related to public transport). The question concerning the availability of actions toward SC implementation in the region over the past three years received positive answers from less than a third of the people surveyed. For the most part, respondents named the possibility of receiving administrative services and making an appointment with a doctor in an online mode, digital bus stops, and smart lighting. About 44% of the surveyed individuals (mostly car owners) associated the SC concept with smart parking but stated that they notice no positive changes in this area.

Big-city residents are likely to see the SC in those narrow categories that are on the present-day agenda. In contrast, the basic technologies that really can make the city smart are not regarded as important. The survey outcomes suggest that, basically, the population associates SC with specific services that can be used today and now — other manifestations of SC in the region are rarely noticed. To a large extent, the concept of SC exists only in discussions and requires a structured approach and active implementation. Therefore, it should be noted that the development of a new city under the current circumstances remains a great challenge since the management structure is yet not smart enough, and the implementation of individual smart elements has rather a project-based nature nor a holistic one. The analysis of big cities' development strategies made it possible to highlight the following negative trends in the implementation of SC initiatives:

- Unclear strategic framework of projects;
- Ignorance of residents' opinions when determining the priority of SC projects' implementation;
- Planning is focused on activities instead of great ambitious objectives and results;
- Absence of quantitative indicators of project performance;

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- Focus on the minimum project cost;
- Additional work on projects continues even though they are already implemented.

These downsides are amplified by the following typical challenges that arise during the development of SC projects and programs:

- Problems are described in general terms and are reasoned insufficiently;
- Target group of users is poorly described;
- No data concerning the previous attempts to solve a specific problem and the results obtained;
- No data on how similar problems are solved in other regions/cities and abroad;
- Consequences of solving the problem and maintaining the status quo are not predicted;
- No logical linkage between the problem and the goals of the program document (usually, goals and objectives of the program/project are formulated in such a way that they do not solve the problem in question but relate to another issue that has not been considered);
- Goals do not reflect actual future benefits;
- Programs/projects do not define any means for their future evaluation;
- Absence of project risk analysis.

In Russia, government bodies responsible for monitoring the city's strategic development have not yet been created. Along with this, practically no research and analytical support are provided for successful SC creation. Under the current conditions, the formation of an SC in the Russian Federation requires the development of novel and safe strategies for big cities based on the use of ICT, sustainable development principles, and an emphasis on infrastructure redevelopment and institutional transformations in management. With regard to the analysis results, the following recommendations for the implementation of SC policy in Russian cities with a population of more than 100 thousand people were developed:

- Application of a systematic approach to city management (for instance, the city's material flows should be optimized throughout the entire logistics chain and not only within a separate enterprise);
- Focus on the most relevant projects for residents, in particular, transport and online services;
- Encouragement of residents and businesses to participate in city life;
- Adoption of an integrated SC model and a smart program management approach.

5. DISCUSSIONS

While discussing the presented research results, the following should be noted. The paper proposes the authors' vision of the modern SC concept, according to which SC is an innovative system that uses open-source data, ICT, and other means to improve quality of life, efficiency and competitiveness of urban operation and services while ensuring that it meets the needs of present and future generations with respect to economic, social, and environmental aspects. This idea is closely related to the concept of sustainable development as it takes into account its basic principles and generally is combined with modern developments, in particular in environmental (Trindade et al., 2017) and social fields (Aurigi & Odendaal, 2020). The European Commission determines SC as a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business (European Commission, 2018b). However, the authors' vision differs from this definition in terms of considering economic, social, and environmental aspects of meeting present and future generations' needs.

The SWOT-analysis of the formulated SC concept has revealed that for developing countries, the introduction of SC technologies may be the way to improve the level and quality of life due to investments made in modern sectors of the economy. It can contribute to dynamic economic growth and creating new, sustainable jobs, reduce the risk of encountering the problems faced by other cities in the region or country (e.g., outflow of young and educated people, depopulation, decline in the competitiveness of goods and services "exported" by businesses located in the city) (Kola-Bezka et al., 2016). The main challenges for the SC programs' implementation were the increased residents' demands to the government, lack of a systematic approach to city management, lack of public participation in city management and solving urban problems.

The needs and expectations of the population from the SC police implementation include social security, high quality of life, improvements in public services, defeated corruption, developed transport infrastructure, reduced air and water pollution. Key areas for further development include improvement of residents' quality of life, modernization and development of the technological infrastructure of the city, use of technological solutions for effective city management, compliance with standards of environmental friendliness, sustainable economic development and social inclusion, and active residents' participation and engagement in city life. The investigation of the readiness of Russian cities for the introduction of SC technologies revealed that standardized and widely used approaches are not applicable in this case. Their major downside lies in the failure to consider the socio-economic policy of the regions, which significantly changes the values of socio-economic indicators. Besides, data for calculating these values were taken only from official sources that do not take into account statistics of the shadow economy sector.

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Thus, the standard indicators of ISO 37120:2014 are not relevant to the Russian Federation since their values are uniform for the entire country territory and depend on the number of residents living in a specific place. It was also found that the use of approaches based on ICT, digitalization, and internet technologies is also uninformative since access to the internet and high digital literacy of residents are characteristic of all Russian regions. Therefore, based on the indicators of the ISO 37120:2014 standard, a modified methodology taking the availability of infrastructure and social indicators into account was proposed. This approach made it possible to establish that the main barrier to the implementation of SC policy is the lack of proper infrastructure as well as its non-compliance with quality standards. In other words, when creating broadband communication networks for information flowing, it is necessary to take into account the city infrastructure specifics and introduce innovative digital cellular land mobile telecommunication systems for the purpose of diagnostics, statistical reporting, and forecasting the development of cities and regions.

In order to successfully implement the SC initiatives in Russia, the main attention should be paid to cooperation between the people and public and private sectors as well as to transparency and accessibility of SC projects (this can be achieved through the development of an open data portal or mobile app). All this will allow residents to understand what the city resources were used for. The SC projects should provide people with the ability to carry out personal activities (such as managing energy consumption, paying bills, and finding the fastest route), address the issue of proper personal data storage and security, prevent interference in the private life. The practical application of the presented approach is not an easy task as the city subsystems are predominantly individual and have their own information bases. Nevertheless, the authors of the present study prepared step-by-step recommendations for municipalities seeking to implement SC technologies. These recommendations are given in the form of a three-stage model presented in Figure 1.

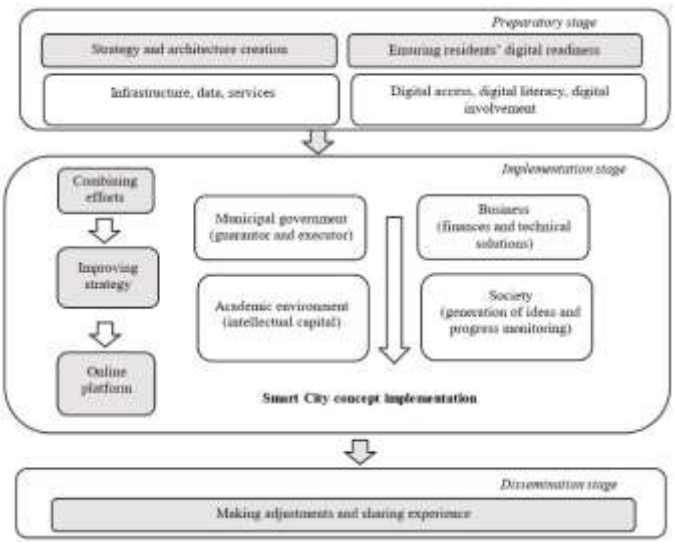

FIGURE 1 - SMART CITY CONCEPT IMPLEMENTATION SCHEME

The preparatory stage is responsible for preparing a specific city for the introduction of smart initiatives. Initiators must ensure that a critical mass is ready to use digital services. Furthermore, it is necessary to provide people and institutions with access to the internet and perform explanatory work on cybersecurity (via information campaigns and lessons in schools and universities). Smart applications and services will be meaningless if the city does not have a properly developed physical infrastructure (pipelines, roads, buildings, electrical grids, etc.). Apart from that, it is necessary to have digital (for storing and analyzing data) and soft infrastructure (qualified specialists to maintain available and develop new services; high-quality communication and the possibility of feedback).

The implementation stage provides for the formation of a common vision of the future city development. At this stage, it is advisable to involve business, academic, and public sectors for discussion. It is necessary to understand what kind of city people are trying to create (define its smart specialization) to identify its possible strengths and weaknesses. The perfect development model should be grounded on the set of initial conditions defined by means of online polls, panel discussions and the like methods. This stage also includes the selection of a responsible body, which can be represented by a whole department or a separate post under the municipality. The more progressive cities with open and well-disseminated information may hold specific events (hackathons and competitions) to coax developers to create new smart services.

The dissemination stage presupposes that the city has already chosen its development path, determined its priorities, and formed corresponding strategies. Therefore, it becomes necessary to launch a national platform for experience exchange. It is advisable to develop a common indicator that would allow tracking the progress of cities and identifying areas requiring additional attention. This is the time for cooperation between cities, the development of joint projects, and the creation of marketplaces.

6. CONCLUSIONS

For the purpose of describing typical models for the implementation of the SC policy in big cities, the research process was divided into several stages. Thus, the study provided the development of the authors' vision of the SC concept, performed its SWOT analysis, and surveyed residents of Russia's big cities concerning their understanding of the SC and its benefits. Taken together, the study findings indicate that achieving SC status requires systemic reforms in the sector of public services, transport, construction, housing and communal services, energy, medicine, trade, social support, security, finance, and the like.

The SC concept envisages not only online services and means of control (video recording, parking) but also stands for the application of new technologies in logistics, construction, communication, as well as requires new city management methods. Even though the sizeable portion of the population of Russia is

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characterized as IT literate, unfortunately, due to the lack of proper infrastructure or its non-compliance with world quality standards, big cities of Russia face considerable difficulties while introducing the SC initiatives. The authorities' primary attention is focused on increasing the informatization of all city activities, while the main areas requiring smart technologies, as indicated by the surveyed residents, are transport (parking, tickets), utilities, and online services.

The primary conditions for realizing the SC ideas are the identification of areas that require modernization; substantiation of a set of tools, the implementation of which will allow achieving the goals set; and reformation of the urban development management system. If the SC concept is reviewed from the perspective of information technology, then it requires organizational support for data exchange between city residents, administration, infrastructure facilities, and those working in the field of sustainable construction. The analysis of Russian national characteristics of the SC concept's implementation made it possible to identify the key components necessary to activate this process in other cities of the country:

- Collaboration between the city administration, private sector, research institutes, and civil society to develop a unified vision of the SC strategy;
- Infrastructure development;
- Provision of ICT accessibility for a wide range of people;
- Creation of SC platform for communication, publishing projects, and organizing events;
- Creation of a unified national platform for experience exchange.

The Smart City strategy should be public, dynamic, and include time-constrained goals and criteria to track progress. Experience shows that cities with a systematic approach and strategies better meet their residents' needs than those just developing smart applications on demand. Cities of Russia are only starting to take advantage of digitalization and smart initiatives; therefore, it is of paramount importance to get the balance right. The selection of respondents based on their profiles on social networks imposed certain limitations on the study. In particular, there is a possibility that the actual place of residence does not coincide with the declared one. Future research in this field will investigate the readiness of medium towns to introduce the SC concept since there is a fine line between cities of various types and thus their mutual influence is obvious.

The practical significance of this work lies in the fact that the proposed recommendations can become the theoretical basis for managing big cities' municipal infrastructure through the SC concept.

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