KEY SUCCESS FACTORS OF SMART CITY PROJECTS: METHODS AND ALGORITHMS FOR PERFOMANCE EVALUTION

Egor V. Zavedeev[1]
Irina V. Sergeeva[2]
Dmitriy A. Fedorov[3]
Evgenia V. Voronina[4]
Natalia N. Milchakova[5]

1. Surgut State University
2. Surgut State University
3. Surgut State University
4. Surgut State University
5. Surgut State University

Abstract: The nowadays tendency for increasing the number of projects based on the postulates of sustainable socio-economic development concept also includes projects based on smart technologies. Currently, there are no reliable methods and procedures for evaluating the effectiveness of such projects. For this purpose, the presented study proposed to apply an integral indicator such as the sustainability of an innovative city, measured by three parameters: the quality of life of the population with the positive dynamics, the efficiency of municipal management, and the economic, social, cultural and environmental competitiveness. Also, the study suggested the rating approaches for evaluation of the efficiency of municipal management of the Russian Federation constituent entities. The authors conducted a comparative analysis of the indicators of socio-economic development of smart cities rated by the National Research Institute of Technology and Communications, as well as the cities that did not fall into this rating. The analysis revealed the influence of Smart City technologies in 30 out of 50 indicators; also, smart cities showings preceded in terms of best values. As a result, it was proposed to rank the cities by two groups of indicators: resource and results. According to the authors, the proposed approach will allow a better assessment of the efficiency of projects based on 'smart' approaches.

Keywords: Smart City projects, projects integral assessment, projects rating, projects efficiency.

1. INTRODUCTION

One of the main directions of the modern state development strategy is to improve the quality of life of citizens as an important criterion for the proficiency of territorial management. In this regard, the concept of smart cities is becoming particularly relevant; the key criterion of the latter, in the first place, is the quality of life as a factor in sustainable territorial development. The introduction of the concept of smart cities into the life of subnational entities is, at present, an obvious and real fact. Several 'smart' projects are already being implemented (energy-saving, environmental, improving the living standards, etc.), 'smart' districts, as well as entire 'smart' cities are being built.

Nevertheless, until now, there was no clear mechanism for assessing the pay-off of the implementation of such projects, as well as of their planned and actual results. Some evidence suggests [1, 2], in particular, that the problem of developing the Smart City concept is not in the formation of generally accepted terminology, but largely due to the lack of a reliable statistical base for measuring its components. Quite many of the existing approaches proposed for assessment are fragmented. Thus, following the results of the conducted review, the authors have placed emphasis on approaches that focus on particular projects (directions) of the Smart City (for example, the sphere of housing and utility services, commute, healthcare, ecology); or vice versa, integrated approaches containing an extensive list of indicators that, according to authors, make difficult an assessment as such.

Since the 1990s several useful features (urban indicators) have been developed and implemented that are designed to measure, monitor and control various aspects of vital systems and city management as a whole. At the same time, considerable efforts were made to perform a comparative analysis of various spheres of urban life, concerning the structural, temporal and inter-city aspects. Currently, the data underlying such projects is becoming more open, there are more and more opportunities for the formation of such indicators in real-time due to several channels, local and social networks, and visual display using interactive resources and data panels via the Internet [3]. Since the beginning of the last century, the governments of developed countries have used a large number of social and economic indicators, such as unemployment rate, gross domestic product (GDP), gross national product (GNP), balance of payments, inflation and consumer price index [4].

After World War II, many supranational institutions (the World Health Organization, the Organization for Economic Cooperation and Development, the United Nations, etc.) compared and tracked the effectiveness of several medical, economic and social phenomena in different countries and regions. The use of indicators is spread across all systems of the public sector and is increasingly being used to monitor and evaluate various aspects of urban life (competitiveness, sustainability, quality of life, social welfare, and urban services). Many cities in the world now regularly generate sets of indicators, using them to enforce efficiency and directing the results to form the policy development for municipal governance [5]. Among these developments, the authors identified the following.

The cited article [6] describes a comprehensive methodology for evaluating Smart City projects to monitor effectiveness through a system of key performance indicators (KPI). The authors identified five so-called Citykeys: people, planet, prosperity, governance, and propagation. The proposed indicators link the planned and actual indicators of the city under the 'smart' concept. It is noteworthy that the team of authors believes that '... cities need a performance measurement system that links strategy and various projects in this area. This system must be flexible, convenient, safe, compatible and safe'. [6, p. 720]. The scientific paper [7] forms the groups of indicators in the context of cities with varying number of populations. Noteworthy here is the multiplicity of indicators, largely in the environmental component of the concept.

Another article [8] develops a system of indicators for assessing a city with a low level of carbon emissions in terms of economy, energy consumption structure, social status and living standards, as well as the level of carbon, environmental conditions, urban mobility, solid waste, and water. The authors of following reviewed scientific content [9] use a combination of the theory of differential rent and general quality management to assess the created value in a smart city. The work [10] provides a list of indicators for assessing the city's sustainability level, with the assessment sample carried out in Malaysia. The article identifies 11 groups of areas of analysis and 56 indicators.

Another reviewed study [11] builds a model for determining the Smart City Index. It should be noted that the indicators included in the index are not homogeneous and contain quite a large amount of information [12]. Of further note is the article [13], where the authors also proposed a system of key performance indicators based on the index of the general condition of the social sphere to assess smart city sustainability. The definition of needs and the formulation of the goals of the parties involved are multifaceted. The combination of multidisciplinary and multidimensional aspects of the Smart City concept creates difficulties in evaluating its efficiency. Thus, the presented article aims to develop an approach to assessing the performance of a smart city and its end-user with concern to the Smart City project implementation.

Referring to the indicated trends in the field of assessing the effectiveness of Smart City projects, the team of authors of the presented article tried to highlight the key parameters necessary for constructing an integrated assessment of such projects that would be simple and not hamper the process of its implementation. These parameters can be used to develop a methodology and algorithms for evaluating Smart City projects and implementing strategic planning for a smart city.

2. MATERIALS AND METHODS

To conduct a study on the proposed methods and algorithms for assessing the effectiveness of Smart City projects, a review of domestic and foreign sources was carried out. It was revealed that there are no methods and algorithms that consider the Smart City concept as a project. Literature and standard regulations are largely referring to the methods aimed at assessing the particular components of the concept. Explaining this trend is quite simple: The Smart City concept affects a wide range of urban activities, as it is represented by such components as urban governance, housing and utility services, commute, security, healthcare, ecology, education, economics and finance, and telecommunications. In this regard, it is rather difficult to formulate an assessment of a complex project at the current stage (i.e. stage of discussion and methodology development). Therefore, at present, the only available methods are the drafts that are more focused on particular components of the concept. At the same time, the analysis of the selected sources revealed the main parameters for the proposed assessment. Also, the authors conducted a statistical analysis of the indicators of socio-economic development of several Russian large and medium-sized cities to identify correlation dependencies between these indicators and indicators for assessing various aspects of the ‘smartness’ advancement of the studied cities (the data were also used to build the smart urban development rating of Russian cities by the National Research Institute of Technology and Communications). Furthermore, a comparative analysis of the level of various indicators of socio-economic development in cities implementing Smart City projects (and those not implementing as well) was also conducted.

3. RESULTS

To calculate the effectiveness of projects and obtain baseline data for urban management, municipal authorities create sets of urban indicators, including ones generated from real-time data obtained using sensors, cameras, and social and local media. Often this happens as part of the implementation of Smart City projects [14]. Currently, there are various types of indicators of the effectiveness of urban functioning. These indicators differ in purpose and application. All of them can be divided into two groups: one-dimensional and composite.

One-dimensional indicators are formed based on measurement or statistics related to one phenomenon. Moreover, from a practical point of view, the most valuable are direct indicators that are clearly defined and unambiguous; they can be reflected as a quantitative indicator with high representativeness. Such indicators are objective, impartial and not dependent on external influences, they are easily tracked over time, can be verified and replicated, and they are unambiguously interpreted, and allow forming a relatively reliable and efficient system for collecting, processing and updating the input required to calculate data indicators [15]. Another group of one-dimensional indicators is indirect. In this case, the main investigated phenomenon is intangible or not directly observable. Also, such indicators can be used in cases where the cost of data collection to establish direct indicators is just too high and it is advisable to replace the indicators obtained based on existing data collected in the course of studies conducted for other purposes [16].

Composite indicators integrate several one-dimensional ones, using a weighting pattern to create a new derived index. Applying such indicators denotes the acceptance of the idea that the various multidimensional phenomena are interconnected, and that no one-dimensional indicator can fully reflect the degree or even complexity of a significant number of problems of urban structure or functioning. Such indicators can be generated either on their own or purchased from specialized analytical centers or consulting companies [17]. The indicators described can be used in the following ways:

1. Descriptive or context-dependent indicators. In this case, indicators provide key information on a specific phenomenon within or between urban areas. Such indicators can be used as important sources of information and evidence for democratic debate and policy development on specific issues, such as planning, environmental and social aspects, economic numbers, as well as requirements evaluation and redeployment of resources [17, 18, 19].

2. Diagnostic indicators, performance indicators and performance targets. These indicators can be used as a means of diagnosing a specific problem or evaluation of the performance in particular cases, and also in terms of the effectiveness (whether the planned results were obtained) and the overall performance (whether the desired outcome was achieved) of the policy or program, particular employees, departments, organizations, and sectors. Also, these indicators can be used to diagnose the cause of the problem and measure the impact of a potential solution, as well as assess whether the phenomenon is being transformed in the desired way or has reached a certain level or goal [20, 21].

3. Predictive and conditional indicators in which data are used not only to assess the very existing situation but also to predict and model future situations and actions; in this case, indicators are used as a key input in various forecasting models. With the benefit of using such sets of relevant and well-defined data, modeling of aspects of urban systems and urban life can be carried out to obtain ideas that can be used to change existing practices and provide desired results in the future [17].

Computation of performance indicators and a comparative analysis of these indicators for different cities and urban areas allow developing expertise in comprising districts and cities in different aspects of the urban economy. Such an analysis makes it possible to reveal (efficiently and sufficiently clearly) the most effective practices, identify the leading and catching up cities and urban areas, and generate ratings according to different criteria for the effectiveness of urban governance. This, in turn, stimulates the formation of a competitive agenda for cities or districts in terms of their relative efficiency compared to other cities or districts and, thus, can be used to motivate the changes necessary to improve their situation in comparison with others [22, 23].

It should be noted that 'an indispensable feature of the Smart City is the commitment to ensure long-term sustainable development' [24]. So, the following definition of 'Smart Sustainable Cities' was developed by the ITU and UNECE at the 76th session of the Committee on Housing and Land Management of the Economic Commission for Europe, held on December 14-15, 2015, in Geneva [25]: '...A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects'.

Based on the above definition, it can be noted that a sustainable city is an innovative city, an 'integrated' system that uses ICTs to: improve the quality of life; improve the efficiency of urban operation and services; increase competitive advantage in economic, social, cultural and environmental aspects while ensuring the satisfaction of the needs of present and future generations. In addition to the above, when evaluating the effectiveness of Smart City projects, it is necessary to take into account that normally the arrangement of the urban environment is implemented through public-private or municipal-private partnership framework. Algorithms for assessing the effectiveness of projects in their implementation using these frameworks are presented in the scientific literature in close detail. There are also regulatory documents of a methodological nature designed to systematize the processes of evaluating the effectiveness and screening projects for governmental funding and support. In particular, under the cited source [26], an assessment of project effectiveness should be based on the following criteria: financial effectiveness of the project; the socio-economic outcome of the project.

Determining the financial effectiveness of the project is carried out, first of all, to assess the profit for a private investor. For authorities, the financial effectiveness of the project is determined by an increase in revenue or a decrease in the expenditure of local, regional and federal budgets. The project effectiveness for a private investor is determined by economic feasibility based on determining the flow of income and expenses from the project implementation and calculating the indicators of the economic evaluation of investment: net present value, payback period, internal rate of return. Assessing the feasibility of implementing a project for federal or municipal authorities is a more difficult task since it is determined not so much by economic feasibility as by the socio-economic effects achieved as a project outcome such as accomplishing the goals and objectives of the territorial development or reaching the numbers of national projects. The achievement of development goals and objectives for any particular municipal area is determined by ensuring (as a result of the project implementation) positive dynamics of the socio-economic indicators.

Based on the fact that this concept is focused on ensuring the sustainability of urban development to socio-economic indicators, the designated indicators that assess the urban structure in the following parameters (urban development areas) should be attributed for Smart City projects: the living standard of residents with its positive dynamics; the effectiveness of municipal governance; the economic, social, cultural and environmental competitiveness of the municipality. Ultimately, the authors are entitled to the opinion that the integral criterion for assessing the social and economic effectiveness of Smart City projects is the sustainability of an innovative city, as measured by three integral indicators characterizing the above areas of urban development. This dependence can be represented in terms of economic and mathematical modeling:

$$f_x = (x_1;\ x_2;\ x_3) \qquad (1)$$

where f_x – is an integral indicator of the sustainability of an innovative city, characterizing the effectiveness of Smart City projects; x_1 – smart city living standards; x_2 – efficiency of municipal governance; x_3 – competitiveness (economic, social, cultural, and environmental).

Each factor that forms the integral indicator also has its characteristics of determining. The living standard is a complex multidimensional indicator. There are a fairly large number of concepts for the formation of this indicator. In accordance with [27, 28], and from a practical point of view, the following models can be distinguished: Diener's Basic and Advanced QOL Indices; Netherlands Living Conditions Index (LCI); Rogerson's Model; Raphael et al/ Model; Murdie et al. Model; Borsdorf Model; Integral indicator of the quality of life by

S.A. Ayvazyan. The latter, according to authors, is of particular interest since the advantage of this indicator allows making an assessment based on official data of government statistics agencies. Moreover, all the characteristics that make up the system and environmental circumstances are combined into the following groups [29]:

- population quality (life expectancy, education level, qualification, birth rate, mortality, etc.);

- population well-being (real incomes and their differentiation, level of consumption of goods and services, level of provision with infrastructure capacities, etc.);

- social security (working conditions, social protection, physical and property security, crime rate, etc.);

- environmental quality (airspace and water pollution, soil quality, biodiversity, etc.);

- natural and climatic conditions (composition and volumes of natural raw materials, climate, frequency and specifics of force majeure situations, etc.

Most data related to the first three groups (income, expenses, household savings; social security and assistance; income distribution; subsistence level, poverty level; income, expenses, and living conditions of households) are publicly available on the official website of the Federal State Statistics Service [30]. Also, certain indicators related to the other two groups can be found there too. Information on the level of biodiversity, the composition and volume of natural resources, climate, etc. can be located on the official websites of the administrations of the reviewed cities.

Accordingly, it appears that in the assessment of the effectiveness of Smart City projects, first of all, it is essential to estimate the positive effect of such project's implementation on the dynamics of the above indicators in the considered territories. The effectiveness of city administrations, in the authors' opinion, should be assessed based on the key performance indicators (KPI). Nowadays, having a performance-based contract of employment is quite common for municipal managers; therefore, the achievement of these indicators or underperformance directly characterizes their effectiveness. The competitiveness of the whole territory, from our point of view, should be considered '... in the context of the problems of territorial separation and leveling ...' [31], featured by the index of territorial asymmetry, consisting of three types of asymmetries: economic, social and institutional.

In the context of economic asymmetry, the calculation should be based on a set of integral and specific indicators. The integral indicators include the gross product of the territory per capita, the territory's capital aggregate value per capita (the value of fixed assets, financial capital, land value, labor costs, the cost of intangible assets), the budgetary provision of the population (budget revenues per capita) , the regional level of subsidization, and investment in fixed assets per capita. Specific ones include any indicators, the content of which is determined by the presence of competitive advantages of the territories (level of development of transport infrastructure, the security of engineering and energy infrastructures, the availability of promising investment projects of national importance to create clusters of an innovative development scenario) [31].

In the context of social asymmetry, integral and specific indicators can also be determined. The integral indicators include cash earnings per capita, average monthly nominal accrued wages per employee, employment level (and unemployment rate), demographic load coefficient, migration balance, and human capital index. Specific ones include provision of social infrastructure (educational, health care, cultural, social services facilities) per resident, accessibility of housing and community amenities for the population (rates per resident for housing services per 1 m2 of living space), availability of comfortable housing (cost of 1 m2 in the primary and secondary markets; interest rate on the use of mortgages, etc.), and the level of environmental well-being for the population.

Institutional asymmetry characterizes the presence of institutional infrastructure conducive to regional development. The triunity of the resulting indicators of the types of asymmetries allows determining the degree of competitiveness of territories based on the rating of the obtained values. Significant difficulties are posed by the process of effective management of a smart city, both in the current and long-term aspects; such cities represent an extremely complex multi-level system in which numerous elements and acting factors interact with each other and with the external environment, continuously absorbing technological and other innovations. Such a structure will not be able to resist numerous challenges if a constant transformation of the control model and its adaptation to changing external conditions are not provided [32].

The management process at the governmental level should be accompanied by the monitoring of key indicators that characterize cities as 'smart'. To identify and assess the relationship between indicators of urban socio-economic development and the success of the implementation of the Smart City projects in Russia, the authors conducted a study of the statistical dependencies of smart city rating indicators obtained in the research work Smart City Indicators NIITS 2017. The latter was carried out by PHC National Research Institute of Technology and Communications (NIITS) followed by reported indicators of Russian cities published on the official website of Federal Statistics Service under the 'City Passports' section. During the process of the rating of the Smart City projects in Russia by NIITS, particular indicators were singled out to assess the level of development of the Smart City technologies; these indicators were grouped in the following 7 key areas [33]:

- Smart Management;
- Smart Technologies;
- Smart Infrastructure;
- Smart Economy;
- Smart Finances;
- Smart People;
- Smart Environment.

An analysis of 16 cities was conducted; it was revealed that the leaders in the development of smart city technologies are the cities of Moscow and St. Petersburg, followed by the effectively developing Kazan and Yekaterinburg. The final ratings are presented in Table 2.

Table 2 – Indicators of Smart Cities by National Research Institute of Technology and Communications (NIITS) 2017 [33]

City	Indicators							Smart city indicators, total
	Smart Mgmgt	Smart Tech	Smart Inf.-structure	Smart Economy	Smart Finances	Smart People	Smart Environment	
	X1	X2	X3	X4	X5	X6	X7	
Moscow	0.75	0.86	0.92	0.36	0.85	0.9	0.43	0.76
St. Petersburg	0.59	0.82	0.63	0.5	0.76	0.66	0.49	0.64
Kazan	0.49	0.56	0.49	0.74	0.71	0.79	0.62	0.59
Yekaterinburg	0.38	0.66	0.38	0.61	0.81	0.84	0.29	0.54
Krasnoyarsk	0.17	0.75	0.44	0.39	0.73	0.76	0.69	0.52
Novosibirsk	0.2	0.56	0.45	0.38	0.79	0.69	1	0.53
Ufa	0.28	0.33	0.47	0.55	0.61	0.79	0.45	0.47
Sochi	0.37	0.17	0.61	0.64	0.63	0.51	0.36	0.467

Perm	0.3	0.58	0.39	0.45	0.64	0.75	0.24	0.464
Rostov-on-Don	0.24	0.54	0.41	0.31	0.73	0.55	0.56	0.45
Voronezh	0.16	0.45	0.54	0.56	0.42	0.61	0.45	0.447
Chelyabinsk	0.18	0.31	0.44	0.41	0.7	0.56	0.68	0.425
Nizhny Novgorod	0.15	0.5	0.34	0.48	0.72	0.81	0.18	0.423
Omsk	0.29	0.3	0.39	0.35	0.66	0.57	0.66	0.422
Volgograd	0.22	0.44	0.24	0.25	0.54	0.63	0.47	0.35
Samara	0.08	0.3	0.32	0.48	0.67	0.55	0.39	0.35

To assess the relationship of the indicators presented in Table 2 with the data on the socio-economic development of these cities, a correlation analysis of statistical data was carried out on the impact of some urban indicators on others. To determine the relationship between the criteria, the pair correlation coefficient was used:

$$r_{xy} = \frac{\mathrm{cov}(X,Y)}{\sigma_x \sigma_y} = \frac{M[(X-m_x)-(Y-m_y)]}{\sigma_x \sigma_y}, \quad (1)$$

where M – is an expectation operator; m_x, m_y, σ_x, σ_y – accordingly, the mathematical expectation and standard deviation of random variables X and Y.

The pair correlation coefficient between two variables demonstrates the strength of the connection and varies in the range between -1 and +1. If the obtained value is closer to 1, this denotes the presence of the strong interconnection, and if it is closer to 0, then the bond is weak. A negative correlation coefficient indicates the presence of an opposite relationship, i.e. the higher the value of one variable, the lower the value of another. The strength of the connection can be shown, including the absolute value of the correlation coefficient. Based on the presented model, a correlation and regression analysis of the indicators of socio-economic development was conducted for both NIITS-rated cities (Table 2) and several other (out of most developed) cities of Russia: Krasnodar, Saratov, Tyumen, Makhachkala, Tolyatti, Barnaul, Izhevsk, Ulyanovsk, Irkutsk, Yaroslavl, Naberezhnye Chelny, Belgorod, Surgut, Nizhnevartovsk, and Veliky Novgorod. The total number of cities for which the analysis was made was 32; for the mentioned cities, an urban development comparison was made out of 50 indicators obtained from the Federal State Statistics Service data [36]. First of all, an analysis was conducted on the relationship between smart city indicators and other urban indicators, which, in the authors' opinion, can influence the creation of favorable conditions for the implementation of Smart City projects. Indicators presented below in Table 3 were selected as such influence agents.

Table 3 – Pair correlation values of the NIITS Smart City indicators and indicators of socio-economic development

Indicators	X1	X2	X3	X4	X5	X6	X7	Total Smart City score
Smart City Final indicator	**0.901**	**0.946**	**0.969**	**0.913**	**0.974**	**0.972**	**0.849**	**1**
Average annual resident population, 2017.	0.732	0.584	0.636	0.255	0.435	0.438	0.271	0.544
Local budget expenditures (actually executed), 2017.	0.650	0.471	0.551	0.146	0.321	0.331	0.159	0.436
Investments in fixed assets at the expense of the municipal budget (averaged for 2015-2017)	0.16	0.26	0.1	0.028	0.15	0.14	-0.01	0.14

Indicators	X1	X2	X3	X4	X5	X6	X7	Total Smart City score
Volume of investments in fixed assets (excluding budgetary funds) per capita (annual average)	0.325	0.1	0.26	0.267	0.14	0.16	-0.04	0.19
Volume of investments in fixed assets (excluding budgetary funds) per capita (2017)	0.422	0.29	0.3	0.251	0.18	0.25	0.001	0.27
The average monthly nominal accrued wages of employees of large and medium-sized enterprises, and non-profit organizations of the urban (municipal) district	0.445	0.325	0.341	0.062	0.19	0.19	0.041	0.27
Local budget revenues per capita, thousand rubles	0.609	0.446	0.499	0.123	0.28	0.27	0.114	0.392
Fixed capital investments made by organizations located in the municipal territory (excluding small businesses) (2015-2017 average)	0.728	0.566	0.626	0.247	0.416	0.421	0.232	0.527
Budget investments increasing the value of fixed assets * (annual average)	0.653	0.624	0.572	0.614	0.628	0.602	0.574	0.642

The following relationships were identified in the course of the calculations:

1. The indicator 'Budget investments increasing the value of fixed assets' showed the greatest degree of correlation with the values of the following rating indicators: the Final indicator (Pearson's r - 0.642), 'Smart Management' (Pearson's r - 0.653), 'Smart Technologies' (Pearson's r - 0.624), 'Smart Infrastructure' (Pearson's r - 0.572), 'Smart Economy' (Pearson's r - 0.614), 'Smart Finance'(Pearson's r - 0.628), 'Smart People' (Pearson's r - 0.602), and the 'Smart environment' indicator (Pearson's r - 0.574).

2. The second place by the degree of interconnection is occupied by the indicator 'Fixed capital investments made by organizations located in the municipal territory (excluding small businesses) (2015-2017 average): the Final indicator (Pearson's r - 0.527), 'Smart Management' (Pearson's r - 0.728), 'Smart Technologies' (Pearson's r - 0.566), and the 'Smart Infrastructure' indicator (Pearson's r - 0.626).

3. The third place according to the degree of interconnection is taken by the indicator 'Averaged annual resident population': the Final indicator (Pearson's r is 0.544), 'Smart Management' (Pearson's r is 0.732), 'Smart Technologies' (Pearson's r is 0.584), and the 'Smart infrastructure' indicator (Pearson's r is 0.636).

4. A fairly close correlation is observed for the indicator 'Average monthly nominal accrued wages for employees of large and medium-sized enterprises, and non-profit organizations of the urban (municipal) district' and the 'Smart Management' indicator (Pearson's r is 0.445).

Further, computations were conducted on indicators of the socio-economic development of cities, which relate to indicators used to assess the effectiveness of local authorities in urban districts and municipalities and which, in authors' opinion, can characterize the degree or indicate the city's level of applications of technologies, related to the Smart City models. These indicators are presented in Table 4.

Table 4 – Pair correlation values

	X1	X2	X3	X4	X5	X6	X7	Smart City Final indicator
The growth rate of budget investments increasing the value of fixed assets*	-0.039	-0.168	-0.033	0.016	-0.192	-0.126	-0.195	-0.108
Average annual resident population growth rate	0.175	0.074	0.219	0.083	0.056	0.043	0.115	0.13
Local budget revenues (actually executed), 2017	0.646	0.466	0.549	0.138	0.316	0.327	0.152	0.432
The growth rate of actually executed local budget revenues (annual average)	-0.06	-0.2	-0.141	-0.17	-0.138	-0.196	-0.222	-0.173
Budget deficit	-0.364	-0.315	-0.223	-0.147	-0.189	-0.124	-0.139	-0.236
The share of the average number of employees (excl. external part-timers) of small and medium-sized businesses in the average number of employees (excl. external part-timers) of all enterprises and organizations	0.187	0.315	0.291	0.363	0.314	0.328	0.314	0.322
The number of small and medium-sized businesses per 10,000 residents	0.14	0.228	0.143	0.245	0.225	0.215	0.23	0.213
Number of hospital beds	0.675	0.525	0.601	0.2	0.397	0.416	0.255	0.497
Average rate of change in the number of hospital beds	-0.275	-0.238	-0.184	-0.273	-0.253	-0.274	-0.114	-0.245
Hospital beds total, per 10 000 residents	-0.287	-0.182	-0.192	-0.225	-0.173	-0.157	-0.061	-0.199
Doctors of all specialties (excl. dentists) in healthcare facilities, total	0.672	0.512	0.592	0.188	0.378	0.399	0.239	0.484
The average growth rate of the number of doctors	-0.324	-0.264	-0.198	-0.271	-0.207	-0.25	0.063	-0.229
Doctors of all specialties (excl. dentists) total per 10,000 residents	-0.079	0.038	0.005	-0.085	-0.014	0.025	0.11	0
The proportion of the length of local public roads that do not meet regulatory requirements in the total length of local public roads, 2017	-0.162	0.059	-0.121	-0.019	-0.095	-0.019	-0.13	-0.074
The rate of the decline in the length of local public roads that do not meet regulatory requirements	0.032	0.094	-0.026	0.059	-0.05	0.034	-0.286	-0.011
The average waiting period from the filing date of construction land plot application till the decision date (or the date of signing a contract following the tender or auction results, etc.)	-0.09	-0.087	-0.109	-0.114	-0.052	-0.058	0.024	-0.088
The average waiting period from the application date for a construction permit to the notice date of obtaining a permit	0.07	0.215	0.203	0.214	0.292	0.256	0.509	0.259

	X1	X2	X3	X4	X5	X6	X7	Smart City Final indicator
The average monthly nominal accrued wages of the employees of municipal children's pre-school institutions	0.350	0.216	0.252	-0.004	0.104	0.117	-0.053	0.173
The average monthly nominal accrued wages of the employees of municipal educational institutions	0.324	0.131	0.205	-0.079	0.013	0.013	-0.011	0.111
The average monthly nominal accrued wages of employees of municipal healthcare institutions	0.87	0.668	0.827	0.87	0.857	0.823	0.861	0.866
The ratio of water supply tariffs for industrial consumers to residential tariffs	-0.164	-0.113	-0.075	0.081	0.02	0.001	0.093	-0.039
The ratio of water disposal tariffs for industrial consumers to residential tariffs	-0.198	-0.15	-0.093	0.097	0.03	0.008	0.139	-0.045
The share of commercially unfeasible organizations in housing and utility services	-0.188	-0.198	-0.166	-0.155	-0.15	-0.21	-0.072	-0.182
Collection rates of payments for the provided housing and utility services	0.186	0.115	0.157	0.204	0.14	0.165	-0.012	0.144
The share of children aged 1-6 receiving preschool educational services and (or) indoor services in municipal pre-school institutions, in the total number of children aged 1-6	-0.386	-0.328	-0.446	-0.363	-0.440	-0.365	-0.444	-0.421
The growth rate of the share of children aged 1-6 receiving preschool educational services and (or) indoor services in municipal pre-school institutions, in the total number of children aged 1-6 years	0.1	0.153	0.139	0.165	0.182	0.173	0.169	0.162
The data on pollutants captured and decontaminated as a percentage of the total amount of pollutants emanating from stationary sources	-0.032	0.069	0.031	-0.069	0.093	0.026	0.314	0.056
Number of municipal electronic services provided by local authorities	0.084	-0.022	0.193	0.081	0.124	0.001	0.137	0.091
Total number of municipal services provided by local authorities	0.336	0.352	0.256	0.305	0.347	0.273	0.183	0.309
The number of priority municipal electronic services provided by local authorities	-0.168	-0.114	-0.166	-0.218	-0.158	-0.164	-0.052	-0.162
Specific value of electric power consumption in apartment buildings, per resident	0.417	0.246	0.152	0.24	0.16	0.2	0.175	0.227

	X1	X2	X3	X4	X5	X6	X7	Smart City Final indicator
Specific value of thermal energy consumption in apartment buildings, per 1 sq. m. of useful floor area	-0.126	0.057	-0.187	-0.152	-0.091	-0.024	-0.122	-0.095
Specific value of hot water consumption in apartment buildings, per resident	-0.001	-0.048	-0.137	-0.066	-0.168	-0.082	-0.229	-0.11
The specific value of cold-water consumption in apartment buildings, per resident	0.065	-0.007	0.089	0.087	0.01	0.015	0.077	0.049
Specific value of natural gas consumption in apartment buildings, per resident	-0.07	-0.383	-0.206	-0.171	-0.212	-0.248	-0.166	-0.232
Specific value of electric power consumption by municipal budgetary institutions, per resident	-0.07	0.058	-0.04	0.063	0.102	0.082	-0.065	0.02
Specific value of thermal energy consumption by municipal budgetary institutions per 1 sq. m. of useful floor area	-0.246	-0.238	-0.269	-0.265	-0.274	-0.274	-0.233	-0.272
Specific value of hot water consumption by municipal budgetary institutions, per resident	-0.327	-0.155	-0.263	-0.318	-0.237	-0.217	-0.350	-0.266
Specific value of cold-water consumption by municipal budgetary institutions, per resident	-0.037	-0.079	-0.1	-0.035	-0.146	-0.1	-0.26	-0.109
Specific value of natural gas consumption by municipal budgetary institutions, per resident	0.115	0.146	0.101	0.108	0.129	0.145	0.135	0.13

The presence of correlation between indicators of socio-economic development and NIITS Smart Cities indicators was revealed by the following indicators (Pearson's r at the level of 0.4) and was also proven by conducted computations.

1. The relationship of the indicator 'The share of the average number of employees (excluding external part-timers) of small and medium-sized businesses in the average number of employees (excluding external part-timers) of all enterprises and organizations' has been revealed with the following NIITS indicators: the Final indicator, 'Smart Technologies', 'Smart Economy', 'Smart Finance', 'Smart People', and 'Smart Environment'.

2. The indicators 'Number of hospital beds' and 'Doctors of all specialties' show the relationship with the Final indicator, as well as with the 'Smart Management', 'Smart Technologies', and 'Smart Infrastructure' indicators.

3. The indicator 'Captured and neutralized pollutants as a percentage of the total amount of pollutants emanating from stationary sources' exhibits the connection to the 'Smart Environment' indicator.

4. The indicator 'The average waiting period from the application date for a building permit to the notice date of obtaining a building permit' also shows the relationship with the 'Smart Environment' indicator.

5. The indicators 'Average monthly nominal accrued wages of employees of municipal children's preschool institutions' and 'Average monthly nominal accrued wages of em-

ployees of municipal educational institutions' shows the relationship with the 'Smart Management' indicator.

6. The indicator 'Share of children aged 1-6 receiving preschool educational services and (or) indoor services in municipal pre-school institutions in the total number of children aged 1-6' shows the relationship with the 'Smart Environment', 'Smart Finance', and 'Smart Infrastructure' indicators.

7. The indicator 'Total number of municipal services provided by local authorities' shows the relationship with the 'Smart Management' and 'Smart Technologies' indicators.

8. The indicators 'Specific value of electric power consumption in apartment buildings per resident', 'Specific value of natural gas consumption in apartment buildings per resident', and 'Specific value of hot water consumption by municipal budget institutions per resident' show the relationship with the 'Smart Management' indicator.

Furthermore, a comparison was made of the average values for the indicators of cities' socio-economic development that fell into the NIITS smart rating with other cities. Verification of the average values of socio-economic development indicators for two groups of cities demonstrated the presence of significant differences for all analyzed averages except for two indicators:

1. Budget investments increasing the value of fixed assets ($p = 0.02$), the hypothesis according to Levene's test on the equality of variances is accepted, since $p = 0.01$.

2. The share of children aged 1-6 receiving preschool educational services and (or) indoor services in municipal pre-school institutions in the total number of children aged 1-6 ($p = 0.029$), even though the hypothesis according to Levene's test on the equality of variances is not accepted, since $p = 0.682$.

For all other variables, the differences are quite significant ($p <0.05$), which indicates the variance in parameters for smart cities and the rest of the participants. In the context of gathering and using indicators to evaluate the effectiveness of Smart City projects, it should be noted that building a municipal economy according to the principles of this concept already provides quite an effective tool for assessing the effectiveness of urban projects. In particular, many cities developing under this concept (London, Dublin, Vienna, Rio de Janeiro, etc.) are using dynamic panels for summarizing, transmitting, and monitoring urban data in real-time mode. Such panels become an important means of analysis and interpretation of indicators and comparative data used to identify the structure and trends of variables [3]. Just as the vehicle dashboard provides important information necessary for high-quality and convenient driving, the indicator panels provide key information for city administrations and organizations operating in the local market. Such panels can go far beyond the framework of a single summary screen, acting as a console for navigation, visualization, and comprehension of numerous layers of interconnected data, which allows researching consolidated data in detail within a single visualization system [6].

Dynamic info panels are often located in control rooms, graphically presenting data for employees of the city administration, or sometimes found in public places to provide information to citizens. Such control centers can accumulate data on car traffic and accidents, the number, and location of criminal acts, weather information and warnings, housing and utility service interruptions, and any other information transmitted by employees and members of the public by phone, via the Internet or radio. The practical significance of such panels lies in the opportunity to rapidly and efficiently provide city administration, and in some cases, the members of the public, with current and detailed information on certain aspects of urban systems and the environment, as well as the real-time updates. Analysis and processing of such data allow identifying trends in data changes and build correlation-regression models of its dynamics, which, in turn, makes it possible to form economic and mathematical models for computing the effectiveness of decisions made or projects being implemented within the framework of an urban economy.

4. DISCUSSION

As follows from the above review and critical analysis of literature and normative materials, as well as from statistical analysis of the indicators of socio-economic development of several Russian cities, the evaluation of the effectiveness of Smart City projects should be based on a combination of an assessment of project's economic outcome and the projected positive dynamics of the integral innovative city sustainability indicator formed on the basis of urban indicators of particular municipality development. However, for the investor implementing the project, the economic effect will be determined by predicting the net cash flow and calculating the classic indicators of investment (net present value, payback period, internal rate of return). Moreover, the methodology for such computations is well developed and widely described in the scientific literature. Difficulties, in this case, will be represented by predicting the possible sales volumes of new and innovative services that will be generated during the operational phase of any project within the framework of Smart City. The main sources of information for conducting such forecasts can be only trial sales, opinion polls, and analysis of sales of similar services.

The economic effectiveness of the project for municipal, regional or federal authorities will be determined by predicting the increase in tax revenues to the budget, revenue growth due to the operational activities or leasing of municipal property, and cost reduction by improving management performance through the use of innovative methods and technologies. It is the latter that will pose the greatest difficulties in forecasting since such forecasting is possible only due to expert methods characterized by a significant level of subjectivity and trial operation methods, which may require significant financial expenses. The process of forecasting the dynamics of indicators of socio-economic development will cause the greatest level of difficulty in assessing the effectiveness of Smart City projects, both from a methodological and a practical point of view. To conduct such an analysis, it will be essential, first of all, to determine the list of indicators on which the project will have a positive impact and the list of circumstances that can cause negative effects during project implementation. Then, it is necessary to compile a statistical series of these indicators over the previous 5-10 years and identify factors that had a positive or negative effect on their value. The next step will require the construction of correlation-regression statistical models of changes in these indicators as a result of changes in factors. Further, it will be necessary to predict a possible change as a result of the project, the magnitude of these factors, and also to forecast the possible values of indicators of socio-economic development using the constructed statistical models.

For a preliminary assessment of the possibility of predicting the socio-economic effect of Smart City projects based on statistical correlation and regression models of indicators of urban socio-economic development, an analysis of these indicators for several largest and most smart-advanced cities of Russia was carried out. This analysis demonstrated the presence of correlation between the indicators of socio-economic development and indicators of NIITS-rated smart cities for the following series of indicators: The budget investments increasing the value of fixed assets; Fixed capital investments made by organizations located in the municipal territory, excluding small businesses (2015-2017 average); The average annual resident population; The average monthly nominal accrued wages of employees of large and medium-sized enterprises, and non-profit organizations of the urban (municipal) district; The share of the average number of employees (excluding external part-timers) of small and medium-sized businesses in the average number of employees (excluding external part-timers) of all enterprises and organizations; The number of hospital beds; The number of doctors of all specialties; The data on pollutants captured and decontaminated as a percentage of the total amount of pollutants emanating from stationary sources; The average waiting period from the application date for a construction permit to the notice date of obtaining a permit; The average monthly nominal accrued wages of the employees of municipal pre-school institutions; The average monthly nominal accrued wages of the employees of municipal educational institutions; The share of children aged 1-6 receiving preschool educational services and (or) indoor services in municipal pre-school institutions, in the total number of children aged 1-6; The number of municipal services provided by local authorities; The specific value of electric power consumption in apartment buildings per resident; The specific value of natural gas consumption by municipal budgetary institutions per resident; The specific value of hot water consumption by municipal budgetary institutions per resident.

The positive impact of Smart City technologies in the urban indicators of socio-economic development is also confirmed by a comparative analysis of the average values for such indicators for NIITS-rated smart cities and for cities that did not fall into this rating. It was found that according to 30 indicators out of 50, the best values are observed specifically in smart cities. Also, the analysis of the above indicators allows dividing them into two conditional groups:

1) **Resource indicators** that assess the conditions and opportunities conducive to the implementation of Smart City projects: 'Budget investments increasing the value of fixed assets', 'Average annual resident population', and 'Investments in fixed assets made by organizations located in the territory of the municipality'. These indicators point to the fairly obvious trend: the higher the indicator value, the more opportunities for the successful implementation of Smart City projects. Accordingly, in the formation of economic and mathematical models for determining the effectiveness of the implementation of Smart City projects, the values of these indicators should be used as factors weakly dependent on the project, but creating conditions conducive to its development.

2) **Result indicators** whose value increases as the value of the indicator (s) of the Smart City rating increases. For example, an increase in the 'Smart Environment' indicator leads to an increase in the 'Captured and neutralized pollutants as a percentage of the total amount of pollutants emanating from stationary sources', and the 'Smart Management' and 'Smart Technologies' indicators have a direct correlation with the 'Number hospital beds' and 'Number of doctors of all specialties' indicators. Some of the indicators of this group can be attributed to the indicators of quality of life, such as 'Average monthly nominal accrued wages ...', 'Share of children aged 1-6 receiving preschool educational services…', 'Number of municipal services provided by local authorities', etc. It is precisely the increase in such indicators that should be expected with the successful implementation of the Smart City project, and, accordingly, the dynamics of these indicators should be predicted when building an integral indicator of the innovative city sustainability and evaluating the effectiveness of these projects.

Based on the conducted analysis of known approaches to assessment, the authors have distinguished two decisive prospects:

– Approaches to the performance evaluation of particular projects (energy saving, housing and utility services, public commute, healthcare and similar),

– Approaches to a comprehensive assessment of cities that implement the 'smart' concept.

The following key factors were identified from the presented approaches to assess the effectiveness of Smart City projects:

– The assessment should be carried out using an integrated approach, taking into account all the components of a smart city;
– The assessment should be carried out not only according to the results but also during runtime, fixing the values of indicators at time-determined intervals to make effective management decisions (dynamic monitoring);
– The performance evaluation of Smart City projects should be aimed at measuring the integral indicator characterizing the key goal of a smart concept as a whole - the quality of life of a smart territory, as the ultimate indicator of performance;
– Following the conducted correlation and regression analysis, the presence of correlations was revealed for several urban indicators of socio-economic development and smart city indicators. This makes it possible to assess the effectiveness of such projects using the fundamental principles proposed in p. 3.
– Urban dynamic data panels launched in many cities developing under the Smart City concept allow identifying current trends in the functioning of the urban economy and build correlation-regression models of their dynamics. This, in turn, makes it possible to form economic and mathematical models for evaluating the performance of ongoing investment projects.

5. CONCLUSION

Thus, after analyzing the known approaches and methods for assessing the effectiveness of Smart City projects, the authors concluded that the main integral indicator of evaluating such projects is the sustainability of an innovative city, which should be measured in three categories: the standard of living of the population and its positive dynamics, the effectiveness of city administrations, and the economic, social, cultural and environmental competitiveness. The positive dynamics of the integral indicator of the innovative city sustainability characterizes the effectiveness of Smart City projects being implemented. In a reverse situation, such projects might be rendered ineffective. Also, the revealed presence of dependencies and trends in the rating of Smart Cities, as well as a certain possibility of classifying them into the above groups, may allow developing prospective economic and mathematical models for assessing the economic and social effects of the implementation of Smart City projects. This will require an improvement of the methodology for computing rating indicators, an extension of the list of indicators used and the availability of their values over several years while developing a database of cities.

The authors believe that to improve the methodology for assessing the effectiveness of Smart City projects, the rating approaches for performance evaluation of the municipalities of the Russian Federation constituent entities are also required. There are quite many such approaches available now; therefore, the authors have conducted a study to identify the relationships between the indicators of the proposed ratings and to be able to classify and improve the list of indicators used. It was determined that when implementing projects for the strategic development of municipalities at the local level, indicators of assessing the living standards should be considered as the most significant. Against this background, the Smart City projects should focus on the application of technological approaches to the organization and management of urban infrastructure, on the needs and competencies of human capital, as well as on increasing the values of qualitative and quantitative indicators characterizing the effectiveness of the urban resources management process, and increasing the assessment indicators characterizing the condition and the level of development of the urban environment and its ability to meet the requirements of residents at the level of living standards generally accepted for the established period.

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