Smart city assessment matrix

Evgeny Popov[1] and *Konstantin* Semyachkov[1,2]

[1]Ural Institute of Management, RANEPA, 66, 8 Marta st., Ekaterinburg, Russia
[2]Institute of Economics, the Ural Branch of Russian Academy of Sciences, 29, Moskovskaya st., Ekaterinburg, Russia

Abstract. The purpose of this study is to create a methodological approach for assessing the development of smart cities. An analysis of existing approaches to assessing the development of smart cities showed that, in general, three main types of such methods can be distinguished. First, these are approaches based on the study of certain components of a smart city. Second, the levels or stages of smart city development. Thirdly, certain narrowly focused areas for studying the development of smart cities (for example, ecology). Based on the systematization of approaches to assessing the development of smart cities, the author's approach is proposed, which consists in combining the study of the components of a smart city and the stages of its development.

1 Introduction

In the context of the development of a digital society, traditional theories of economic development of territories often lose their predictive properties. Increasingly, theories of regional competitiveness are trying to fill this gap through the study of intangible assets such as knowledge, social connections, human and intellectual capital accumulated in a given territory. The basis for the development of intangible assets in modern conditions is digital technologies. Therefore, digital technologies are increasingly considered as the main driver of development, capable of solving most of the problems of modern society as a whole, as well as individual territories, regions and cities. Modern cities are increasingly becoming the object of research in the context of the impact of digital technologies, finding ways to solve problems such as urbanization of territories, environmental changes under the influence of humans, and socio-economic instability. In this regard, one of the promising models of spatial development is the smart city model, the basis for the formation of which is digital technologies [1, 2].

Modern science is actively developing a theoretical and methodological apparatus that describes the processes of functioning of smart cities. Interest in the development of smart cities is manifested in most countries of the world, which indicates a great interest in the formation of new conditions and principles for the development of modern cities. This focus generates a significant number of approaches to the consideration and analysis of smart cities. Among the main approaches to considering smart cities, we can single out a component approach, a staged approach, as well as more specialized approaches designed to assess the state of a particular area of a smart city. The component approach boils down to considering the main subsystems or components of a smart city. Usually, 6 components

of a smart city are distinguished: smart mobility, smart environment, smart living, smart economy, smart governance, smart people [3, 4].

An approach that characterizes a certain sequence of development of a smart city, stages or levels of a smart city can be called a milestone. The main idea of this approach is that in order for a city to become smart, it needs to go through several stages, consisting in creating a certain infrastructure, collecting and analyzing data, using this data in decision-making systems with the aim of improving the quality of life of citizens, reducing emissions pollutants, increasing the efficiency of using various resources and achieving other socio-economic effects.

More specialized approaches to the study of smart city development focus on specific areas of the functioning of urban systems. A significant number of such studies are devoted to the use of digital technologies in urban environments. Indeed, it is safe to say that the use of digital technologies in the urban environment makes modern cities smarter [5].

Due to the rapid population growth, many cities face two conflicting challenges. On the one hand, urban economy is based on overexploitation of resources, pollution of the environment, and the desire to achieve economic growth at any cost. On the other hand, more and more attention is paid to environmental issues, rational use of resources and environmental protection [6-8]. The methodological basis for analyzing the development of smart cities can be the well-known model of the triple helix, which is a network mechanism for the formation of an innovative environment. The triple helix model describes the interaction of the main actors of the post-industrial society, government, business, science, society in order to form a consensus on the principle of coordinating joint actions by means of network forms of organizing relations. As the experience of successful projects in the field of digitalization of the urban environment shows, only joint activities and the integration of common efforts of all stakeholders is a condition for the formation of long-term and sustainable growth that can improve the quality of life of urban residents [9].

Real practice shows that it can take a long time for a city to become truly smart. This transition is complicated by many factors of an economic, social, institutional, technological nature [10]. However, the desire to improve the quality of life, solve socio-economic problems and achieve economic growth requires the introduction of smart solutions in the field of infrastructure, water supply, energy, transport, health, education and security, that is, smart solutions for new cities [11, 12]. This raises a number of questions that require the development of adequate solutions [13, 14]. Due to limited resources, it is necessary to identify the most important areas of city improvement. To describe a smart city and its characteristics, it is necessary to develop an understandable model, characterized by certain indicators for assessing smart cities.

2 Methods

As an object of research, this article examines the modern concept of digitalization of cities in various ways of economic activity. The subject of this study is the socio-economic relations that are formed in various spheres of the economic application of digital technologies in modern cities. The theoretical basis of the study is scientific research, reflected in periodicals, as well as the author's results of the study of digitalization processes in modern cities. The research method consists in a systematic logical analysis of various stages of digitalization and directions of development of modern cities.

3 Results

As the experience of digitalization of the urban environment and the development of modern cities show, this process is associated with the passage of a number of stages. From our point of view, there are 7 stages (priorities) in the development of a smart city. On the other hand, as the experience of the development of smart cities shows, they are based on certain components (smart economy, smart management, etc.). Thus, we propose an approach that takes into account both the stages of development of smart cities and the main components of such development (Table 1). This matrix approach allows us to assess the evolution of the development of a smart city and its main characteristics.

Table 1. Smart city development assessment matrix.

Components → / **Levels ↓**	**Smart economy**	**Smart living**	**Smart governance**	**Smart people**	**Smart envoironment**	**Smart mobility**
Institutions	InsEc	InsSl	InsGo	InsPe	InsEn	InsMo
Infrastructure	InfEc	InfSl	InfGo	InfPe	InfEn	InfMo
Intranet	IntEc	IntSl	IntGo	IntPe	IntEn	IntMo
Integration	IngEc	IngSl	IngGo	IngPe	IngEn	IngMo
Interfaces	IfcEc	IfcSl	IfcGo	IdcPe	IfcEn	IfcMo
Innovations	InnEc	InnSl	InnGo	InnPe	InnEn	InnMo
Implementation	ImpEc	ImpSl	ImpGo	ImpPe	ImpEn	ImpMo

where:

InsEc (Institutions for Economy): strategies, plans for the development of a smart economy; *Institutions for Smart living (InsSl):* strategies, plans for the development of a smart urban environment; *InsGo (Institutions for Governance):* strategies, plans for the development of smart governance; *InsPe (Institutions for People):* strategies, plans for the development of human capital; *InsEn (Institutions for Environment):* strategies, plans for the development of a smart environment; *InsMo (Institutions for Mobility):* strategies, plans for the development of smart mobility; *InfEc (Infrastructure for Economy):* infrastructural support of economic activity; *InfSl (Infrastructure for Smart living):* infrastructural support of the urban environment; *InfGo (Infrastructure for Governance):* infrastructure for the control system; *InfPe (Infrastructure for People):* infrastructure for human capital development; *InfEn (Infrastructure for Environment):* infrastructure for environmental protection; *InfMo (Infrastructure for Mobility):* transport infrastructure; *IntEc (Intranet for Economy):* access to the network for employees of companies and economic facilities; *IntSl (Intranet for Smart living):* the number of public WI-FI access points in the city; *IntGo (Intranet for Governance):* access to the network for employees of municipal organizations; *IntPe (Intranet for People):* access to the network among the population; *IntEn (Intranet for Environment):* environmental quality control systems with Internet access; *InfMo (Intranet for Mobility):* public transport equipped with wireless internet; *IngEc (Integration for Economy):* the number of open data sets that are published in the public domain; *IngSl (Integration for Smart living):* the number of open data sets that are published in the public domain; *IngGo (Integration for Governance):* the number of open data sets that are

published in the public domain; *IngPe (Integration for People):* the number of open data sets that are published in the public domain; *IngEn (Integration for Environment):* the number of open data sets that are published in the public domain; *IngMo (Integration for Mobility):* the number of open datasets that are published in the public domain; *IfcEc (Interfaces for Economy):* user interaction interfaces with the smart economy system; *IfcSl (Interfaces for Smart living):* user interaction interfaces with the smart city environment system; *IfcGo (Interfaces for Governance):* interfaces of user interaction with the smart government; *IdcPe (Interfaces for People):* interfaces of user interaction with the human capital development system; *IfcEn (Interfaces for Environment):* user interaction interfaces with the environmental protection system; *IfcMo (Interfaces for Mobility):* interfaces for user interaction with the transport management system; *InnEc (Innovations for Economy):* opportunities for creating innovations in the economic sphere; *InnSl (Innovations for Smart living):* opportunities for innovation in the urban environment; *InnGo (Innovations for Governance):* opportunities for innovation in municipal governance; *InnPe (Innovations for People):* opportunities for creating innovations in the field of human capital development; *InnEn (Innovations for Environment):* opportunities to create innovation in the field of environmental protection; *InnMo (Innovations for Mobility):* opportunities for innovation in the transport sector; *ImpEc (Implementation for Economy):* introduction of innovations in the economic sphere; *ImpSl (Implementation for Smart living):* implementation of innovations in the field of smart urban environment; *ImpGo (Implementation for Governance):* introduction of innovations in the field of municipal management; *ImpPe (Implementation for People):* introduction of innovations in the development of human capital; *ImpEn (Implementation for Environment):* implementation of innovations in the field of environmental protection; *ImpMo (Implementation for Mobility):* implementation of innovations in the transport sector.

In general, from our point of view, a matrix approach to assessing the development of smart cities based on assessing the stages of their formation, as well as studying the components of a smart city, is more consistent with the tasks of such studies and is more comprehensive and adequate in cases of analyzing the functioning of smart cities. It is worth noting that the list of indicators for assessing the development of a smart city given above cannot be called final or exhaustive. This is due to the fact that, firstly, the technologies used in the development of smart cities are changing, which, accordingly, affects the indicators used to assess the development of smart cities, and secondly, the very priorities of assessing the development of certain cities often change. Currently, it is not uncommon for a situation when, even within the framework of one methodological approach developed by a certain organization, in different years of research, a different set of indicators for assessing the development of smart cities is used, which indicates the variability of views on the processes taking place in modern cities.

4 Conclusions

A key challenge in assessing smart city development is to create standardized smart city metrics that provide meaningful assessment that is city and citizen focused. Currently, national and international standardization initiatives play an important role in the development of smart city standards and indicators, shaping approaches to assessing urban development. Moreover, standardized measurement indicators provide value for development policy and the potential to transform the governance of modern cities. Thus, a methodological approach to assessing the development of smart cities should take into account both strategic plans and priorities for the development of the urban environment, and the effects obtained from the implementation of these projects. The assessment plan should be consistent with smart city projects, the levels of project implementation and their

scale, and should be developed in cooperation with the main stakeholders of urban development, their interests in the implementation of projects. Consideration should be given to the choice of methods for assessing urban indicators and data sources that can determine the impact of smart city projects on the lives of citizens, as well as measure the socio-economic and environmental effects of smart city development.

Holistic approaches to the design of systems for assessing the development of smart cities are necessary to involve experts and stakeholders of the urban community in the assessment processes, solving problems at the level of projects, programs and cities. The integration of assessment methods into city performance management processes is essential to determine the value, results and benefits of intellectual development for cities and people. Thus, it gives an understanding of how effectively modern urban problems are being solved through the introduction of digital solutions and the implementation of smart city projects.

As a result of the study, the author's approach to assessing the development of smart cities is proposed, based on highlighting the development levels of a smart city (model 7I) and a smart city component (smart economy, smart governance, smart city environment, smart people, smart mobility, smart environment).

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