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"Smart City" Management: Environmental and Ecosystem Sustainability

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Abstract

This paper aims to analyse the potential of "smart city" management facilitated through the integration of economic-legal and technological tools.

Based on an expert survey, measures are identified to integrate economic-legal and technological tools in the concept of "smart city" management, and a model of "smart city" management is developed. Foreign practices of "smart city" management are reviewed in the context of raising environmental and ecosystem sustainability.

It is shown that "smart city" management is contingent upon the implementation of specific measures to integrate economic-legal and technological tools, as well as on the development of a model of "smart city" management and adoption of existing foreign practices in raising environmental and ecosystem sustainability.

Keywords: Urbanization, Smartisation, Information and Communication Technology, Internet of Things, Big Data Analysis.

1. Introduction

Despite the spread of suburbanisation in developed countries, globally, the trends are still toward the growth of cities and, accordingly, growing urban populations (Goryainova: 2020; Deeva et al.: 2020). The WHO estimates that by the 2030s, 60% of the world's population will reside in urban

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areas. Such rapid growth of urbanisation is likely to cause excessive pressures on urban infrastructure and result in environmental problems (Halpern et al.: 2013).

To mitigate potential risks that will inevitably occur in overpopulated cities, the solution might be to implement the "smart city" concept (Fiofanova: 2020; Kirillova et al.: 2019; Kozlov et al.: 2020). It is also likely that "smart cities" can right now significantly improve living standards in major cities and agglomerations with millions of populations (Gogiberidze et al.: 2020; Bancerova: 2020). This approach would enable prompt response in complex situations and smooth coordination. It would also contribute to better quality and resource efficiency of services, in particular, with regard to spending. All city utilities would operate in a single information environment, resulting in improved service standards and better environmental and ecosystem sustainability and enabling real-time public control of their performance (Deakin, Al Waer: 2011; Glebova et al.: 2019).

A major proponent of "smart city" transformations has been the European Union. In 2009, the EU approved the Smart Cities and Communities Industrial Initiative, which came into effect on June 21, 2011, and regulated the development of framework initiatives to introduce energy efficiency and environmental security principles in the energy sector and transportation. June 10, 2012, marked the beginning of cooperation between EU member states under the European Innovation Partnership on Smart Cities and Communities, which integrated the foundation of the EU Industrial Initiative combined with the development of information and communication technology. On October 14, 2013, the EU adopted the Strategic Implementation Plan, which took effect in early 2014 under the European programme Horizon 2020 (Kola-Bezka et al.: 2016).

The primary lines of modernisation and improvement were energy-efficient housing and transportation, prudent management of energy, deployment of information and communication systems across the utility sectors and so on (Savina et al.: 2020; Nurutdinova, Bekisheva: 2020). Examples of investment programmes in "smart cities" in the EU are COOPERATE (Control and Optimization for Energy Positive Neighbourhoods), BESOS (Building Energy decision Support systems fOr Smart cities), DAREED (innovative business models and energy efficiency), EPIC-HUB (Energy-Hub approach) and others (Sujata et al.: 2016).

2. Literature Review

J.M. Eger (2009) proposed a classification of major cities trending toward service smartisation according to three types: magnet cities, i. e., major economic centres or capitals attractive from the employment and livability perspectives; strategy cities implementing high-technology projects, innovation concepts targeting improvements in long-term comfort of living for residents; innovative cities which survived a crisis as a result of the demise of traditional economic industries and were able to employ an innovative approach to set new growth spots and attract intellectual resources.

Under this concept, "smart cities" are understood not as objects of public governance but as objects of spontaneous economic development, which is not always driven along a set strategic course.

Another approach is adopted by the developers of the concept of European "smart cities" from the Vienna University of Technology. In their view, a "smart city" is a management category, a city that makes optimal use of all the interconnected information available today to better understand and control its operations and optimize the use of limited resources, including those of its residents (Neirotti et al.: 2014).

Consider what comes into the notion of a "smart city" through the lens of different approaches to its interpretation. Table 1 lays out definitions of the notion of "smart city" through the lens of institutional, social, economic and technological approaches and the integrated management approach based on them.

Table 1 - Definitions of a "smart city" through the lens of different approaches

Approach	Definition of a "smart city"
Institutional approach	A city connecting the physical infrastructure, the IT infrastructure, the social infrastructure and the business infrastructure to leverage the collective intelligence of the city (Al-Hader, Rodzi: 2009)
	A city that makes a conscious effort to innovatively employ information and communication technologies (ICT) to support a more inclusive, diverse and sustainable urban environment (Albino et al.: 2015)
	A "smart community" shaped and aligned around a system of specialised institutions integrated into the urban environment (Hollands: 2008)
Social approach	A city well performing in a forward-looking way in six smart characteristics (factors): smart economy, smart mobility, smart environment, smart people, smart living, smart governance, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens (Shapiro: 2006)
	A comfortable livable environment created, in particular, through the efficient use of human factor and intellectual capital to support progressive institutional and economic transformations in the city (Komninos: 2011)
Economic approach	A city well performing in a forward-looking way in economy, people, governance, mobility, environment and living built on the smart combination of endowments and activities of citizens and fueling sustainable economic growth and high quality of life, with a wise management of natural resources, through participatory governance (Bronstein: 2009)
Technological approach	A city combining ICT and Web 2.0 technology with other organizational, design and planning efforts to dematerialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity to improve sustainability and liveability (Maeda: 2012)
	A city where computing technologies are used to make the critical infrastructure components and services of a city – which include city administration, education, healthcare, public safety, real estate, transportation and utilities – more intelligent, interconnected and efficient (Kourtit, Nijkamp: 2012)
Integrated management approach	A city that monitors and integrates conditions of all of its critical infrastructures, can better optimize its resources, plan its preventive maintenance activities and monitor security aspects while maximizing services to its citizens (Paskaleva: 2009)
	The term refers to the relation between the city government administration and its citizens. Good governance or smart governance is often referred to as the use of new channels of communication for the citizens, e. g., e-governance or e-democracy (Deakin et al.: 2011)

The above classification of definitions according to the four proposed approaches helped us to aggregate the findings and arrive at our own definition of a "smart city" following the integrated management approach, referring to a complex and multi-factor municipal system combining institutional, social, economic, environmental and technological constituents ensuring, through their efficient, well-aligned and integrated operation, sustainable urban development and better usability of improved services.

This paper aims to analyse the potential of "smart city" management facilitated through the integration of economic-legal and technological tools.

Objectives:

- to define measures to combine economic-legal and technological tools;
- to propose a model of "smart city" management;
- to analyse foreign practices of "smart city" management in the context of raising environmental and ecosystem sustainability.

Research hypothesis: "Smart city" management is contingent upon the implementation of specific measures to integrate economic-legal and technological tools, development of a model of "smart city" management and adoption of existing foreign practices in raising environmental and ecosystem sustainability.

The findings suggest that the research objective is met.

3. Methods

The research was conducted from 05.08.2020 to 25.09.2020.

The following general scientific methods were used to address the objectives:

a) theoretical methods: analysis of peer-reviewed scholarly sources on the subject to find the aspects of the management approach to a "smart city" and a review of foreign practices of "smart city" management;

b) empirical methods: an expert survey. The experts were asked to address the following objectives: to determine measures to integrate economic-legal and technological tools, to substantiate technical instruments of a "smart city" management model, to refer to foreign practices to showcase main requirements to the "smart city" management.

The first stage of research involved the analysis of available data and scholarly papers on the subject.

The second stage involved the development of a questionnaire as a semi-formalised list of questions concerning the problems of "smart city" management.

The third stage involved conversations with the experts (online) in accordance with the performed questionnaires. The survey was conducted in Russian on 16.09.2020 among the experts (30 individuals), specifically municipal officials with more than five years of professional experience in digital adoption in urban management. All participants were notified regarding the purpose of the survey and the intent of the organisers to publish the findings in aggregate.

4. Results

According to the experts, efficient "smart city" management requires the implementation of measures to integrate economic-legal and technological tools (Table 2).

Table 2 - Measures to integrate economic-legal and technological tools

Item	Measures	%*
1	legal and regulatory support of e-governance development locally	85%
2	development of proper "smart city" infrastructure at the city level	82.5%
3	ensuring security, specifically, cybersecurity	82.5%
4	efficient operation of administrative service centres, including e-services	80%
5	setting up collaboration and e-docflow systems	80%
6	proper operation and content management of the city's official website	77.5%
7	citizen participation in local governance decision-making (e-petitions, e-consultations, e-discussions and other instruments of e-democracy)	77.5%
8	provision of open data access	75%
9	public initiative support	72.5%
10	open budget	70%

Note: based on the expert survey; * indicates the percentage of expert references

Based on the expert survey, a model of "smart city" management was developed with a focus on the quality of functioning and organisation of the objects of an urban environment using modern technology to accommodate the needs of people and improve environmental and ecosystem sustainability (Table 3).

Table 3 - A model of "smart city" management

Item	Technical elements	Expert input
1	Broadband connections	Unrestrained Internet access contributes to a better business environment and progress in the city and results in better economic performance
2	Internet of Things/Internet of Everything (IoT)	A concept of a communication network of physical or virtual objects ("things") powered by technologies enabling their interaction between each other and with surrounding environments, as well as perception, communication and generation of new information without human engagement. The use of measuring devices, sensors, video cameras, GPS devices, thermostats and weather stations, drones to monitor traffic, weather and CO_2 levels, track the routes of public transport, control emergencies in utilities, safety of buildings, etc. The concept of "smart city" means these devices would be interrelated, interoperable and linked to a single city operating platform
3	Smart personal devices	Providing residents and visitors with the opportunity to use personal devices (smartphones, tablets) for their own needs by developing useful applications for prompt and qualitative use of e-services, tourist routes and information, the opportunity to track public transport services and congestion, locate free parking spaces, take part in voting, submit petitions, attract consultations, etc.
4	Cloud computing	Sets of technologies of data storage and/or processing as services offered to the customer by the provider using hardware and software available on the Internet with the traditional client-server architecture
5	Big data analysis	Big volume, high speed and wide range of information assets requiring new forms of operation, including more wide-ranging decision-making and process optimisation. Big data for "smart cities" provide an opportunity for transition to a higher quality of management and improved response to numerous needs of residents and the city as an ecosystem. Big data is a new technology requiring considerable investment and powerful IT-infrastructures. Technological standards contribute to quality decision-making related to technology

Note: based on the expert survey.

5. Discussion

As can be seen from foreign practices, "smart cities" are largely powered by flexible telecommunications architecture, open platforms and continuous monitoring. Urban "smart infrastructures" are developed on modular (cassette) technologies.

"Smart city" systems crucially integrate sensors, meters (wired or wireless) and various peripheral devices transmitting on-line data to the processing centre on a continuous or regular basis.

E. g., the information and communications networks in Santander, Cantabria, in northern Spain integrate more than 20,000 sensors (to register pollution levels, noise, traffic, parking, etc.), buildings, utility grids (water supply, gas, electricity, lighting), transport links, utility and support services. Such "smart infrastructure" facilitates efficient urban operation, coordination of services and institutions and helps to ensure proper security (Aletà et al.: 2017).

Over the past decades, "smart cities" have operated broadband telecommunication networks to provide e-services and monitor the ecosystem in a cluster, community or region. Berlin has been advancing intellectual networks powered by Big Data and analytical processing of data from global monitoring of the vital structures of the megapolis (Harris: 2014).

Across the world, green "smart cities" have been on the rise recently as an innovative model based on the digitalisation of municipal development and facilitating not only cardinal improvements in prosperity and living standards but also environmental security and energy-saving. A major proponent of "smart city" transformations has been the EU.

A green IT strategy has been developed and implemented in Stockholm as part of the "smart city" strategy. The Green IT strategy aims to reduce the environmental footprint by using such IT functions as energy-efficient buildings, monitoring traffic and development of e-services (Bibri, Krogstie: 2020b).

London, which is one of the leaders of digital adoption in municipal governance among European "smart cities", experimented to set a green area, i. e., an area of restricted access in the city centre, which helped to considerably decrease harmful emissions in the air due to an increase in the speed of vehicles by 15-20% and lower congestion in the streets and helped businesses save fuel costs and ensure timely delivery of orders. In Barcelona, one of the leading cities in advancing IoT solutions in urban governance, garbage containers track the volume of waste and optimise garbage

collection routes; new sensors are able to detect harmful and dangerous waste (Bibri, Krogstie: 2020a).

In June 2014, the Smart City Wien Framework Strategy was adopted, which envisaged the introduction of advanced solutions powered by ICT. The strategy will be implemented till 2050 to facilitate gradual and continuous modernisation of the city which is meant to produce: energy consumption cuts, reductions in greenhouse gas emissions without abandoning the technology responsible for their accumulation, mobility driven by broadband, intellectual ICT and innovative solutions; responsible efficient use of resources; efficient methods of organisation of urban transport networks; protective management of water resources, waste, heating systems and lighting in buildings, streets, ad or information billboards, etc., interactive method of work in urban administration; improved security in public spaces (Kylili, Fokaides: 2015).

According to the experts, a functional, optimal and reasonable system of managing a "smart city" is the one generating data, integrated down to the detail level, which may be analysed and allows optimisation of such principal resources and urban functions as transport, infrastructure, energy, public health and security. When using such data gathering tools, cities may be unaware of the directions and methods of how to improve the functioning of the urban environment. All such data is practically invisible and cannot be seen physically, but if a prudent approach is adopted to gather city data to inform decision-making, local living standards would improve significantly. It is also crucial that such data should be integrated at the lowest granular level and systematised in a single picture.

It is specifically data integration that is, according to the experts, a city's path to become a "smart city." To enable data integration and processing, city administrations should prepare in advance. One of the first steps toward rising as a "smart city" is the analysis of the already available "smart city" systems and the respective data. The focus should be also placed on the existing models of data gathering and processing. Based on the above, city authorities have the opportunity to determine optimal programmes and architectures for storing, merging and using data according to the functional purpose and take strategic management decisions based on the expected outcomes.

6. Conclusion

Following a concept analysis of the notion of "smart city" through the lens of institutional, social, economic, technological and integrated management approaches, as proposed in previous research, we refined the category framework of the subject area of this research.

In a general sense, a "smart city" is a system facilitating the most efficient use of available resources of city services and ensuring maximum security of city life. Such city ceaselessly raises the number and quality of services for people, while ensuring the sustainability of the environment to support comfort and the quality of life through such improved environmental and ecosystem sustainability.

From the point of public governance, a "smart city" is a managed and multi-factor complex system integrating the above components and aligning them with the context of sustainable development. The purpose of development in such system is to ensure improved comfort of urban life and environmental security, a key requirement underlying the idea of what is reasonable in city management.

As can be seen from the findings and review of foreign practices, the research hypothesis holds that "smart city" management is contingent upon the implementation of specific measures to integrate economic-legal and technological tools, development of a model of "smart city" management and adoption of existing international practices in raising environmental and ecosystem sustainability.

Further substantiation is needed to derive a complex of scholarly propositions to build the principal methodological basis for implementing and continuous improvement of the "smart city" system for big Russian cities, which should be facilitated by the adoption of corresponding methodological and technological support for these processes.

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