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ARTICLE

SMART CITY: INTEGRATION OF INFORMATION AND COMMUNICATION TECHNOLOGIES

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ABSTRACT

Rapid environmental degradation, substantial complication of municipal facilities and urban interrelations result in increased interest to the problem of steady economic development regarding metropolitan agglomerations, which assumes implementation of three interrelated constituents in the frames of smart city concept: economic, environmental, and social. The research is aimed at determining smart city concept in terms of environmental development and ecosystem sustainability. In order to achieve the goal set in the research, the authors have defined approximate set of theoretical (analysis, synthesis, comparison, generalization) and empirical (survey) methods. Theoretical methods implied studying scientific literature on the state of the research problem; while the main research method was surveying. Students and experts were invited to fill in a semi-formalized questionnaire on a voluntary basis. The main provisions of the problem have been theoretically analyzed in this article, including analysis of smart city concept and its properties. On the basis of expert survey, the main constituents of smart cities have been determined, the actions required for implementation of smart eco-city concept have been defined, and the existing project types of smart eco-cities in the world have been identified. The research results have shown that currently quite a few cities have adopted the "smart city" concept as the main direction of their activities; however, significant obstacles to the implementation of the smart city concept are created by a lack of funds and legislative incentives. The results of the research have confirmed that the implementation of the smart eco-city concept is possible after implementing specific measures and using the existing foreign experience depending on the natural conditions of the territory.

KEY WORDS
smart city; environment; environ mentalization; smart eco-city; Internet of Things

INTRODUCTION

Nowadays the term "smart city" is used more and more widely in reports of politicians and governmental officers, in titles of public discussions, scientific conferences, as well as in mass media [1, 2]. According to Allwinkle and Cruickshank [3], in recent decades due to wide access to Internet and miniaturization of electronics, development of nanotechnologies, the smart city concept has been mainly used for presentation of a city as an efficient robot. This concept was created in hi-tech corporations, such as IBM, Cisco, Microsoft, and Software AG, which expected to acquire significant profit from municipal contracts [4]. One of the most common scientific definitions of smart city has been proposed by R. Hollands [5]: smart city is a city perspective in terms of economy, population, management, mobility, environmental protection, and quality of life, based on successful combination of contributions and activity of purposeful, independent, and conscious citizens.

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Batty et al. [6] defined the smart city as instrumented, interrelated, and intelligent city. Tools provide data acquisition and collection using sensors, personal devices, cameras, smartphones, implanted medical devices, Internet, and other data collection systems, including social networks as human sensors. Interaction means integration of these data into the system of corporate settlements and interrelation of these data with municipal services. Intelligence means involvement of complex analytics, simulation, optimization, and visualization in operational business processes aiming at adoption of best operative decisions. Dameri and Benevolo [7] believe that smart city can be considered as large organic IT system, which combines numerous integrated subsystems and components. Deakin and Al Waer [12] compare smart city with a body with an artificial nervous system, which allows the city to perform intelligent and coordinated actions. Vanolo [8] concentrates attention on improvement of stability and ordering (availability for life) of the city. Lombardi P. et al. [9] consider smart city as a combination of intelligent computation techniques for infrastructure services. Such techniques present new generation of integrated equipment, software, and network technologies, which allow to use IT system online aiming at optimization of business projects [10-12]. Capra [13] believes that the smart city concept means efficiency based on intelligent management and integrated information and communication technologies, as well as active participation of citizens. New type of management is considered – real participation of citizens in governmental policy [14-16].

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The researchers in [17] summarized the properties of smart city: the use of network infrastructure aiming at improvement of efficiency of economic and political spheres of urban life, as well as promotion of social

and cultural transformations; ability and possibility to attract and deploy new business projects; implementation of innovations for social integration; coexistence and complementarity of hi-tech equipment and infrastructure; attention to the role of social and relational capital; provision of environmental stability. Shapiro [18] concentrated attention on interrelation between various properties of smart city, including social and intellectual capital, health, and management. The applied approach was based on the triple helix model. Another point of view is shared by the researchers in [19] who consider social innovations as the main goal of smart city, and the smart city itself is developed for creating managerial, infrastructural, and engineering conditions for implementation of social innovations, solution of social problems aimed at economic growth, including improvement of quality of life, with participation of various local entities: citizens, business, and corporations.

This research is aimed at analysis of the smart city concept in terms of development of environment and stability of ecosystems. The considered hypothesis is as follows: implementation of the smart eco-city concept is possible after execution of certain actions and application of existing foreign experience depending on natural conditions of territory. Based on the obtained results, it is possible to conclude that the formulated aim of the research has been achieved.

METHODS

In order to achieve the formulated target, the authors determined approximate set of theoretical and empirical research methods: theoretical methods (analysis, synthesis, comparison, generalization) to analyze scientific publications devoted to the state of research problem; empirical methods (survey).
Surveying was the main method. Students and experts were proposed to fill voluntarily semi-formalized questionnaire. Experts (40 persons), officers of municipal authorities, employees of IT companies involved in implementation of information technologies into operation of municipalities for more than 10 years, participated in the survey. The experts were proposed to answer a number of questions concerning environ mentalization of smart cities, opportunity to implement the concept of smart eco-city in Russia, as well as international experience of implementation of smart eco-city concept. All participants in the surveys were informed about the final aim of survey and about intention to publish the survey results in generalized form.

The study of the smart city concept in terms of environmental development and ecosystem sustainability was carried out in three stages: preparatory, during which the goal and hypothesis of the research were formulated, the questions posed to the experts were developed; the main one, which was carried out within 20 days and included the practical implementation of an expert online survey, the final one, which provided for the analysis and interpretation of the data obtained.

RESULTS

Main constituents of smart cities environ metallization

According to the opinion of surveyed experts, the main constituents of smart cities environ metallization are as follows [Table 1]:

Table 1: Main constituents of smart cities environ mentalization

No.	Environmentalization constituents	%*
1	Development of renewable power generation within the city boundaries, namely: wind, solar, geothermal, etc., depending on natural conditions of territories	90%
2	Construction of energy efficient buildings consuming minimum electrical and thermal power	87.5%
3	Decreasing demand in automotive transport due to optimum planning of territory, development of bicycle transport, as well as accurate operation of municipal transport	85%
4	Provision of high portion of green areas in cities and stability of natural systems and biodiversity in their frames	82.5%
5	Minimization of formation of solid wastes, provision of their classification and maximum deep reprocessing	80%

Note: based on expert survey; * – percent of expert references

Measures to implement the smart eco-city concept

For the full implementation of the smart eco-city concept in a single modern Russian city, experts listed the actions shown in [Table 2].

Efficient execution of all listed actions should be based on wide promotion activity among citizens, mainly regarding the aspects of green construction and necessity to increase the cost of energy carriers and transport services. It would be appropriate to oblige developers to apply modern technologies and environmentally safe materials for construction of new buildings. Taking into account long-term pay-off period of such investments, it is necessary to develop exemption scheme for house owners.

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Table 2: Actions of smart eco-city concept implementation

No.	Action	Substantiation
1	Development of experimental passive house adapted to local climatic conditions	This would initiate new projects in this field and increase popularity among population. In some years it would be possible to develop experimental residential complex based on the concept of passive house at affordable prices
2	Obligatory insulation of houses with simultaneous reconstruction of facades and repair of utility systems	It is important most of all for historic areas of cities, practical implementation can be facilitated by private investors interested in development of facilities of touristic infrastructure
3	Development of electric transport	This can be supplemented by ordering of transport traffic, in particular, by administrative prohibition of traffic in certain places and at certain times
4	Modernization of heat supply system	Among other things, this should stipulate opportunity to operate using various fuels, including renewable power sources

Note: on the basis of expert survey

Experience in implementing the smart eco-city concept

The experts' opinion is that the smart eco-city concept should not be considered as absolutely new since it is directly interrelated with the concept of steady development, which assumes achievement of balance between environmental and social constituents upon provision of economic growth. In addition, according to one of the surveyed persons, close relation with green economy is observed since traditionally cities are sources of economic life and it is the economy of cities that should be modified accounting for critical pollutions of all environmental components. The experts believe that an important issue is as follows: should smart eco-cities be considered as an ideal model which cannot be implemented in the nearest future, or as the trend of practical activity, which should be reflected in program documents and implemented in projects and urban specifications?

The experts' survey demonstrated that the incentives regarding construction of environmental settlements in the last 20 years were received from public organizations, governments of countries with high economic growth (China, United Arab Emirates), construction companies, and territorial communities. The existing models of eco-cities are quite different in terms of scale, target purpose, the rate of environmental safety and others.

The experts highlight four project types of smart eco-cities [Table 3].

Table 3: Projects of smart eco-city

No.	Project of smart eco-city	Name, location	Peculiar features of smart eco-city
1	Extensive future projects	Masdar City, United Arab Emirates	Not completed. Total conversion to renewable power sources (solar and wind) and total reprocessing of wastes. The city area will be 700 ha with 50 thousand inhabitants. After completion of the project the main specialization of the city will be scientific and educational activities in the field of eco-technologies.
2	Smart eco-cities near developed municipal settlements	Dongtan, Shanghai (China)	The city is located 15 km from Shanghai. The project would provide for 80% recycling and 100% power supply from renewable sources. The basis of the economy is eco-industry, R&D projects in the field of eco-technologies, management of wastes, etc. Population of the city is 25 thousand inhabitants (the first stage was commissioned in 2010).
		Songdo, Seoul (South Korea)	The city has certain specialization: tourism, international trading of high-tech products, logistics. Peculiar attention is paid to transport and modern telecommunications, which should be used everywhere. Environmental characteristics: high level of energy efficiency, collection and reprocessing of wastes, efficient use of water resources.
3	Retrofitting of municipal areas	Vauban, Freiburg (Germany)	Former French military base, completely reconstructed in 2000. The main principles: no transport except for bicycles, power generation from renewable sources (mainly solar power).
4	Development of small eco-settlements in environmentally clean areas	St David's (Wales, Great Britain)	The smallest town in Great Britain located in Pembrokeshire Coast National Park. The town community initiated conversion of local economy to low carbon model of development.

Note: on the basis of expert survey.

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The performed analysis of foreign experience of implementation of smart eco-city concept allows to state that the concept was transformed from an ideal resource consuming model to the problem with several acceptable pragmatic solutions. For Russia with wide spectrum of environmental urbanistic problems, according to the opinion of most surveyed experts (85%), the most acceptable are the third and the fourth types of smart eco-cities. Evolutional approach to solution to energy saving issue, solution to the issue of domestic wastes, reasonable use of natural zones are at present the most preferred actions in Russia concerning environ metallization of cities. As mentioned by Zygiaris [20], modern understanding of smart city concept assumes higher environmental safety in several dimensions: a) public services and behavior of consumers; b) environmental efficiency of industrial production; c) incentives for consumers; d) support for research in the field of innovative use of environmentally friendly technologies. Thus, in North America these are San Francisco (USA) and Vancouver (Canada). The latter receives 90% of electric power from renewable sources.

The concept of smart eco-city is developed most intensively in the countries of Northern Europe, where numerous projects are proposed: decentralized electricity supply (Denmark); electric transport (Germany); smart meters (Sweden); combined generation of heat and electricity (Sweden and Denmark); centralized heat supply by means of natural energy sources (Denmark); combustion of biomass in order to obtain electricity (Germany); generation of energy from wastes (Sweden) [21]. When establishing ratings of the quality of life in cities around the world, environmental factors are primarily taken into account: the availability of renewable energy sources, the energy efficiency of buildings, the state of the transport infrastructure, and access to healthy (organic) food. The citizens of Western Europe and North America are interested in economic performances only in combination with environmental components, which is the quintessence of the smart city concept [22]. The scientists believe [23] that smart cities will be major places of IoT activity, such companies as Cisco expect significant business opportunities with respect to provision of wide range of technologies and services required for creation of really smart city: sensors, networks, communications, programs, information panels, data standards, safety, analytics of data, etc. required for all these things aiming at their efficient combination.

Despite the experts' opinion that smart eco-city is just a concept rather than reality, numerous cities initiated programs and projects under the aegis of various incentives [24]. According to the experts' opinion, though there are attempts to develop from scratch new eco-cities (for instance, Masdar City), in most cases the smart eco-city concept is implemented in already existing cities. Their transformation requires for stage-by-stage approach with consideration for existing environmental and social structures. Despite the fact that long-term planning is of decisive importance, it should include identification and determination of preferred steps to be executed to achieve success.

The main initiator of reconstruction of regular cities into smart eco-cities is European Union. Thus, in 2011 European innovation partnership on smart cities and communities became valid, which resulted in development of new frame incentives stimulating implementation of energy efficiency principles and environmental safety in municipal power generation and transport (wind and solar power generation, capture and storage of carbon, a package of energy efficient and environmental standards for vehicles, etc.). In this regard numerous cities execute real projects. For instance, in Copenhagen municipal administration together with businessmen perform the policy of promotion and obligations concerning environmentally safe logistics, decrease in power consumption, environmentally safe energy generation. In Vienna combined efforts of governmental authorities and entrepreneurs resulted in Climate Protection Program aimed at development of integrated, comprehensive and electronic system of transport, logistics and servicing [19]. In Barcelona, one of the leaders of implementation of IoT concept into municipal management, the trash containers monitor amount of waste and optimize routes of garbage collection, new sensors can detect harmful and dangerous wastes [25]. The experts mention that most projects of smart eco-cities in this or that way are related with transport, in particular with reduction of CO2 emissions. Thus, in London, which is a leader of implementation of digital technologies into municipal management in European smart cities, the Green Quarter experiment was initiated: validation of area of restricted access in the city center, which allowed to significantly reduce the amount of harmful atmospheric emissions due to increase in vehicle speed by 15-20% and decrease in traffic jams [26].

In addition, in the frames of the smart eco-city concept, European countries widely use the ideology of passive house, which is partially attributed to implementation of the respective directive regarding energy performances in construction adopted by EU in December, 2009 (stipulates approach of all new buildings to energy neutrality, that is, construction of at least passive houses) [27]. In particular, the experts mentioned that experimental passive houses were constructed in Denmark, USA, Sweden, Canada, Germany. Nowadays accelerated development of the concept is observed in Germany, Austria, Sweden, where passive houses become consistent element of cityscape.

CONCLUSION

There exists urgent necessity to implement projects in the frames of smart eco-city concept in Russia, which is stipulated by high level of pollution of major environmental components and mismatch between activity of numerous entrepreneurs and modern environmental regulations. Among the analyzed types of ecological settlements, in Russia the most acceptable projects are comprised of reconstruction of municipal areas and development of small eco-settlements in environmentally clean zones as less

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expensive variants. Implementation of modernization and construction can be funded by private investments and budgetary ones. In order to promote reasonability of own cities, numerous countries introduce regulations aimed at implementation of power saving technologies, increase in efficiency of municipal services and environmental safety of townscape. Many cities accepted the concept of smart city as primary trend of their activities and had already achieved positive results. However, in most countries, implementation of the smart city concept is inhibited by insignificant funding and legislative incentives, which should facilitate modernization actions. Therefore, the research hypothesis has been confirmed that implementation of the smart eco-city concept is possible in the case of execution of certain measures and application of existing foreign experience depending on natural conditions of territory. The advantage of the research has been the definition of conceptual framework for smart cities environmentalization. The novelty of the research lies in the definition and substantiation of measures for implementing the smart eco-city concept.

CONFLICT OF INTEREST

There is no conflict of interest.

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