Smart City Technologies for Sustainable Rural Development

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Abstract. Smart City technologies are increasingly coming to the population daily living. Smart City technologies provide efficient city services, as a central instrument of receiving various services for residents (energy and water supply, urban infrastructure, transportation etc.). The purpose of research is the definition of methodological approaches of a settlements development modelling. Methods include collation of local and foreign experience in modeling the territorial development of urban and rural settlements. Justification Pentagon-model used for such problems solution was shown. The systems/factors of a rural settlement sustainable development are based on a systematic analysis of existing development models of urban and rural settlements, as well as the authors-developed method for estimating the agro-towns development level. All this allowed to build the rural development model, which consists of five major systems: ecological system, economic system, administrative system, anthropogenic (physical) system and social system (supra-structure). As a results, the methodological approaches for building an estimating model of rural settlements development were revealed (Smart City concept, Pentagon concept). The basic motivation factors that provide communication systems were identified; the critical factors for each subsystem were devoted and substantiated. Such approach was justified by the composition of the tasks for spatial planning of the local and state level offices. The expediency of applying Smart City concept and the basic Pentagon-model that were successfully used in solving the analogous problems of sustainable development was shown.
Key words: Smart City, Smart City concept, Smart Village, sustainable development, settlement system, rural settlement, pentagon model, developmental model, development concept, development factor, critical factor, motivation factor.

1. Introduction

Smart City technologies are increasingly coming to the population daily living. Smart City technologies provide efficient city services, as a central instrument of receiving various services for residents (energy and water supply, urban infrastructure, transportation etc.).

Effective approach for Smart City technologies development is the organization of large-scale international events that require a perfect transport, security and management. A typical example is Rio de Janeiro, a part of Smart City group (figure 1).

Figure 1. Calendar of international events in Rio de Janeiro [1]

Projects of urban development and information technology investment, living conditions improvement, allowed to host large international events in Rio de Janeiro. The city has the second largest gross domestic product (GDP) in Brazil, estimated in \$108 billion (2012), and human development index (MHDI) is equal to 0,799 (the highest in the country among more than 5,000 Brazilian municipalities). The city economy comprises mainly of the service sector – 86%, agricultural sector – 1%, and the rest – industrial sector involving multinational companies Petrobras and Vale and oil industry. The leading Smart Cities include: Moscow, New York, London, Barcelona, Sydney, and St. Petersburg. Typically, Smart Cities are capitals, agglomerations and largest cities due to its economic and human potential. The city administration must have enough funds for implementing Smart City technologies, at the same time, citizens should have high living and education standards for using and functioning the system.

Today the largest cities remained the analogue of the most economic successful civilization centers in world community minds. Besides, it's safe to say that the most successful modern cities thrive because of their ability to «connect smart people» [2].

It should be noted that Urban Development Code of Russian Federation confirms the need of developing the Concept of Information Systems Designed for Urban Planning (ISDUP). These systems are an organized and systematized code of regulations about the territories development, housing, land parcels, capital construction facilities and other information for urban planning. Urban planning documents are public. Therefore, these documents should be the basis for the development of smart city technologies for the successful implementation and monitoring of planning. This will ensure sustainable urban development planning.

2. Materials and methods

The system approach allows obtaining the full information about the object and taking into account the most significant factors for the sustainable system functioning. The basic system properties are wholeness, indivisibility and interrelation. Each system includes a set of smaller subsystems. The overall system properties are not the sum of subsystems properties, i.e. the system has synergistic properties.

The main object of system research is the sustainable development of rural settlements and the settlement system as a whole. The main tasks were formulated to achieve this goal: ensuring the social welfare of the population; ensuring the ecological territory balance; economy and manufacturing sector development; transport and engineering infrastructure development; improving the decision-making process; ecological and economic solutions optimization [3].

Other specific problems can be set for achieving the main goal.

The main stages, methods and techniques for modelling implementation include [4]:

- Selection and rationale the settlement development model.
- Defining necessary and sufficient criteria (factors) for modelling implementation.
- Selecting the solution method.
- Results interpretation.

Today there is no universally accepted definition of a «Smart city». This is due to the diversity of needs and opportunities of the different localities. Therefore, the concept of «Smart city» can vary from region to region and depends on a level of development, willingness to change and reform, resources and residents aspirations.

Some definitional boundaries are necessary for the city management. As seen by residents, the «smart city» picture is represented by a list of infrastructure and services relevant to their needs. Urban planning activities should be aimed at sustainable development of urban system for satisfying residents' requirements. So, the urban system can be represented as main directions of sustainable development: institutional, physical, social and economic infrastructure. This can be a long-term goal, and cities can work towards developing such comprehensive infrastructure incrementally, adding on layers of «smartness».

The «smart city» approach provides the development of cities that ensure the basic infrastructure and adequate living standards, clean and sustainable environment, and application of «smart» solutions. At the same time, special attention is paid to sustainable and inclusive development. The idea is in creating a replicable development model for settlements in different regions.

On the one hand, the main «smart city» infrastructure elements are presented in following systems, defining the appropriate development criteria, such as adequate water supply, assured electricity supply, sanitation, including solid waste management, efficient urban mobility and public transport, affordable housing, robust IT connectivity and digitalization, good governance, especially e-Governance and citizen participation, sustainable environment, safety and security of citizens, health and education [5]. An illustrative list is given below (figure 2). It should be noted that this list is not exhaustive, and cities are free to add more applications.

Figure 2. An illustrative list of «smart solutions» [5]

Accordingly, the purpose «smart cities» is in stimulating economic growth and improving the living quality by creating opportunities for local area development and using technologies for smart results. Zonal development will transform existing areas while increasing quality of urban living. New areas will be developed around cities to accommodate the expanding population. Application of smart solutions will enable cities to use technology, information and data for improving infrastructure and services. Consequently, the inclusive development will improve the living quality, create employment and increase incomes.

2.1. Smart City Features
Many different approaches have been proposed to solve the issue of sustainable development [6]–[11].
As a result, the characteristics of sustainable development of «smart cities» are described below.

- Sustainable land using
- Housing accessing
- Creating walking and cycling localities
- Conservation and development recreational spaces
- Transport engineering
- Making governance citizen-friendly and cost effective
- Giving an identity to the city
- Applying Smart Solutions for sustainable development

2.2. Smart-city Strategy
The decisions of the three models of area-based smart city development are the strategic components. They comprised:

- City improvement (retrofitting). Retrofitting will introduce planning the existing built-up area to achieve smart city objectives, along with other objectives, to make the existing area more efficient and liveable. Existing structures are largely to remain intact in this model. So, it is expected that more intensive infrastructure service levels and a large number of smart applications will be packed into the retrofitted smart city. This strategy may also be completed in a shorter time frame.
- City renewal (redevelopment). Redevelopment will replace the existing built environment and will create a new layout with improved infrastructure with mixed land use and high density development.
- City extension (Greenfield development). Greenfield development will introduce the most intelligent decisions for previously vacant territories. This assumes the use of innovative planning tools, financing and projects implementing. In contrast to retrofitting and redevelopment Greenfield development projects can be accepted by local governments.

Smart-city development concept envisages application of selected Smart Solutions to the existing city-wide infrastructure. Application of Smart Solutions will involve using the technology, information and data to make infrastructure and services better.

The smart city proposal is expected to encapsulate either a retrofitting or redevelopment or Greenfield development model, or a mix thereof and a Smart-city feature with Smart Solution/solutions.

2.3. Smart-city Challenges

State and local governments should be a key players in the smart cities development. Smart leadership and vision at this level and the ability to act decisively, will be important factors in determining the success of interventions.

Understanding the concepts of retrofitting, redevelopment and Greenfield development by the policy makers, implementers and other stakeholders at different levels will require capacity assistance.

Additionally, the Smart Cities concept requires smart people who actively participate in governance and reforms. Citizens' participation in Smart-city living is provided by using information and communication technologies, especially mobile tools.

3. Results

Today, methods of estimating the development of urban and rural settlements are based on socio-economic criteria, engineering and transport infrastructure indicators, etc. Generalizing the scientific-technical publications shows that models consist of three - or four-component systems with different set of factors. For example, in accordance with studies [12] a four-part model is proposed for determining the factor of urban areas sustainable development. The model consists of economic, environmental, urban and social factors and includes 41 base indicator. Three-component model («spatial development», «socio-economics», «ecology environment») is used for assessing the sustainable rural development according to [13], [14]. The studies [3], [4], [15] are based on the «model of socio-economic rural settlement development» and a four-part «sustainable development model», which includes 72 indicators for determining the «rural development index» and showed its effectiveness for a certain period (figure 3).
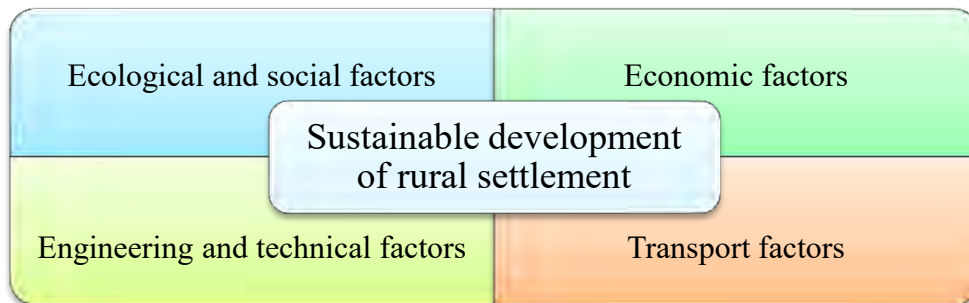
Figure 3. Model for a sustainable rural development

Take all these points together it is necessary justifying the systems/factors of rural settlements sustainable development for building the «Smart village model». The most significant are political, socio-economic, environmental and infrastructural factors [16-18]. The political factor reflects the quality of management system and decision-making, that almost all reviewed models don't include. In foreign practice the «Pentagon model» is in wide use among multi-criteria and multi-dimensional systems.

On the other hand, in accordance with studies [4] the Pentagon concept consists of five main systems, required for achieving the sustainable development goal: ecological system, economic system, administrative system, anthropogenic (physical system), social system (suprastructure) (figure 4).
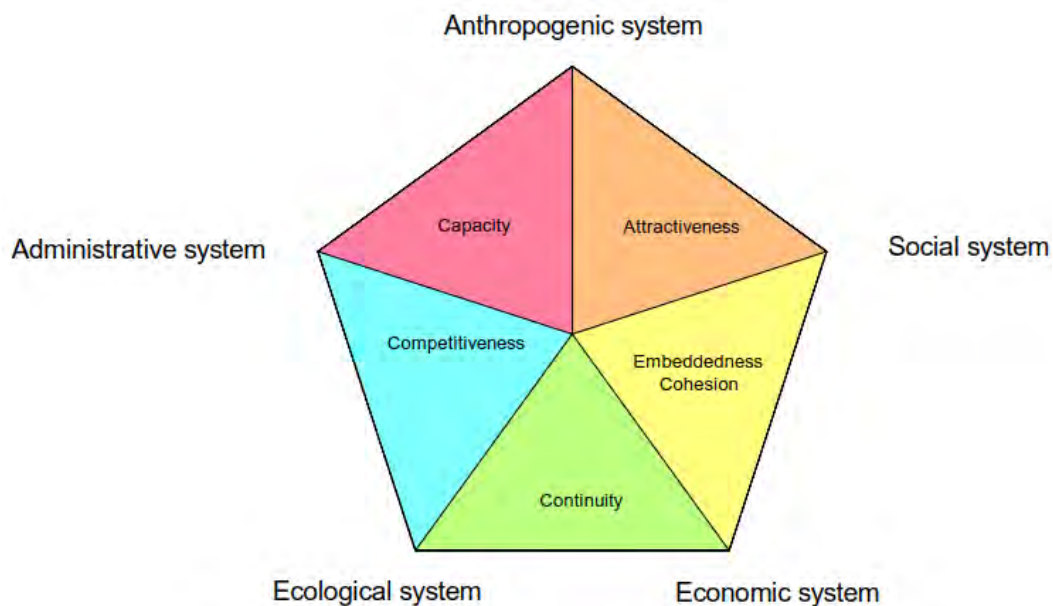

Figure 4. The system of critical and motivating factors, which are necessary for achieving the sustainable development

Thus, the ecological system reflects the quality and potential of the natural environment, sustainability under the influence of anthropogenic factors. The economic system contains indicators for characterizing the economic activity. The administrative system represents terms and conditions for deciding administrative and management activities. Anthropogenic (physical) system, as a manufacturing quality, is necessary for determining living standards. Social system (suprastructure) characterizes social settlements quality.

The research generalizing allowed offering Smart village model, comprising five major systems of enablers and processes (figure 5). The combination of these systems determines the necessary conditions for successful policy of local and state governance level.
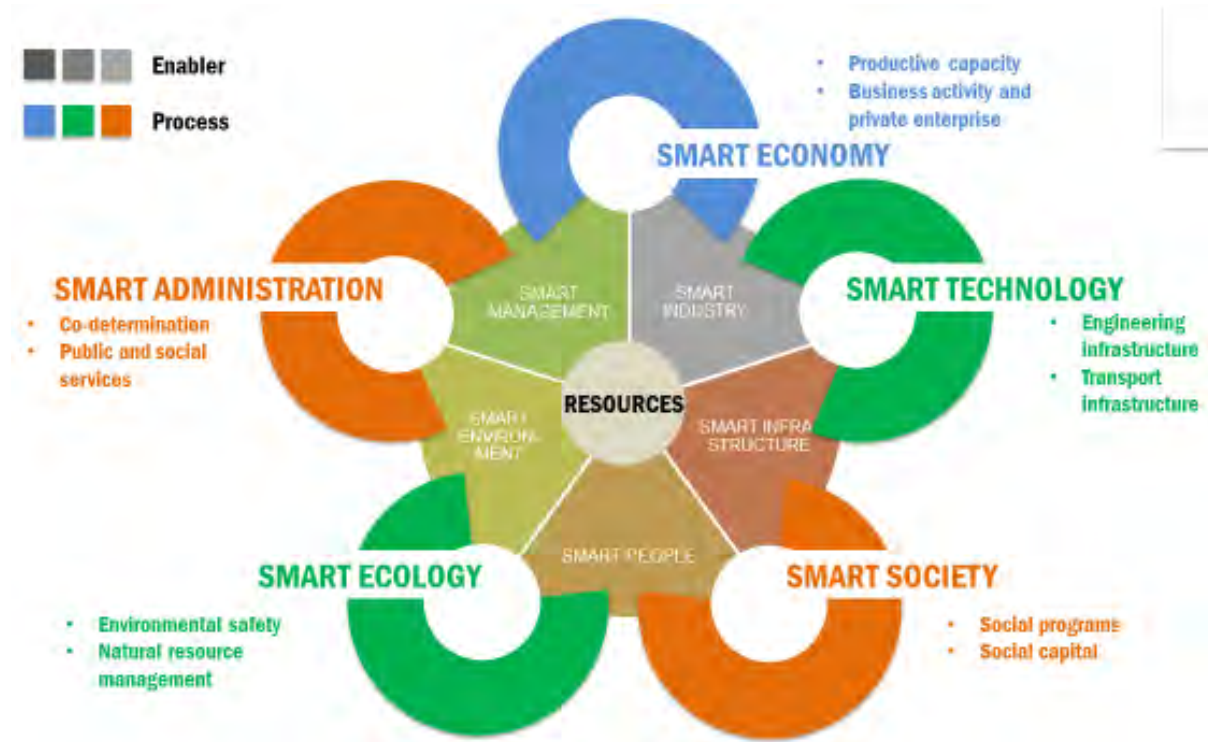
Figure 5. Smart-village model

In accordance with Smart-village model, each enabler is described with corresponding process and services. Thus, Smart Economy is corresponding with productive capacity, business activity and private enterprise. Smart Technology is corresponding with engineering and transport infrastructure. Smart Society includes social programs and social capital. Smart Ecology contains environmental safety and natural resource management. Smart administration includes co-determination, public and social services.

4. Conclusions

Therefore, Smart City technologies development is of considerable interest to rural settlements in Russia, which are the main elements of the rural settlement system and agriculture development. The resulting model can be used for identifying and substantiating the critical factors for Smart Village sustainable development, as well as providing administrative estimations guidance.

Currently, one of the problems, that prevent the rural settlements system development, is the lack of smart villages. Existing settlements development solutions (the concept of «smart city», the Pentagon-concept) are available and has shown a proven experience. Therefore, a strategy based on an integrated planning and execution of measures for rural sustainable development are needed. The settlement structuring is needed for a designing such a growth strategy generation. At the same time, it is necessary to consider the location and settlement investment climate. The resulting multi-purpose strategy «Smart-village» should be available for different settlements in accordance with local conditions.

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