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Integration of Industry 4.0 technologies for “smart cities” development

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Abstract. This article presents main trend of modern urbanization associated with smart cities development on the basis of 4th industrial revolution. The article presents retrospective analysis of smart city concept, identifies key features of smart city like smart economy (smart or 4.0 industry), smart population, smart government, smart mobility, smart environment, smart living, intelligent infrastructure. “Smart city” term is defined as a concept and model of new urbanization based on 4th industrial revolution and application of new generation technologies of Industry 4.0 (Internet of things, cloud computing, cyber-physical systems, big data and other technologies) for planning, construction, management, integrated industrialization, informatization, modernization and sustainable development of the cities. The article analyzes integration and interaction between new urbanization and development of new technologies of Industry 4.0. On the one hand, technologies of the Industry 4.0 create fundamentally new infrastructure of the “smart city”. These new technologies allow to solve problems of resources utilization and energy efficiency improvement, organize urban production and demographic changes in megacities. On the other hand, development of “smart city” promotes new industrialization, creates new conditions for living, work, education, accumulates social and human capital, and attracts financial resources for business development.

1. Introduction

Today more than half of world's population (54% in 2014) lives in urban areas [1]. Global urbanization shows increasing development. Promotion of population living in urban areas accounted for 30% of the world's population in the 1950s. By 2050, according to experts, proportion of urban residents will increase to 66% (an increase by 2.5 billion people relative to 2014). Most urbanized regions are North American countries (82% of population live in urban areas in 2014), Latin America and the Caribbean (80%), Europe (73%). Today, according to Rosstat, 74% of RF population also live in urban areas. Despite the fact that earth's surface is occupied by only 2% of urban areas, urban settlements accumulate more than 50% of population and consume up to 75% of natural resources [2]. Therefore, the problem of “smart” urban development, retrieving solutions of population growth and migration problems, climate change, education and health, affordable housing and urban life transformation under the influence of information and communication technologies (ICTs, digital



technologies) in the context of 4th industrial revolution have attracted increasing attention in the last decade and the problems of “smart” urban development are discussed in different formats, for example, Ecocity World Summit [3], Smart City Expo World Congress [4], World Smart City Forum [5].

Despite popularity gained by smart application there is no common consensus about what “smart” means. Some researches have focused to study different “smart” areas of a city: transport system with modern technologies (Dirks, Keeling, 2009; Giffinger, 2007) [6, 7], role of human capital and education in “smart” urban development (Giffinger, 2007; Caragliu, Del Bo, Nijkamp, 2009) [7, 8], “smart” management (Giffinger, 2007) [7]. Most “smart city” definitions focused initially on ICT, and, subsequently, on digital and other modern technologies. For example, IBM “smart city” definition includes three key characteristics: instrumented, interconnected, and intelligent (Harrison, Eckman, Hamilton, Hartswick, Kalagnanam, Paraszcak and Williams, 2010) [9]. “Instrumented” means availability of efficient links between physical world and virtual world via sensors, personal devices, smart phones, appliances, Internet.

Therefore, concept of “smart city” was supplemented by analysis of technological changes caused by 4th industrial revolution and Industry 4.0 development. “Industry 4.0” term became publicly known in 2011 when the same initiative was presented (Kagermann, Lukas and Wahlster, 2011), and the “High-Tech Strategy 2020 for Germany” initiative (and Plattform Industrie 4.0 as its part) was announced [10, 11]. An important component of Industry 4.0 development is fusion of physical and virtual world (Kagermann, 2014) [12] which becomes a topical subject of special researches (Hermann, Pentek and Otto, 2016) [13].

2. Evolution of the “smart city” concept under the conditions of 4th industrial revolution.

Research goal of Eugène Hénard, one of the first urban planning researchers, was “tell about influence exerted by progress of modern science and industry on planning, and, particularly, on “future city” aspect.....” [14]. Modern studies of future (or “smart”) cities have several dimensions and multidisciplinary content.

Among them - issues regarding sustainable social, ecological and economic development of cities («sustainable city» or “ecocity”) and issues regarding complex city ecosystems management so as to gain access to basic resources like housing, clean air, clean water for entire inhabitants. The Sustainable Cities Index includes these aspects of the “smart city” concept. For example, the 5-top of global cities (according to Sustainable Cities Index 2016) are Zurich, Singapore, Stockholm, Vienna, London. Moscow ranks 57 overall [15].

Interest of the researchers focused on the “digital city” in the 1990s as the importance of “digital” had been increased when the EU government supported the program “European Digital City” in 1996-1999 [16]. During this period, interest of researchers, politicians and economists was focused on development of different information services for citizens providing interaction of urban inhabitants and municipality by using new technologies. The concept of “European Digital City Index” was proposed in 2015 aiming to support digital entrepreneurship in the EU and to identify existing and would-be centers of digital entrepreneurship [17]. Later in 2017 the EU launched the “Digital Cities Challenge” program [18]. Purpose of this program was to select 15 cities and assist them in realizing the potential in development and digital policy implementation which would change lives of inhabitants, businesses, workers and entrepreneurs.

In 2008, IBM CEO Samuel J. Palmisano, noted that “our planet is becoming smarter” [19] because the world has been increasingly equipped with “digital” tools (sensors are being introduced into all ecosystems). The world is becoming more and more interconnected (inter alia, on system and object levels) and more smart (emerging new computing powers, models and supercomputers). Active development of the “smart” culture began at the end of the first decade of 2000’s when “smart” prefix began appearing in variations word expressions like “smart development”, “smart growth”, “smart regulation”, “smart city”, “smart factory”, “smart home”.

A. Townsend, analyzing modern urbanization trajectory, defines “smart city” as a place where “information technology is combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic, and environmental problems” [20]. Experts give different examples of how digital technologies make the city “smarter” from infrastructure “digitalization” (using sensors to control street lighting and traffic lights, monitoring plumbing and eliminating water leaks, air quality control and using video sensors by community policing authorities) to urban residents entertainment “digitalization” (the project of public art “Shadowing” by Jonathan Chomko and Matthew Rosier, winner of the Playable City Award) [21].

“Smart city” term is used in official papers to describe a city with physical infrastructure, social capital, public institutions and digital technologies which are jointly ensuring sustainable economic and social development, creating attractive environment for everyone, providing not only feedforward, but also feedback (about services quality or roads/ environment status) between citizens and service providers (management) [22]. The above examples once again convince that there is no one absolute «smart city» concept because we are still observing the changes in modern urbanization caused by digital technologies of 4th industrial revolution.

We can identify several key features of a smart city based on the above analysis (table 1).

Table 1. Key features of smart city development [7, 22].

Feature	Content of a smart city development
Smart economy	“Smart city” is a city with ICT-based economy and other Industry 4.0 technologies. That implies industries in fields of ICT as well as other “smart” industries implying ICT and new technologies in their production processes and business models.
Smart people	“Smart city” is a city where residents have ICT skills and high level of education. “Smart city” is a city with high quality of social and human capital.
Smart management (authorities) «smart regulation»	“Smart city” is a city with smart management and administration which is using new forms of interaction and communications with citizens (“e-democracy”, “e-management”,).
Smart mobility	“Smart city” is a city with modern transport technologies, logistics and new transport systems as “smart” systems improving urban mobility and living.
Smart environment	“Smart city” is a city with safe, “green” and sustainable environment, with new technologies integrated into natural conditions without environment and living hazards.
Smart living	“Smart city” is a city where every resident becomes a more active participant in the community, actively interacts with public and private services provided to him and determines their suitability for him in the best way. “Smart city” ensures high quality of life through cultural objects, health status, individual security, housing quality, etc.
Smart infrastructure	“Smart city” is a city with infrastructure based on intellectual systems, Internet of Things and other technologies of Industry 4.0.

Thus, “smart city” term is understood as a new concept and a new model of urbanization based on 4th industrial revolution [23, 24] and application of new technologies generated by development of Industry 4.0 (Internet of things, cloud computing, cyber-physical systems, big data and other technologies) for the purpose of planning, construction, management, integrated industrialization, informatization, modernization and sustainable development of modern cities.

3. “Smart city” development based on Industry 4.0 technologies.

In the concept of “smart city” sufficient importance was previously given to providing citizens with public services. Emerging new ICT generation is causing all elements of city and its infrastructure (economy, transport, education, medical care, public order, and management) to become “smarter”.

On the one hand, development of Internet of things, integrated systems and their global networking (for example, smart transport network that is used to regulate congestion), of cyber-physical systems create new opportunities for building “smart city” and transition to “smart economy” based on Industry 4.0. Development of Industry 4.0 will solve some problems of resources and energy efficiency, urban production, demographic changes in megacities. Industry 4.0 makes production harmless to urban environment. Production becomes intellectual, digital and integrated not only at the level of a simple factory or plant. Industry 4.0 technologies provide not only vertical integration linking processes within organization from design and procurement through production to logistics and service. Digital technologies create conditions for horizontal integration which is going beyond the “smart factory” and promote automated chains of value creation at local, regional, national and global levels.

On the other hand, the development of “smart cities” as a goal of urban, industrial, economic, social, environmental policy promotes new industrialization and digitization of modern economy. “Smart cities” are creating more attractive conditions for living, work, education, accumulate social and human capital, attracting financial resources for business development. The term “smart cities” is applied not only to cities [25] but is treated today more widely. “Smart cities” can be regarded as agglomerations or “Mega hubs” of today’s digital economy.

Expert conclusions stipulating that despite terminological difference existing between “smart city” and “Industry 4.0” concepts the concept of industry has always been an integral part of city concept [26], [27] may be considered duly substantiated.

Relationship between these categories is shown in figure 1. It is essential to consider development of Industry 4.0 as creation of “smart cities” and agglomerations as well as other objects like “smart factory”, “smart home”, “smart street”, “smart campus” and others which are jointly shaping digital economy at the level of the city, region, country.

New digital technologies are not only transforming simple production into value chains based on the Internet of Things and cyber-physical systems and creating new forms of interaction in production systems but also creating new links between manufactures, suppliers and customers. “Smart” technologies and solutions are going beyond production complexes, transforming logistics, marketing and other components of business processes at all levels of the economy (country, region, city), transport, energy systems and other infrastructure elements creating new city environment - integrated, interconnected, equipped by tools of Industry 4.0. Industry 4.0 is creating industrial and technological basis for emerging “smart cities” whose development and integration becomes an integral element of economy digitalization.

4. Conclusions

Development of “smart city” fundamentals was accompanied by evolution this concept content. Earlier, the “smart city” concept focused more on development of “smart city” considered as a complex ecosystem whose management required provision of steady access to basic resources without damage to the environment. Subsequently, with growing impact of new “digital” technologies exerted on the process of urbanization, researchers focused on “digitalization” of public life of citizens and development of various information services. Finally, development of Industry 4.0 technologies (Internet of things, cloud computing, cyber-physical systems, big data and others) has made it possible to make whole urbanization process smarter: urban planning and construction (“smart home”), production and business (“smart factory” and “smart economy”), management (“smart regulation”)

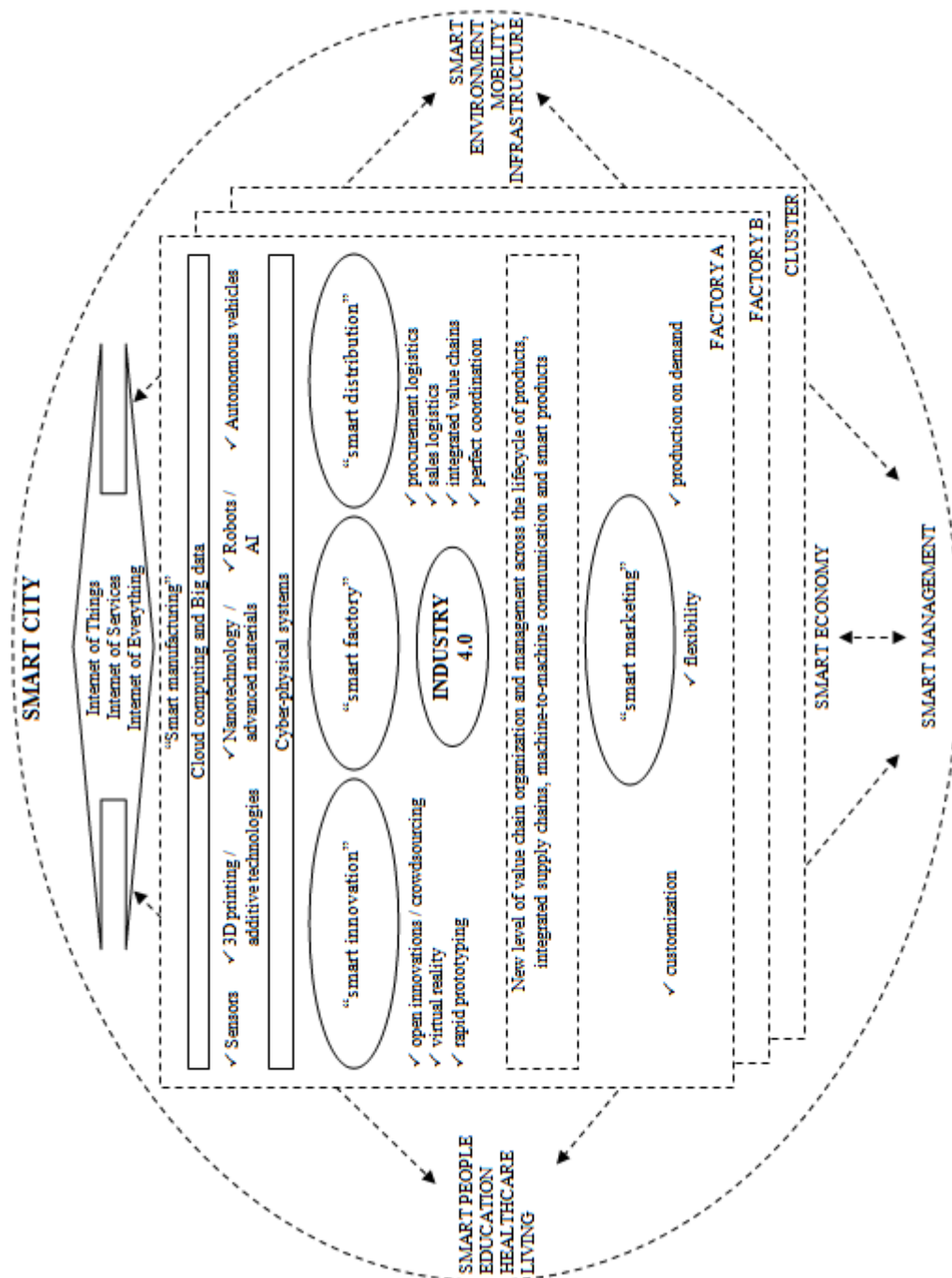
and create conditions for development and accumulation of social and human capital (“smart populations”).

Therefore, Industry 4.0 technologies are generating today a fundamentally new infrastructure of the “smart city”, creating new opportunities for resolving particular problems regarding resources and energy efficiency, urban production organization, demographic changes in modern megacities. In turn, “smart city” development becomes a form of new industrialization of the modern economy.

Directions for further research may be realized by means of new political and economic measures enabling promotion of “smart” urbanization based on new technologies of 4th industrial revolution in modern Russia.

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Appendix A. Schematics of "Smart city" and Industry 4.0 integration.

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