Analysis of various definitions for Smart City concept

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Abstract. In this paper several qualitative definitions of the "smart city" concept are considered as well as an attempt to quantify the degree of "intelligence". The generic characteristics of smart cities are distinguished in each of these definitions. At the same time, each of these definitions under consideration has its own differences. This affects, for example, what the emphasis is in each definition. Several possible functions that can describe the dynamics of the development of cities described by some quantitative indicator are considered. Various well-known statistical distributions can be used as such functions. Authors suggest using one of these distributions – the three-parameter Weibull distribution. It is proposed to modify this distribution by introducing the fourth parameter, which is obtained by splitting the third parameter of the Weibull distribution into two new independent parameters. In this case, a new, four-parameter distribution better describes the various dynamics of the selected quantitative indicator of the city's development. You can also get good opportunities to describe the dynamics of development of some selected indicator of the city's development, if you consider the distribution coefficients, not constant, but time-dependent. But then it will be necessary to obtain a functional dependence of these coefficients on time from the results of observations, which will further complicate the task of forecasting. Various aspects of the concept of smart cities are qualitatively considered. The article proposes the application of a modified Weibull distribution for forecasting the development of some quantitative indicators of the level of the city's development.

1. Introduction

According to forecasts in the second half of this century, every 7 out of 10 inhabitants of the Earth will live in cities. According to Russian legislation, the city is a locality where more than 12 thousand inhabitants live and more than 85% of production is not agricultural [1]. Cities have arisen because the concentration of various resources in one place made it possible to achieve more effective results and to ensure the livelihoods of many people [2]. But now the situation is changing. Urban civilization has approached in its development to a period of great challenges. These challenges include limited resources, overloading of public, technical and communication infrastructure, aggravation of transport and environmental problems. These problems can be solved by involving all stakeholders in the process of necessary high-tech innovation transformations. Among these stakeholders, citizens and government bodies of all levels, private investors, business and public development institutions, scientific organizations should be active participants. One way to solve these problems is related to the concept of the development of "smart cities". In this paper, several qualitative definitions of the concept of "smart city" are considered, as well as an attempt to quantify the degree of "intelligence" on a given scale with the example of two medium-sized European cities. Various aspects of the concept
of smart cities are examined qualitatively. To predict their possible development, it is proposed to use a slightly modified Weibull distribution [3, 4].

2. The definitions and models currently used

There are many definitions for Smart Cities in use. The definitions given below are given in fragmentary form [5 and references in it]: (Bodytext style).

Other Definition 1. SAC (Standardization Administration of China – the working group of Chinese national smart cities standardization) uses the following definition: Smart Cities is a new concept and a new model, which applies the new generation of IT to facilitate the planning, construction, management and smart services of cities.

Definition 2. BSI (British Standards Institution) PAS 180 provides the following working definition of a Smart City: Smart Cities is a term denoting the effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens [6].

Definition 3. ITU-T FG (Focus Group) on Smart Sustainable Cities develops the following definition: A smart sustainable city is an innovative city that uses ICTs (information and communication technologies) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects.

Definition 4. ISO TMB (Technical Management Board) Smart Cities Strategic Advisory Group uses the following working definition: A Smart City is one that dramatically increases the pace at which it improves its social economic and environmental (sustainability) outcomes, responding to challenges by fundamentally improving how it engages society, how it applies collaborative leadership methods, how it works across disciplines and city systems, and how it uses data information and modern technologies in order to provide better services and quality of life to those in and involved with the city, now and for the foreseeable future, without unfair disadvantage of others or degradation of the natural environment.

Definition 5. The team [7] uses the following smart city model: a Smart City is a city well performing in 6 key fields of urban development, built on the "smart" combination of endowments and activities of self-decisive, independent and aware citizens.

The team [7] works on the issue of smart cities and in cooperation with different partners the European Smart City Model was developed. Basically it provides an integrative approach to profile and benchmark European medium-sized cities and is regarded as an instrument for effective learning processes regarding urban innovations in specific fields of urban development.

3. Analysis of various definitions

What are the main characteristics of the Smart City based on these definitions? It can be seen that the Definition 1 makes the main sign of the Smart City the developed and widely used IT technologies in the city economy, in planning and managing city services. The Definition 2 is very general, one can say academic. In it the first place is the sign of integration of different structural systems. The Definition 3 attempts to replace the definition of Smart City with an Innovative City. As in the Definition 1, the Definition 3 makes the main sign of the Smart City the developed IT technologies. But, unlike the Definition 1, "other means" are also mentioned, without specifying their nature. The Definition 4 places emphasis on a rapid increase in the pace of economic transformations and changes in the environment.

The Definition 5 is transitive from the previous four qualitative definitions to the quantitative definition of the Smart City concept [7]. To compare the different indicators it is necessary to standardize the values. For this, the team [7] considers the Smart City in the form of a combination of different-level sub-concepts: fields, domains and indicators. These six fields – "Smart Economy", "Smart People", "Smart Governance", "Smart Mobility", "Smart Environment", "Smart Living" – have 27 domains, containing 90 indicators of different aspects of urban construction, infrastructure
and management. The "Smart Economy" field contains 6 areas: Innovative spirit, Enterpreneurship, City Image, Productivity, Labour Market, International Integration. The "Smart People" field contains 4 areas: Education, Lifelong Learning, Ethnic Plurality, Open-Mindedness. The "Smart Governance" field contains 3 areas: Political Awareness, Public and Social Services, Efficient and Transparent Administration. The "Smart Mobility" field contains 4 areas: Local Transport, (Inter-)national Accessibility, ICT-Infrastructure, Sustainability of the Transport System. The "Smart Environment" field contains 3 areas: Air Quality (no pollution), Ecological Awareness, Sustainable Resource Management. The "Smart Living" field contains 7 areas: Cultural and Leisure Facilities, Health Conditions, Individual Security, Housing Quality, Education Facilities, Touristic Attractiveness, Social Cohesion.

One method to standardize is by z-transformation [7]. This method transforms all indicator values into standardized values with an average 0 and a standard deviation 1. This method has the advantages to consider the heterogeneity within groups and maintain its metric information. Furthermore a high sensitivity towards changes is achieved.

The main objectives of the development of Smart Cities, these definitions are called 1) to facilitate the planning, construction, management and smart services of cities; 2) to deliver a sustainable, prosperous and inclusive future for its citizens; 3) to improve quality of life, efficiency of urban operation and services, and competitiveness; 4) to provide better services and quality of life to those in and involved with the city.

4. Discussion
In addition to the above qualitative definitions of the Smart City, we can say the following. The city does not exist separately in either the public-state, or the chronological (historical) plan, or the spatial (geographical) plan. Each city is part of some society/state with its history, based on its place and in its time. Therefore, the Smart City outside of the connection with Smart Villages, outside of the connection with other Smart Cities inside the Smart State is an inferior model. And if we supplement and expand the concept of the Smart City as part of the Smart State, as a number of new questions and contradictions are revealed. These are the questions "What is a Smart Village?", "What is a Smart State?" and so on. These are the contradictions between the interests of different cities, the contradictions between the interests of the state and the city, the contradictions between the interests of the city and the countryside, the contradictions between the past of the city (in various senses) and its present.

A characteristic feature of all the above definitions is implicitly expressed optimism: for every challenge Smart City will always find a solution by applying new technologies. However, this is a controversial statement. Very many problems will be solved only partially, creating new problems. And, perhaps, some problems will never be solved.

Taking into account the above, we can offer the following model of the Smart City: first the City appears, in its development it comes to the improvement of its productive forces and enters the high-tech development phase, which marks the entry into the period of the Adult City. At the same time, the growth of emerging problems forces the city to seek a number of compromise solutions, taking into account the increasing number of increasingly deteriorating parameters. It is this phase of solving a large number of problems and challenges and is the phase of the Smart City (or Mature City). The next phase of development is the period of the aging and disappearance of the City – the phase of the Senility City. Moreover, the same City can at the same time in one parameter be in one phase of its development, and in other parameter – in another. In this case, the City itself is regarded as one of the forms of human community.

Therefore, the Smart City is a City at a certain stage of its development that has reached the peaks in the development of the productive forces, which solves a large number of tasks using new technologies and processes a large amount of information in order to obtain the most effective solution. Solving the maximum number of emerging problems with a minimal set of modern high-tech tools to extend their own existence is actually the main feature of the Smart City.
Consider the mathematical aspect of evaluating the parameters of the development of the Smart City from the point of view of the dynamics of this parameter in time. For example, consider such an important parameter as the proportion of urban residents. On the threshold of the second and third millennia, an event took place, the importance of which is yet to be assessed. For the first time, the number of urban residents of the Earth exceeded the number of rural residents. As an important parameter for the development of urban civilization, it is necessary to take the parameter $K$, equal to the ratio of the number $U$ of city residents to the total number $N$ of inhabitants of the community in question:

$$K = \frac{U}{N}.$$ 

For example, based on general considerations, we can say that for a value of $0 < K < 1/4$, urban civilization experiences a period of formation, with $1/4 < K < 3/4$ urban civilization experiences a period of development, including its highest points – metropolitan cities, at $K > 3/4$, the sunset of this civilization sets in.

If we divide the time of existence of civilization into three periods: birth, rise and decline, then we can consider the value of the parameter $K$ in each of these periods. At the same time, different parameters of $P$ can serve as an estimation parameter. The simplest such scheme is shown in Fig. 1.

\begin{figure}
\centering
\includegraphics[width=0.5\textwidth]{figure1.png}
\caption{Three main periods in the development of each parameter $P$ of the City.}
\end{figure}

Such a relationship can be described by different functions. As a mathematical approximation of the graph $P(t)$, a normal distribution function, a beta distribution or a gamma distribution can act. A good approximation [3,4] may be a two-parameter Weibull distribution (for $t \geq 0$)

$$P(t) = \frac{k}{\lambda} \left( \frac{t}{\lambda} \right)^{k-1} \exp \left( - \left( \frac{t}{\lambda} \right)^k \right).$$

Sometimes add a third parameter $m$:

$$P(t) = \frac{k}{\lambda} \left( \frac{t-m}{\lambda} \right)^{k-1} \exp \left( - \left( \frac{t-m}{\lambda} \right)^k \right).$$

The values of the parameters $k, \lambda, m$ can be obtained from the data from the past by selecting the best set of parameters from a given grid of sets of parameters, for example, by the method of least squares. For example, in Fig. 2 shows a two-parameter Weibull function with $m = 0$ and a three-parameter function with $m = 1.5$ for the same values of $k = \lambda = 1$. 


Figure 2. Weibull function: two-parameter (dashed line) and three-parametric (solid line) for predicting the dynamics of parameter $P$ in time.

Of course, the scheme in Fig. 2 describes only the general structure of the dynamics of civilization. At each stage of its development, local origins, blooms and deaths of its individual elements can be observed. To describe such local development cycles, the authors propose using a new four-parameter Weibull model, which is obtained from a three-parameter model by introducing two shift parameters: $m_1$ for the power part and $m_2$ for the exponential part (Fig. 3):

$$P(t) = \frac{k}{\lambda} \left( \frac{t-m_1}{\lambda} \right)^{k-1} \exp \left( -\left( \frac{t-m_2}{\lambda} \right)^k \right).$$

Figure 3. The addition of the fourth parameter in the Weibull function makes it even more adequate for describing the dynamics of the parameter $P$.

5. Conclusion
Several definitions of the Smart City are considered. These definitions are proposed to be supplemented with the sign of the Smart City as one of the phases of the City in its own development. To quantitatively examine the dynamics of changes in the estimated parameters of the development of the Smart City, it is proposed to use the Weibull's three-parameter function. To make this model more adequate, the authors proposed to change the Weibull's function by adding the fourth parameter to it.
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