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Smart Cities Prospects from the Results of the World Practice Expert Benchmarking

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Abstract

Smart cities involve complex sociotechnical systems which are built on the flows of an increasing amount of data coming from multiple sensors, thanks to the technology of the Internet of Things. In this context, smart cities aim to provide sustainable urban development worldwide. This paper presents the results of world practice benchmarking for 20 smart cities and it seeks to determine the most successful cases that could be of interest for better urban development. B. Cohen's Smart City Wheel was used as the system of indicators, and expert assessment, document analysis, and statistical methods were applied to the research. Results indicate that the cases of Songdo, Singapore, Melbourne, Bodo, Delft and Toronto got the highest marks. Also, the level of resource management, e-government infrastructure, education and safety indicators showed a positive impact on the other smart city components.

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1. Introduction

Nowadays, the popular term "smart city" implies the intertwining of several parallel social and technical processes in modern society. Firstly, it encompasses the process of scientific and technological progress and the constant

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diffusion of technology as well as their implementation into all spheres of human life. The second process is the desire to improve the quality of life and create comfortable living conditions, which characterizes the modern development of the urban environment. The third process reflects the transformation of a territorial management system, the use of innovative approaches to the allocation of resources as well as the setting of tasks and the coordination of their implementation. It is assumed that synergy across three processes should lead to the creation of new social values and urban sustainable development [1].

However, when the technological component is absolutized, there is a risk of giving in to the illusion of creating a "smart city" from typical technological units, and to believe that this design will work effectively.

It becomes then obvious that for the effective functioning of new "smart cities" it is necessary to consider the adaptive capacity of the population, as well as the management factors that determine the resource provision of the territories. This paper takes that into consideration by providing results of a smart cities' benchmarking identifying the most successful cases that could be of interest for better urban development. This research is committed with revealing successful cases from a systematic point of view, based on experts' assessments. The collected data could be helpful for the researchers and practitioners who are going to make simulations involving smart cities.

2. Literature review

Many attempts to conceptualize smart cities have been made. While a variety of researchers have focused on definitional boundaries [2], there seems to exist a lack of consensus about what a smart city really is [1, 3, 4].

Researchers have found clear definitional overlaps, with cities being portrayed in a myriad of ways. Chourabi et al. [4], for instance, have referred to smart cities as being intelligent, digital or creative based on a variety of attributes like their ability to govern "stakeholder's relations" and to leverage an IT infrastructure. Expanding upon one of the first works in the realm [5], authors have looked at smart cities as having the ability to integrate through information and its technologies [6, 7]. Others will focus the consider innovation and entrepreneurship as being more central [2, 8, 9].

Definitions, nevertheless, seem to clearly depend on the context and the lenses through which smart cities are studied. That means that the extent to which a city can be considered smart depends on how the problems inherent to that city are tackled [10]. For instance, for Anthopoulos & Vakali [11] and Batty [12], city planning seems to be a critical component if a city wants to be efficient at tackling its problems, while others see better governance [13, 14] and city-participation as deserving more attention [15, 16]. Particularly, information and knowledge seems to be a crucial component. For instance, Nam & Pardo [7] have highlighted that smart cities are able to use information through policies, technologies and people. That finds echo on the work of Kourtit and Nijkamp [17] who implied that smart cities are "knowledge- intensive" the problems to be solved involve addressing performance issues. Harrison et al. [18], on the other hand, implied that smart cities leverage "collective intelligence". Although interest in information and knowledge remain, more attention has been given to the use of data analytics and big data as a potential catalyzer of smartness in local governments [19, 20]. Henceforth, it is possible to say at this point that smart cities disclose commonalities that really allow for an easier identification of local governments that are really advancing in the smartness agenda.

A team of researchers from Indonesia [21] prepared a generalized analysis of research works in the subject "Smart City" and identified the following areas, which are now actively engaged by researchers from all over the world: ICT infrastructure [22]; development of public transport systems [23]; environmental sustainability [1]; social and cultural pluralism in the conditions of "smart cities" [24] development of educational potential and training systems [25]; health services [26]; entrepreneurship and innovation [23]; social security and protection [27]; economic planning and organization [28]; ICT and e-government technologies [29]; "smart house" system [30]; open government and open data [31, 32].

The emergence of "Smart Cities" in foreign and domestic literature is often called a risky initiative, because at this stage there are not many unambiguous evidences confirming their effectiveness and contribution to improving the quality of life of the population.

The smart city concept is multileveled and is often associated with the cities of the future. However, the concept of these cities of the future is quite old and it means a city which is innovate quickly, build big, with the focus on commercial infrastructure, and ready to be copied. In the book "A History of Future Cities", Daniel Brook [33]

observes the histories of four cities: St. Petersburg, Shanghai, Mumbai and Dubai, which were modern and innovative at the time they were established. The term in Brook's book embraces modernity in city-planning and also the cultural and socio-psychological aspect of the future cities' inhabitants [33]. Those cities were also strategically planned to be developed not only as a space for living and economy development point, but also as an instrument for developing strong long-termed strategic partnerships and strengthening the state's position on the international arena. However, the smart cities concept nowadays is focused mainly on the technological excellence in urban space development. Although landscape perception is influenced by advanced technology, the cultural aspect is often regarded as being less important. Table 1 summarizes an overview of different definitions of smart cities and their fields.

Table 1. Summary of Perspectives on the literature review about smart cities

Relevant Factors and Perspectives	Contributors
"stakeholders relations", "information technologies" and "e-government"	Hall et al., 2000 [5] Lombardi, Giordano, Farouh, & Yousef, 2012 [29] Chourabi et al., 2012 [4] Gil-Garcia & Aldama-Nalda, 2013 [6]
"knowledge-intensiveness" and "information intensiveness"	Kourtit and Nijkamp, 2012 [17] Nam & Pardo, 2011 [7]
"innovation and entrepreneurship"	Hollands, 2008 [2]; Paskaleva, 2011 [8]; Zygiaris, 2013 [9]
"city planning"	Batty, 2013 [12]; Anthopoulos & Vakali, 2012 [11]
"citizen-participation"	Gil-Garcia, Zhang, & Puron-Cid, 2016 [15]; Granier & Hiroko Kudo, 2016 [16]
"governance"	Meijer & Bolívar, 2016 [13]; Pereira, Macadar, & Testa, 2016 [14]
"open government and open data"	T. M. Harrison et al., 2012 [31]; Kuk & Davies, 2011 [32]
"environmental sustainability"	Pardo & Gil-Garcia et al., 2015 [1]
"social and cultural pluralism"	Priano & Guerra, 2014 [24]
"education and training"	Lazaroiu & Roscia, 2012 [25]
"health services"	Carli, Dotoli, Pellegrino, & Ranieri, 2013 [26]
"social security and protection"	Afonso, dos Santos Brito, do Nascimento, Garcia, & Álvaro, 2015 [27]
"economic planning and organization"	Perboli, De Marco, Perfetti, & Marone, 2014 [28]
"data analytics and big data"	Aguilar, 2016 [19]; Hashem et al., 2016 [20]

3. Research methodology

Conducting the proposed scientific research involves the use of an integrated and interdisciplinary approach. This study uses the benchmarking methodology for the assessment of modern smart city cases. In that context, 20 smart cities were selected. They address the following criteria:

- cities that represent an unique case of a smart city with a focus on a specific field;
- cities that show smart city development in different scales (including megapolicies, cities, towns);
- cities that have an ability to identify the specific emotional perception of smart city development by the area inhabitants (via some open materials in the Internet and communication with local experts).

The selected cases were distributed across countries from different parts of the world. There were: 7 cases from Europe, 5- from Asia, 4- from America, 3- from Australia, and 1 from African countries.

Then, the Smart Cities Wheel indicators system created by B. Cohen [34] is used. The indicators' wheel was first presented in 2014 for assessing the smart cities, and now this methodology is established as in its field. The Smart Cities Wheel includes 6 main fields: Smart Economy, Smart Government, Smart People, Smart Living, Smart Mobility, Smart Environment [34]. Each field contains three subfields. When the researcher receives all the information he or she needs on all of 18 indicators from the city of interest, such information is converted into statistical data that is convenient for assessment. According to Cohen, the maximum number of points that a field can receive is

15. If the city is successful in each field, then it gets a high amount of points for each of the fields. That leads to a maximum 90 points, 15 per each category [34]. This methodology of assessment is very holistic and comprehensive. It allows to consider the process of «smartization» of cities and identifying their strengths and weaknesses.

This research will assess the selected smart cities based on Cohen's methodology and revealed the coverage of indicators in different smart cities. A 5-point scale for each subfield was created. The research group worked with official documents and open materials. Traditionally, the difficulty of obtaining reliable data is considered to be the main weakness of the benchmarking technique. One step to overcome this barrier was bringing the experts' opinion to the data analysis, and we invited the experts from the studied Smart City to vote for the estimations. A shared table was created to collect their subjective attitudes presenting the real feeling of life improvement with new technologies. Further, with the help of qualitative data analysis (cases' descriptions, document analysis), as well as statistical correlations, conclusions for better urban development within smart cities were made.

23 experts from the studied smart cities and international organizations took part in the research. The main criteria for expert selection was their profound understanding of ICT and their impact. While ordinary population has more of practical consumer/user experience, deeper understanding of technology means better comprehension of complicated smart cities development processes. Thus, we worked with the experts' profiles, analyzed their activities (affiliations, projects, experience, publications) and revealed the proper candidates for the evaluation.

4. Findings

During the research process, data was collected on 1) identifying each case, and 2) key areas in which Smart City development was focused in each situation. Then the experts' assessment in accordance with Cohen's Smart City wheel indicators were collected.

4.1. Smart City Cases

The following smart cities have been analyzed in the research: Bangkok, Berlin, Bodo, Buenos-Aires, Canberra, Chicago, Delft, Dubai, Hague, Helsinki, Honk Kong, Johannesburg, Malmo, Melbourne, Moscow, New York, Singapore, Songdo/Incheon, Toronto, Wellington.

According to the summarized experts' assessment (Fig. 1) the higher marks belong to Songdo, Singapore and Melbourne. Songdo began its smart history in early 2000s. The cost of the city is estimated at 40 billion dollars [35]. Every city resident has a smart card that allows them to use city services easily. Smart cities experts have a rather ambiguous attitude to town Songdo, even calling it «too smart» [35].

In 2014, Singapore adopted the Smart Nation program [36]. The implementation of the program helps to solve a number of important problems: the level of security has significantly increased due to the CCTV system that was installed in the city. By using a Virtual Singapore platform, the authorities have the opportunity to analyze the situation in the city and effectively address emerging problems as well as prevent them. In 2017, Melbourne was ranked the smartest city in the world according to the Intelligent Community Forum (ICF) [37]. Melbourne is far from being considered a beginner in "smartization". The city has been actively innovating in various areas of city life for several years in order to make it as comfortable, safe and modern as possible. The Open data platform is used in the city since 2014 and is «aiming to increase transparency, improve public services and support new economic social initiatives». Also in any area of Melbourne, people can easily connect to free Wi-Fi, which adds merit to smart city efforts in the city.

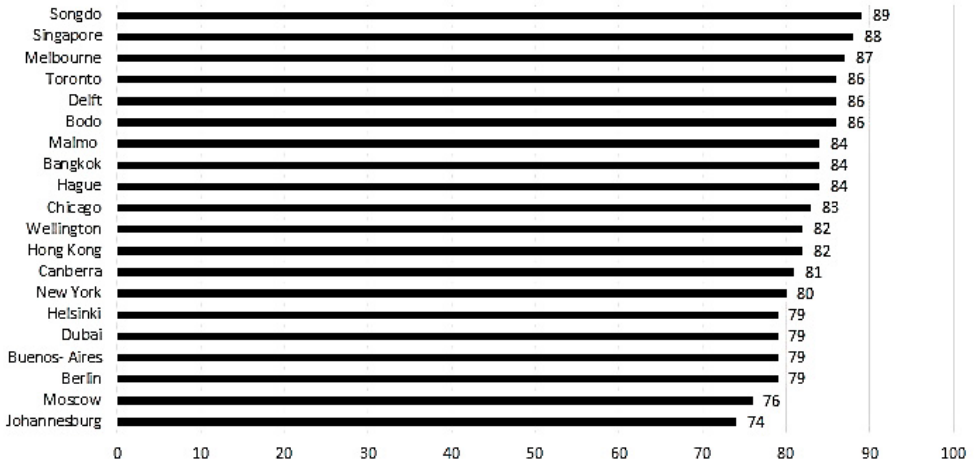

Fig. 1. Experts' summarized assessments of smart cities, the authors' calculations

The study also found the areas that were among the very first priorities of smart city development in each case. Results show that transportation issues have become drivers for smart cities in Hague [38], Chicago [39], New York [40], Toronto [41], Bangkok [42], Dubai [43], Hong Kong [44] and Moscow [45]. For instance, the citizens' quality of life was of significant interest for the administrators of Berlin [46], Canberra [47], and Melbourne [37]. Special projects addressed the smart response to the flooding have been found in Buenos Aires [48] and Delft [49]. Ecology and sustainable environment have been detected as key areas for Scandinavian cities like Bodo [50], Helsinki [51] and Malmo [52]. In Wellington's case [53, 54], much attention is given to development of intellectual potential, as well as to international cooperation and knowledge sharing. Johannesburg is the main innovation center of Africa that supports world trends and realizes the existing need for qualified specialists for the smart future. In 2015, Johannesburg introduced «…a program referred to as COJEDI to educate 'digital interns' and prepare them for careers in information and communications technology (ICT)» [55].

4.2. Experts' assessment

Table 2 summarizes the assessments that each city received during the research. The total mark is presented in the brackets near the city name. In this study, this systematic view is not focused on official statistics on the use of technological applications for smart cities, but a subjective estimation of its' effectiveness and comfort perception of usability by inhabitants. The indicators ranged from 1 to 5, where 1 demonstrates low level of deployment; 3 – medium level of development and intermediate usability; 5 – high level, high usability. When considering the results and implications of this study, it is also important to mention that while Cohen's indicators were used. The results from these findings also consider well-defined aspects of this method. The experts went through the questions on different aspects in order to get a more profound understanding of each direction, and then tried to estimate the aspect ranging the mark from 1 to 5. After focusing on different sides of the aspect it is easier for the expert to range the aspect. For instance, Smart Living included facilities for healthy lifestyle, safety, conditions for cultural heritage protection and esthetic personal development. Smart Government reflected online administrative services, open government, clear infrastructure of administrative organizations, less bureaucracy. Smart people measured a level of education, conditions and facilities for creative thinking, inclusive society. Smart mobility proposed ICT for faster transportation inside the city, multi-modal access to personal services, ecological and energy efficient vehicles. Smart economy: equal distribution of resources, opportunities for entrepreneurship, digitalization of economic processes, vast network of domestic and international economic connections. And Smart environment belonged to thoughtful urban planning, smart constructions (illumination, thermal comfort, air quality, physical security, sanitation), advances management of allocation of resources.

Table 2. Smart Cities Benchmarking Results, 2017

Actions and Indicators		Smart Cities																			
		Bangkok (84)	Berlin (79)	Bodo (86)	Buenos-Aires (79)	Canberra (81)	Chicago (83)	Delft (86)	Dubai (79)	Hague (84)	Helsinki (79)	Hong Kong (82)	Johannesburg (74)	Malmo (84)	Melbourne (87)	Moscow (76)	New York (80)	Singapore (88)	Songdo/Incheon(89)	Toronto (86)	Wellington (82)
Smart Economy	Opportunity	4	5	4	5	4	5	4	5	4	4	5	5	4	5	4	5	5	5	5	5
	Productivity	5	4	5	5	5	5	4	4	4	4	5	4	4	5	5	5	5	5	4	4
	Local & Global interconnectedness	5	5	4	4	4	5	4	5	5	4	5	4	4	5	5	5	5	4	5	4
Smart Living	Health	5	5	5	5	5	5	5	5	5	4	4	4	5	5	4	5	5	5	5	5
	Safety	4	5	5	4	5	4	5	5	5	5	4	4	5	5	3	3	5	5	5	5
	Culture and Happiness	5	4	5	5	5	4	5	4	4	4	5	4	4	5	5	5	4	5	5	5
Smart Gov	Online Services	4	4	5	4	5	5	5	4	5	4	5	4	5	5	4	5	5	5	5	4
	Infrastructure	5	5	5	5	5	5	5	5	5	4	5	4	5	5	4	4	5	5	5	5
	Open Government	5	5	5	4	5	5	5	4	5	5	4	4	5	5	5	4	5	5	5	5
Smart People	Education	5	5	5	5	5	5	5	3	5	5	5	4	5	5	5	5	5	5	5	5
	Inclusive Society	5	5	5	5	5	4	5	5	5	5	5	4	5	5	4	4	5	5	5	5
	Creativity	5	4	4	5	4	5	5	3	4	4	4	4	4	4	5	5	5	5	5	4
Smart Mobility	Mixed-modal access	4	3	4	3	3	4	5	4	4	3	4	4	4	4	4	4	5	5	4	4
	Clean& non-motorized mobility	4	4	5	4	5	5	5	5	5	5	5	4	5	5	4	4	5	5	5	5
	Integrated ICT	5	4	5	5	4	5	4	5	5	5	4	5	5	5	5	5	5	5	5	4
Smart Environment	Smart Buildings	5	4	5	4	4	4	5	4	5	4	4	4	5	5	3	4	5	5	4	4
	Resource Management	4	4	5	3	4	4	5	4	4	5	4	4	5	4	3	3	4	5	4	4
	Urban Planning	5	4	5	4	4	4	5	5	5	5	5	4	5	5	4	5	5	5	5	5

5. Conclusions and discussion

The conducted benchmarking stressed the case of Songdo/Incheon as most the “fully equipped” smart city. Singapore, Melbourne, Bodo, Delft and Toronto are also not far behind the leader. According to the official programs and plans, the following key areas of development in the cases were identified: ecology transport, comfort of life. However, the studied Smart Cities got quite high ranks in the following areas: Smart Living, Smart People, Smart Government.

To determine the most critical factors among the assessed indicators, we applied correlation analysis and revealed the following trends. The high level of Smart Environment resource management indicator statistically connects with a high level of Smart Economy opportunity (0,7 coeff.), Smart Living Safety (0,7), Clean and non-motorized mobility (0,6), Smart Building (0,6), and Open Government (0,5). At the same time, the higher the level of Resource management indicator in the measured cases, the lower was the level of Smart Economy Local and Global interconnectedness (-0,5) and Smart Economy Productivity level (-0,3). In turn, the Smart Economy Productivity level influences positively on Smart Living Culture and Happiness indicator (0,5) and Smart People Creativity (0,45).

In the studied smart cities, the higher the mark for Smart People Education, the higher was the level of Smart People Creativity (0,6), Open Government development (0,54), Online services delivery (0,4), Smart Living Culture and Happiness (0,38) and Smart Economy Productivity (0,34). The Smart Living Safety indicators correlates positively with Smart Gov Infrastructure (0,6), creation of an Inclusive Society (0,78), Clean & non-motorized mobility (0,71), Smart Building construction (0,54) and Smart Living Health indicator (0,4). However, the higher the Smart Lining Safety, the lower Smart Economy indicators like productivity (-0,5) and local and global interconnectedness (-0,3)

were. The high level of Smart Gov Infrastructure results in a higher level of Smart Lining Health system (0,7), Inclusive Society creation (0,68) and Online Services delivery (0,4).

Implementation of IT is also, and to a great extent, influenced by the average age of the population and the city itself. That might explain why older European cities are more oriented to complicated design with friendly usability for the older population. The flexibility is higher in Asian cities and in the latest "cities of the future". So far, the outcome of variables may be categorized in the same way, but the nature of smart cities technologies is different. Nature protection and ecology is seen more as an indicator of comfort living in the older places, while being a matter of urban planning in new ones. For example, the Statutes of Singapore give the ground for building and nature harmonization and provide the planting, maintenance and conservation of trees and plants simultaneously.

Finally, because smart cities are complex socio-technical systems, citizens' and experts' perceptions need to be considered so sustainable urban development can be achieved iteratively and effectively. Some limitations of the current research exist, those include a not large scale of experts' coverage, as well as a limited list of smart cities. Another critical point could related to experts' possible overestimation of the cities' smartness. We should stress the comparative nature of the scores, that means that 3 points among the indicators indicate not a medium, but a real gap in comparison with the other components. However, if the same methodology is applied for those cities that are just thinking about the smartization, this framework could shed a light on the gap areas for development. The achieved results could be used for detecting the gaps the prominent areas for better smart city development. Future research should continue to explore the aspects identified in this preliminary work and to advance understanding on under-explored ones, such as citizen-centric metrics and perspectives.

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