Vulnerabilities of Smart Cities Development in a Context of Uncertainty at European Level

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Abstract

The current context for the development of smart cities is affected by the economic and social uncertainties generated by the multiple crises that are manifesting themselves in the European space both through the declining geopolitical conflict and the economic recession that the European Union is going through.

We aim to conduct a study on smart city vulnerabilities in the current context of uncertainty in order to identify the contribution of smart governance components to increase social welfare. We will also develop a regression model of social welfare for smart cities using empirical and econometric methods (multiple linear regression).

The results of the study will highlight the level of smart city development of 10 European regions (Bulgaria, Denmark, France, Germany, Hungary, the Netherlands, Poland, Romania, Sweden and the EU27 average) over the period 2012-2021. The results will be useful for national decision-makers to improve public policies related to smart city development in Europe.

Keywords: *smart city, smart governance, econometric model, economic development, vulnerabilities, social welfare*

JEL classification: *F 63, O 1, O 35*

DOI: 10.24818/RMCI.2023.11.847

1. Introduction

The development of smart cities is a highly topical new dimension that combines climate neutrality, sustainability and social protection in a dynamic concept aimed at improving the quality of life of the inhabitants of large urban agglomerations. Through European projects, significant steps have been made in the smart transformation of cities across the EU, with the use of sustainable energies, more efficient urban transport, digital connectivity, and the boosting of citizens' initiatives. These aspects have helped European cities to transform themselves both in terms of energy, reducing consumption and carbon emissions,

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and in terms of urban development by systematizing transport networks and improving urban mobility. Involvement of citizens in decision making has been increased through smart grid systems and digital platforms that have allowed better interaction between citizens and decision makers and thus more sustainable urban management.

A smart city can be defined as an urban area that uses technology and data to improve the quality of life of its inhabitants and to enhance the efficiency of its services. It is a city that harnesses innovative solutions to address challenges such as energy consumption, waste management and public safety. Although the usefulness of smart city transformation is well known, there is not yet a homogeneity of smart development at European level. According to the report Mapping Smart Cities in the EU (European Parliament, 2014) the characteristics of smart cities are presented, each with different objectives and implementation methods. These characteristics are shown in Figure 1.

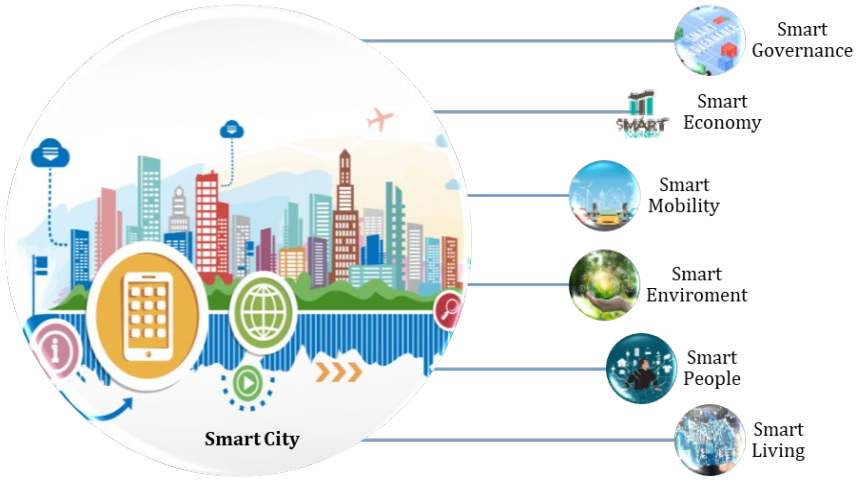

Figure 1. Main characteristics of Smart city
Source: Elaborated by the authors after report Mapping Smart Cities in the EU (European Parliament, 2014)

An innovative concept with a significant role in smart city transformation is smart governance, which involves integrated governance within and between cities, involving public and private organisations. It uses ICT, smart processes, and data to operate efficiently. In this respect the functional congruency refers to the match between stakeholders' expectations regarding the implementation of a social responsibility code and their perceptions on how an organization or system is assessed form the social perspective (Cristache, N., Năstase, M., Petrariu, R. and Florescu, M., 2019).

The objectives of smart governance are to improve decision-making in line with social will, increase the quality of services through digitalization and make e-

government more efficient. Another specific aspect of smart cities is the smart economy which aims to strengthen e-commerce, increase productivity, production, innovation, and new ICT-based products/services, create smart clusters and ecosystems, and promote interconnection and international integration of goods, services, and knowledge.

Smart urban mobility refers to integrated transport and logistics systems, supported by ICT, that focus on clean options. It provides real-time information improving transport efficiency, saving costs and reducing carbon emissions. Based on intelligent mobility, reliable planning of urban transport flows can be achieved with long-term benefits. Smart environment encompasses renewable energy, ICT-based networks, green building renovation, green urban planning, resource efficiency, resource reuse and substitution, and monitoring of urban services such as street lighting and waste management. Smart people encompass e-skills, ICT-enabled work, education, training, human resources, and capacity management in an inclusive society. Smart Living refers to ICT-enabled behaviour and consumption, promoting quality safe housing, housing, and social cohesion in a dynamic city.

By investing in renewable energy sources and promoting green businesses, cities can create new job opportunities and attract investment. Implementing energy efficient technologies and practices can lead to cost savings for both the city and its residents (Petrariu, R. I., Năstase, M., Croitoru, G., Florea, N. V., Cristache, N., & Ibinceanu, M. C. O., 2023). This, in turn, can stimulate economic growth and improve quality of life. Focusing on environmental sustainability in a smart city brings environmental benefits and contributes to the city's economic growth. By reducing pollution (air and water) smart cities contribute to improving social well-being.

We propose to carry out a study on the vulnerabilities of smart city development in the current context of uncertainty manifested at the community level, research aimed at identifying the contribution of smart governance components to increase social welfare through a regression model to achieve the following objectives:

O1. Carrying out a critical study of the specialized literature on the impact of the development of smart cities on social well-being.

O2. Strengthening databases for the analysis of correlations between smart governance indicators and social well-being.

O3. Making the econometric model of social welfare for smart cities.

O4. Identify the main vulnerabilities affecting the uneven development of the smart city.

2. Literature review

In the literature, the concept of the smart city has been studied extensively by some researchers. The smart city concept refers to the use of technology and innovation to improve the quality of life in cities. This concept involves the integration of communication systems and infrastructure to make the management

of resources such as energy, water, and transport more efficient. By implementing smart solutions, the aim is to reduce carbon emissions, increase energy efficiency and improve public services, thus contributing to the sustainable development of cities.

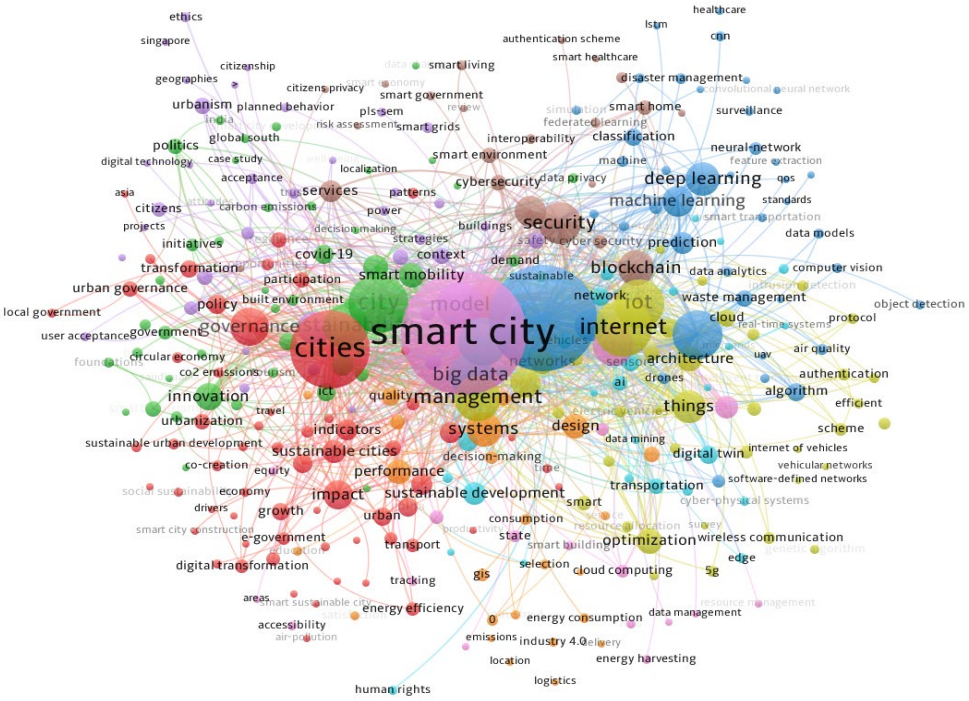

Figure 2. Bibliometric analysis of the literature on the Smart city concept
Source: Elaborated by the author using VOSviewer software

According to the Web of Science database in 2023, 5,720 articles were published with a citation rate of 5.437 per article without self-citation and a Hirsh index of 22 points. From Figure 2 it can be seen that the most significant areas of research were on digital public infrastructure for smart and sustainable development of cities (Chen et al., 2024; Cuc et al., 2023; Nyussupova et al., 2022; Ramirez Lopez & Grijalba Castro, 2021), improvement of social and economic sectors, information technology (Bălăşescu et al., 2022; Liu et al., 2021), digitization of the economy (Negrea et al., 2019), smart city for a green transition towards sustainable development (Ulpiani et al., 2023), etc.

An interesting paper (Lim et al., 2023) analyses the impact of smart city development considering first wave smart cities where the effect of smart development is based on providing smart mobility and security compared to second wave smart cities that value smart governance, the third category being non-smart cities. The authors propose a new index called the Smart City Impact Index based on observable indicators of environmental and social economic sustainability

complemented by indicators of smart governance and show that smart cities that focused on smart governance enjoyed higher economic development than the first wave but lower environmental and social dimensions (Paes et al., 2023). The authors highlight the importance of citizen participation in decision-making but also the negative effects of this action in terms of ensuring confidentiality in some aspects of decision-makers' activities.

Another study by Tara Vanli and Taner Akan (Vanli & Akan, 2023) presents a comprehensive framework for examining the interrelationships between smart city indicators and outcomes. The authors identify influencing factors using network analysis and propose an updated framework for smart cities based on network community detection. They argue that there are few trade-offs in the network of smart city indicators compared to existing synergies. A smart city framework based on digitisation, innovation, and sustainable infrastructure as well as human and social capital has been developed. However, limitations include a focus on identifying smart city indicators as well as a lack of reliable city-level data. Another relevant paper (Chen et al., 2024) focuses on improving urban environmental economic efficiency through smart city pilot projects. The authors use the Data Envelopment Analysis-Slack Based Model to measure green economic efficiency and evaluate its impact using the PSM-DID model. The authors conclude that smart cities can improve efficiency through technological, structural and energy effects.

The rapid progress of 5G technologies leads to innovations in Smart City technologies. Authors Zaheer Allam and David S. Jones (Allam & Jones, 2021) explores the potential of 6G technology in addressing socio-economic impact in cities with digital infrastructure and in promoting sustainable development goals. The authors mention that the development and application of 6G technology should align with policy agendas to support sustainability transitions, guiding the design, manufacture, and operation of IoT devices to be more sustainable and align with current and future climate resilience policies.

Another interesting study (Savastano et al., 2023) examines the current state of smart mobility and the factors influencing its proliferation through ICT applications and social media. The authors use content analysis from over 1000 reviews on Milan's smart city digital platforms and compare it with users of public urban mobility services. The authors use the STEEP method and SWOT analysis are used to provide a comprehensive perspective on social, technological, environmental, economic, and political issues. The study points to the need for smart mobility solution providers and institutions to effectively deploy digital services at various touch points.

Another research by the authors (Aceleanu et al., 2019) analyse the circular economy in the context of sustainable development, with a focus on improving resource use, reducing waste and recycling. The authors stress the importance of the circular economy in providing resources for future generations and in developing smart cities. They identify the main actions recommended at EU level to promote this vision, highlighting economic and institutional barriers. Romania

has made progress in implementing efficient municipal waste management to promote the circular economy vision. However, the study recognises the challenges in developing sectors related to resource circularity and the emergence of employment opportunities, which require active involvement from both the public and private sectors. Another relevant paper (Ibănescu et al., 2022) examines the integration and implementation of smart city concepts in Romanian cities, focusing on smart mobility and smart applications. The authors note a growing openness on the part of authorities to integrate smart components, but discrepancies between statistics and available information suggest the need for clarification and harmonised statistics to create more effective evidence-based policies. The authors conclude that smart city implementation is still in its early stages in Romania's major cities. Although they cover a wide variety of forms from common adaptations such as apps to integrated projects covering urban infrastructure and large-scale strategies, smart city policies still lack uniform statistics, national funding, and a harmonised approach. According to author Bokolo Anthony Jr. (Anthony, 2023) the urbanisation process requires the implementation of efficient transport systems to achieve climate targets and create a technologically advanced living environment. Electric mobility as a service (eMaaS) has the potential to increase sustainability in urban areas. According to the author this fosters integration and encourages the use of green transport in smart urban areas as well as revenue generation from new technologies.

3. Findings

According to Lukacs Edit, (2002), „the evaluation of performances is the process of setting the way the employee does his tasks and responsibilities according to the job description, comparing to the set standards and the communication of the results to the employees". The evaluation of the performances is a base activity of the human resources management and takes place with the purpose of establishing the way the employees in a company do their tasks and their responsibilities, which has a direct impact on the performance of the hotel.

To achieve the purpose of the research we used the analytical approach of Eurostat databases from which the following indicators were collected for the period 2012-2021, for a number of 10 countries, namely Bulgaria, Denmark, France, Germany, Hungary, the Netherlands, Poland, Romania, Sweden and the EU27: IA - Level of internet access - households (Percentage of households) (Eurostat, 2023d); IU - Internet use by individuals (Percentage of individuals) (Eurostat, 2023c); RW - Recycling rate of municipal waste (Percentage) (Eurostat, 2023f); EITC- Employed ICT specialists – total (Eurostat, 2023a); GDPITC - Percentage of the ICT sector on GDP (Eurostat, 2023e); HSIC- High-speed internet coverage, by type of area (Percentage of households) (Eurostat, 2023b).

The analysis set out to prove the following working hypotheses:

H1. Amid the acceleration of digitalization and the increase of household access to the internet, the impact of this indicator on welfare social growth tends to be reduced.

H2. Increasing the number of specialists in the IT sector as a support for smart city development has a significant positive impact on the growth of social welfare.

H3. Promoting environmental care and improving the selective waste collection capacity in smart cities has a positive and growing impact on social welfare.

H4. The multiple crises manifest a significant disruptive effect on the correlation between social welfare and social well-being of European smart cities.

Using the linear regression method, we designed the econometric model of social welfare for the smart cities in the 10 regions analyzed and determined the annual welfare equations according to the formulas below.

$$GDPITC2012 = 0.055 * IA - 0.077 * IU + 0.017 * RW + 1.571 * EITC + 0.003 * HSIC + 0.234 \quad (1)$$

$$GDPITC2013 = -0.129 * IA + 0.071 * IU + 0.006 * RW + 1.031 * EITC - 0.007 * HSIC + 5.502 \quad (2)$$

$$GDPITC2014 = -0.157 * IA + 0.082 * IU + 0.01 * RW + 1.069 * EITC - 0.008 * HSIC + 6.699 \quad (3)$$

$$GDPITC2015 = -0.067 * IA - 0.006 * IU + 0.008 * RW + 1.131 * EITC - 0.003 * HSIC + 6.025 \quad (4)$$

$$GDPITC2016 = -0.118 * IA + 0.038 * IU + 0.005 * RW + 0.926 * EITC - 0.006 * HSIC + 7.835 \quad (5)$$

$$GDPITC2017 = 0.01 * IA - 0.115 * IU + 0.019 * RW + 1.222 * EITC - 0.006 * HSIC + 7.897 \quad (6)$$

$$GDPITC2018 = -0.047 * IA - 0.072 * IU + 0.034 * RW + 0.777 * EITC + 0.004 * HSIC + 10.153 \quad (7)$$

$$GDPITC2019 = -0.041 * IA - 0.113 * IU + 0.025 * RW + 1.024 * EITC - 0.011 * HSIC + 13.587 \quad (8)$$

$$GDPITC2020 = -0.262 * IA + 0.016 * IU + 0.013 * RW + 0.832 * EITC - 0.008 * HSIC + 23.616 \quad (9)$$

$$GDPITC2021 = -0.277 * IA - 0.027 * IU - 0.009 * RW + 0.805 * EITC + 0.003 * HSIC + 29.384 \quad (10)$$

The regression equations show that the level of household internet access showed a low inverse proportional correlation of at most 15% in 2014 with social welfare as reflected by the GDPITC indicator - Percentage of the ICT sector on GDP. This confirms Working Hypothesis 1, amid accelerating digitization and increasing household access to the internet the impact of this indicator on welfare growth tends to reduce. In the same sense a weak correlation was also manifested by the rates of boarding school use by individuals which did not influence by more than 11.5% the increase in social well-being through the variation of the dependent

variable. This was also observed in the high-speed inland coverage in which case the impact on GDPIT variation was maximum 1% in 2019. In the case of smart municipal waste collection capacity, it can be observed that higher correlation rates were obtained until 2019, with the pandemic triggering a reduction in the impact of this factor on social welfare. By 2019 we can estimate that hypothesis 3 is confirmed, i.e. promoting environmental care and improving selective waste collection capacity in smart cities has a positive and increasing impact on social well-being. Analysis of the correlation between the number of specialists in the IT sector and the increase in social welfare was observed based on regression equations to be over 122% until 2017, after which this correlation showed a fluctuating trend between 77% and 102% in the pre-pandemic years, again showing that the pandemic had a diminishing effect on the impact of this indicator on social welfare. However, even in 2021, this indicator had an impact of 80% on the variation of the dependent variable, confirming working hypothesis 2: the increase in the number of specialists in the IT sector to support the smart development of cities has a significant positive impact on the growth of social welfare.

The summary of the model is shown in Table 1 below.

Model Summary

Table 1

Model [a,b]	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
2012	0.960	0.922	0.825	0.738	0.922	9.482	5	4	0.024	2.296
2013	0.932	0.869	0.706	0.553	0.869	5.328	5	4	0.065	1.641
2014	0.948	0.899	0.773	0.488	0.899	7.140	5	4	0.040	2.153
2015	0.909	0.827	0.611	0.615	0.827	3.822	5	4	0.109	2.356
2016	0.880	0.774	0.491	0.660	0.774	2.734	5	4	0.176	2.680
2017	0.878	0.771	0.486	0.633	0.771	2.701	5	4	0.179	1.805
2018	0.871	0.759	0.458	0.684	0.759	2.518	5	4	0.196	1.897
2019	0.854	0.728	0.389	0.708	0.728	2.146	5	4	0.240	2.338
2020	0.905	0.819	0.592	0.694	0.819	3.614	5	4	0.119	2.644
2021	0.904	0.817	0.588	0.775	0.817	3.572	5	4	0.121	1.401

a. Predictors: (Constant), HSIC, IA, RW, EITC, IU
b. Dependent Variable: GDPITC

Source: Authors' calculations using SPSS v 26

Table 1 shows that the model is significantly influenced by external factors, with the significance level ranging from 82% at the beginning of the period to 58% in 2021. In fact, we can speak of an applicability of the model in the context of a stable economic development (until 2015 after which we note that the high level of the margins of the Sig coefficients above the 10% error representation limit certifies that the economic vulnerabilities affect differently the countries of

the Community area and it is not possible to identify a valid correlation of social welfare growth in the context of smart governance homogeneously for the 10 regions analysed. Since the onset of the pandemic, the level of Sig coefficients tends to re-approach the 10% significance threshold. This demonstrates working hypothesis 4: multiple crises manifest a significant disruptive effect on the correlation between smart governance and social well-being in European smart cities. The Anova test was performed according to the data presented in Table 2.

Anova

Table 2

Model [a,b]		Sum of Squares	df	Mean Square	F	Sig.
2012	Regression	25.804	5	5.161	9.482	0.024
	Residual	2.177	4	0.544		
2013	Regression	8.155	5	1.631	5.328	0.065
	Residual	1.225	4	0.306		
2014	Regression	8.504	5	1.701	7.140	0.040
	Residual	0.953	4	0.238		
2015	Regression	7.222	5	1.444	3.822	0.109
	Residual	1.512	4	0.378		
2016	Regression	5.954	5	1.191	2.734	0.176
	Residual	1.742	4	0.436		
2017	Regression	5.415	5	1.083	2.701	0.179
	Residual	1.604	4	0.401		
2018	Regression	5.896	5	1.179	2.518	0.196
	Residual	1.873	4	0.468		
2019	Regression	5.373	5	1.075	2.146	0.240
	Residual	2.003	4	0.501		
2020	Regression	8.695	5	1.739	3.614	0.119
	Residual	1.924	4	0.481		
2021	Regression	10.714	5	2.143	3.572	0.121
	Residual	2.400	4	0.600		

a. Predictors: (Constant), HSIC, IA, RW, EITC, IU

b. Dependent Variable: GDPITC

Source: Authors' calculations using SPSS v 26

From the data presented in Table 2, significant differences can be observed between the F function values favourable to the 2012-2015 period after which the function level decreases up to 4 times compared to the beginning of the period. In 2019 the onset of the pandemic favoured the increase of F function values recorded in 2015 knowing that during the pandemic period there was a significant reduction of urban mobility together with the growth of the digital economy which favoured smart city governance.

The data were analysed graphically by means of annual P-P plot charts showing that most errors are attributed to cities in developed countries (Denmark, Sweden, Germany, France) while the other countries tend to align with the trend line along with the EU27 European average.

The results of the model confirm the disparities between the smart developments of cities in developed European countries compared to cities in the other countries analysed and demonstrate working hypothesis 4.

The analysis revealed that although the indicators of smart governance are growing in the sample, there are significant regional disparities, with two regional clusters, namely that of developed countries (Denmark, Germany, Sweden, Netherlands, and France) and the developing countries (Bulgaria, Hungary, Poland, and Romania). The European average being the one at the middle of the interval separating the two clusters. Romania ranks last in terms of smart city governance, followed by Bulgaria and Poland, this shows that besides the elements specific to digitalization, the success of intelligent governance as a source of social welfare is determined by regional economic development, reduction of the level of bureaucratization, and flexibility of the administrative apparatus and active involvement of citizens in the decision-making act.

4. Conclusions

The study aimed to identify the vulnerability of smart city development in the current context of uncertainty manifested at the level of the community space. The research highlighted that vulnerabilities are differentiated according to the level of regional economic development and unfavourable developments are recorded especially in the less developed countries in the community space.

The research has achieved the study objectives, being conducted a critical study of the specialized literature that highlighted that digitization, resource circularity, innovation and technological revolution contribute to the development of smart city. At the same time, the econometric model of social welfare for smart cities was developed and implemented, a model that proved to be sensitive to the elements of uncertainty generating valid results for periods of economic stability.

The main vulnerabilities affecting the uneven development of smart city were identified, consisting of uneven regional economic development, bureaucratization, lack of flexibility of the administrative apparatus and lack of active involvement of citizens in the decision-making act. The study is useful for national decision makers to improve public policies in the smart city field. The limits of the study consist of the relatively small number of indicators used in the analysis and the period for which the data were available (until 2021), the authors proposing to extend the study to highlight other vulnerabilities affecting the smart city development of European cities.

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