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THE SMARTNESS PROFILE OF SELECTED EUROPEAN CITIES IN URBAN MANAGEMENT – A COMPARISON ANALYSIS

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Abstract. The smart cities concept plays an important role in urban management worldwide as well as should be implemented with the participation of residents and with consideration for their needs. This study examines an analysis of the smartness diversity of European cities on the basis of the International Organization for Standardization 37120 norm dealing with sustainable development of communities. Cities with a higher level of certification exhibit more effective management and their residents show greater commitment to civic life. The assessment of the level of smartness was based on statistics collected by the World Council on City Data using Multidimensional Comparative Analysis. Hellwig's (1968) synthetic indicators were used to create a ranking gauging the level of smartness of European cities which were classified into four groups. The investigation shows large disparities in the smartness of selected European cities.

Keywords: territorial management, spatial management, smart city, urban management, ISO37120, European cities.

JEL Classification: M0, M19, C18.

Introduction

Cities constitute places of innovation, creativity and knowledge worldwide. The approach to urban management is evolving as a result of the above challenges. Implementation of the concept of the smart city becomes a solution to all urban issues. Cities are subject to permanent transformations. Smart, sustainable and inclusive growth is one of the challenges of modern world. It is also a priority of the EU 2020 Strategy. The permanent improvement of the life quality of residents is particularly important in the context of urban areas characterized by a degraded natural environmental and many problems. The need for measurability of smart development is undisputed and does not require justification.

The object of the study was to assess the level of smartness of European cities which have implemented the ISO 37120 norm. The article made use of the Multidimensional

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Comparative Analysis method utilizing synthetic meters to compare individual urban centres. The aim of the paper was to present differences in the level of smartness of European cities and to find groups of cities with a similar level of smartness. In the theoretical part of the work, a diagnosis of conditions for smartness in city management was made using the cognitive–critical analysis of desk research with particular emphasis on reports of scientific institutions, international publications and strategic national documents. In the empirical part of the work an assessment of the implementation of the concept of smartness in selected European cities was made using statistical methods.

1. Background literature

Cities have become large population centers, as well as global hubs in the flow of capital, knowledge, innovation, specialized business services and consumer trends. On the other hand, cities face many problems, including congestion, environmental pollution and social segregation. The concept of a smart city has been raised in world literature since the nineteenth–century of the last century. Assessment of smartness and classifications of cities are important subject in this issues.

According to European Union (2014), 750 of the largest cities in the world generate 57% of global GDP. Contemporary researchers have created many models of cities such as the smart city, the digital city, the wired city, the learning city, the sustainable city (Duran-Sanchez, Rio-Rama, Sereno-Ramirez, & Bredis, 2016). In world literature there is a lack of an explicit definition for the concept of the smart city (Albino, Berardi, & Dangelico, 2015; Schuler, 2016; Hajduk, 2016). Furthermore, Kobayashi Kaneko, Kniess, Ribeiro Serra, Nogueira Ferraz, and Ruiz (2017) prepared a bibliometric analysis of publications dealing with the smart city. In recent years, many concepts have emerged regarding the urban management, particularly within the concepts of the network model, intellectual capital, e–governance, metropolitan specialization, urban foresight, the cluster, value–based management, reengineering, innovative organization, lean management (Flynn, 2012; Andrews & Van de Walle, 2013; Ricciardi & Za, 2014). Otherwise Pike, Rodriguez-Pose, and Tomaney (2006) claims that the evolution of urban management is an attempt to develop an effective methodology for strategic planning and management of metropolitan and municipal levels.

Local authorities use various tools to stimulate and control the processes taking place within the city. In this regard important concepts include sustainability, knowledge–based organization and intelligent growth forming the foundations of the concept of the smart city. In the past smart city focused on technological aspects and hard infrastructure. The smart city has been defined as an urban intelligence system that connects devices and sensors with increasingly efficient digital telecommunication networks (Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014; Hu, Li, Ngai, Leung, & Kruchten, 2014; Rathore, Ahmad, Paul, & Rho, 2016). Whereas, other definitions focus on social capital (Komninos, 2006; Labra & Sanchez, 2013). Moreover Dameri and Ricciardi (2015) suggest that smart city is an area of high learning and innovation which fosters creativity through research and development institutions as well as organizations of higher learning. According to Nam and Pardo (2011), the concept of the smart city is linked to such fundamental components as: (I) technology factors (intelligent city, ubiquitous city, wired city, hybrid city, information city): physical infrastructure, smart technologies, mobile technologies, virtual technologies, digital technologies; (II) human factors (creative city, learning city, knowledge city): human infrastructure, social capital; (III) institutional factors (smart community, smart growth): governance, policy, regulations, directives.

Definitions of the smart city are various. According to Giffinger (2015) smart city is a well performing, forward–looking city built on the intelligent combination of activities of citizens who are independent and aware. Rios (2008) asserts that smart city is a place for sharing culture, knowledge and life, a city that provides inspiration and motivates its inhabitants to create and thrive within their own lives. Harrison's et al. (2010) approach describes it as an instrumented and interconnected where instrumentation enables the integration of real–time, real–world data through the use of sensors, personal devices, appliances, smart phones, the web, and other similar data–acquisition systems, its interconnectivity allows the integration of that data into the enterprise's computing platform and the communication of such information to various city services while its intelligence refers to the inclusion of modelling, optimizations and visualizations into companies' operational business processes to make better operational decisions. Hollands (2014), on the other hand, suggests that smart city helps to solve problems connected with urbanization especially pollution of environment, land consumption, urban sprawl, transport congestion, energy needs, difficulties related to accessing public services as well as encompasses a diversified set of public initiatives including the creation of better transportation systems, supporting creative innovation and knowledge or development of energy-saving policies. Dirks and Keeling (2009) support the integrated attitude to smart city and emphasize the fact that no system operates in a vacuum. Moreover Komninos (2011) indicated four dimensions of smart city connected with ICT: (I) the application of digital technologies to create a knowledge-based city; (II) the use of ICT to transform inhabitants' life; (III) ingraining of information technology in urban infrastructure; (IV) exploitation of ICT by people to provide growth of innovation. Dameri and Garelli (2014) claim that the smart city implementation requires the participation of various shareholders. Finally, Shapiro's (2006) version argues that quality of life cannot be an isolated feature of smart city because all actions within other dimension should contribute to the improvement of the quality of life.

Current challenges faced by urban centers influence changes in city management. The New Public Management model promotes corporate style of management in the public sector. It moves away from the control of inputs and procedures for the measurement of results in the pursuit of excellence and high quality standards (Baclija, 2012). The Public Governance model builds a civil society and treats citizens as co–decision makers. The Multilevel Governance model includes horizontal and vertical stakeholders in city management (Salet & Thornley, 2007). The Excellence Quality Management model is based on increasing the competitiveness of cities in the pursuit of excellence (Ntungo, 2007). The Total Quality Management model promotes the achievement of success through the quality activities of its employees. Urban leaders often use outsourcing, crowdsourcing, e-government (Aleksjeczuk & Sachpazidu–Wójcicka, 2015), benchmarking, metropolitan foresight (Braid, 2001; Roberge,

2013) and urban specialization. Urban Living Lab supports local authorities in the search for effective ways of solving urban problems using creativity and innovation of city stakeholders (Voytenko, McCormick, Evans, & Schliwa, 2016).

An important strategic document referring to a citie's smart sustainability is the local spatial development plan. Unfortunately, many Polish cities have not created such plans. Average planning coverage is 49.6% for cities (30.2% for Poland) and 15.6% of areas have only a project of such plan. Additionally, planning coverage is characterized by great diversity, for instance Lodz is covered by plans in only 16.1%, but Gdansk – 65.4% (Hajduk, 2018). Lack of spatial development plans causes chaotic development and urban sprawl of cities (Howe & Langdon, 2002; Fertner, Jørgensen, T. A. S. Nielson, & K. S. B. Nilsson, 2016). An important issue is the development of sustainable transport in the context of spatial management. Contemporary cities need to better use available technical and organizational solutions to improve the current urban transport situation (Hajduk, 2017). Furthermore, citizens' participation should become the base for all strategic decision–making (Antunes, Sapateiro, Zurita, & Baloian, 2010; Horelli, 2013).

Literature contains many procedures for testing a city's performance and numerous organizations and institutions have prepared city rankings (Institute for Urban Strategies, 2016) in particular relating to the life quality. Foundations for the study and measurement of smart city has been created by Giffinger et al. (2007). The most intelligent cities turned out to be Luxembourg, Aarhus and Turku. Kearney (2017), on the other hand, developed his Global Cities Index on the basis of the following factors: economic activity, human capital, information exchange, cultural experience and political commitment. In turn, Lombardi's, Giordano, Farouh, and Yousef (2012) approach to measuring determinants of urban development is reflected in his analysis sixty urban features through the use of the Analytic Network Process. The author identified entrepreneurship and innovation as the most important features of urban development. Moreover, Caragliu, Del Bo and Nijkamp (2011) argued that the presence of the creative class and transport accessibility significantly influence urban development. The issue of urban development factors is extensively described in literature. Innovation, entrepreneurship and creativity are its most important determinants. Furthermore, CITYkeys suggested five themes of smart city: people, the planet, prosperity, governance and propagation (Bosch et al., 2017). Cohen (2012) identified 62 indicators of the six components of the Smart Cities Wheel such as safe, healthy, energy, urban planning. Whereas, Neirotti, De Marso, Cagliano, Mangano, and Scorrano (2014) indicated twelve domains which are highlighted in a number of urban development studies and whose main features include natural resource and energy, transport and mobility, buildings, living, government and economy, people. He (2017) construct an evaluation index system based on the Analytic Hierarchy Process which is suitable to Chinese conditions. Moreover Dall'O', Bruni, Panza, Sarto, and Khayatian (2017) create a methodology for assessing smartness used for medium and small cities in northern Italy. In scientific literature there are a lot of methods to measure a smart city. In this context it is important finds classification of European cities. Table 1 presents the most popular ranking of smart cities. The leaders are London, Paris and New York in five rankings.

Table 1. Characteristic of the most popular ranking of smart cities

Name	Important cities	Domains of indicator
Global Smart City Performance	Singapore, London (UK), New York (USA)	Mobility, healthcare, public safety and productivity
Global Cities Ranking	London (UK), New York (USA), Paris (France)	Business activity, human capital, information exchange, cultural experience and political engagement
Ranking of Cities in Motion	New York (USA), London (UK), Paris (France)	Economy, human capital, technology, environment, international outreach, social cohesion, mobility and transport, governance, urban planning, public management
Ranking of World Cities	London (UK), New York (USA), Tokyo (Japan)	Advanced business services such as financial, accounting, consulting, legal, advertising
Global Power City Index	London (UK), New York (USA), Tokyo (Japan)	Economy, R& D, cultural interaction, livability, environment, accessibility
Innovation Cities Global Index	London (UK), New York (USA), Tokyo (Japan)	Cultural assets, human infrastructure, networked markets

Note: author's elaboration on the basis of Juniper Research (2017), A.T. Kearney (2017), IESE (2017), Globalization and World Cities (2016), The Mori Memorial Foundation (2017).

The most popular model of smart city are International Organization for Standardization 37120: Sustainable Development of Communities (ISO), British Standards Institute Maturity Model (BSI) and International Data Corporation MaturityScape (IDC). Lynch (2015) suggest that the ISO 37120:2014 standard helps to compare cities in terms of urban service performance and quality of life. World Council on City Data (WCCD) Open Data Portal, based on the ISO 37120 international standard of city data, allows the examination and monitoring 46 member cities (Steele, 2014; Fox, 2015; McCarney, 2015). Table 2 presents individual regions of the world along with selected cities which are connected in the WCCD. The most cities are from Europe (31%) and North America (30%). According to Marsal-Llacuna (2015), the ISO 37120 norm has used 46 basic and 54 additional indicators including 17 thematic groups. Appendix 1 shows their characteristics in relation to fundamental indicators. The most indicators (together 10) have the solid waste. The waste water consists of only 5 core indicators.

Table 2. List of Smart Cities

Regions	Cities (Country)
Europe	Amsterdam (Netherlands), Eindhoven (Netherlands), Heerlen (Netherlands), Rotterdam (Netherlands), Zwolle (Netherlands), Helsinki (Finland), London (United Kingdom), Koprivnica (Croatia), Zagreb (Croatia), Aalter (Belgium), Gdynia (Poland), Barcelona (Spain), Valencia (Spain), Porto (Portugal), Sintra (Portugal)
Asia	Shanghai (China), Amman (Jordan), Dubai (United Arab Emirates), Haiphong (Vietnam), Jamshedpur (India), Pune (India), Surat (India), Makati (Philippines), Makkah (Saudi Arabia), ArRiyadh (Saudi Arabia), Taipei (Taiwan)

End of Table 2

Regions	Cities (Country)
Africa	Johannesburg (South Africa), Tshwane (South Africa), Minna (Nieria)
America North	Boston (USA), Los Angeles (USA), Oakville (USA), San Diego (USA), Cambridge (Canada), Saint–Augustin–de–Desmaures (Canada), Shawinigan (Canada), Surrey (Canada), Toronto (Canada), Vaughan (Canada), Guadalajara (Mexico), Leon (Mexico)
America South	Bogota (Colombia), Bueno Aires (Argentina)
Oceania	Brisbane (Australia), Greater Melbourne (Australia), Melbourne (Australia)

Note: author's elaboration on the basis of (World Council on City Data, 2017).

2. Material and methods

The empirical material in this study was based on currently available statistical data listed by the World Council on City Data between 2014 and 2017. The measurement of socio-economic development is very complex due to the wide range of factors. Hence, the development level of European cities' was investigated through the application of the Multivariate Comparative Analysis method and the linear ordering of objects, developed originally by Hellwig and allowing the creation of ranking of objects measured using multiple variables. Through in this method objects being studied are arranged on the basis of their distance from the established reference object.

Hellwig's synthetic indicator was created on the basis of diagnostically selected variables relating to substantive, formal and statistical criteria. In this investigation significance, the level of variability and the level of correlation of variable pairs were important. The final set of diagnostic variables described the cities' economic situation as well as their inhabitants' social conditions. In relation to formal assumptions selected variables are characterized by measurability, completeness and accessibility. Statistically criteria concerns an appropriate level of variable variation and exhibit a low correlation between them (Guyon & Elisseeff, 2003). The level of variation was calculated using the following formula (Panek, 2009):

$$V = \frac{S_{Xj}}{\overline{x}_j} \cdot 100\%, \quad (1)$$

where: V – the coefficient of variation; S_{Xj} – the standard deviation of j-th variable; j – the number of variables; $\overline{x}_j$ – the mean value of j-th variable.

Next, variables with a coefficient of variation below 10% were eliminated and correlations between remaining variables were calculated using Pearson's correlation coefficient whose critical value was establish as the absolute value of 0.5. Variables with value slower than this threshold were selected for analysis and, in the end, twelve variables were identified:

X_1 – share of students completing secondary education [%];

X_2 – ratio primary education students to teacher [–];

X_3 – number of total residential electrical energy use per capita [kWh/yr/capita];

X_4 – number of natural disaster related deaths per 100 thousands of population [units/100,000/yr];

X_5 – number of in–patient hospital beds per 100,000 of population [units/100,000];

X_6 – under age five morality per 1,000 of live births [units/1,000];

X_7 – number of homicides per 100,000 of population [units/100,000/yr];

X_8 – share of city population living in slums [%];

X_9 – number of cell phone connections per 100,000 of population [units/100,000];

X_{10} – length of high capacity public transport system per 100,000 of population [kilometres /100,000];

X_{11} – number of public transport trips per capita in year [units/capita/yr];

X_{12} – share of the city's wastewater receiving tertiary treatment [%].

It is important to determine the nature of the objects describing variables. Stimulants are variables whose high value means a favorable level of researched phenomenon development. On the other hand, inhibitors are variables whose high values signal a negative impact on the phenomena being studied. Characteristics X_2, X_3, X_4, X_6, X_7, X_8 were identified as inhibitors while the rest were accepted as stimulants. A numerical description of the set of objects can be presented as an observation matrix:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}, \tag{2}$$

where: x_{ij} – the value of *j*-th characteristic for *i*-th object ($i = 1,2,\ldots,n; j = 1,2,\ldots,m$).

On account of the variables' various units and values the next step involved the normalization of selected variables. The arithmetic mean of the j-th characteristic ($\overline{x_j}$) and the standard deviation of the *j*-th characteristic (s_{xj}) were calculated using the method of standardization having the following formula (Panek, 2009):

$$z_{ij} = \frac{X_{ij} - \overline{X_j}}{S_{Xj}}. \tag{3}$$

These transformations resulted in the creation of a matrix of standardized values of characteristic *Z*:

$$Z = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1m} \\ z_{21} & z_{22} & \cdots & z_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ z_{n1} & z_{n2} & \cdots & z_{nm} \end{bmatrix}, \tag{4}$$

where z_{ij} – the standardized values of x_{ij}.

And finally, Euclidean distances between the object and the ideal object P_o (c_{io}) were calculated using the following formula (Młodak, 2006):

$$c_{io} = \sqrt{\sum_{j=1}^{n} \left(z_{ij} - z_{oj} \right)^2}, \tag{5}$$

where: $z_{oj} = \begin{cases} \max_i \left\{ z_{ij} \right\}, \text{ for stimulants} \\ \min_i \left\{ z_{ij} \right\}, \text{ for destimulants} \end{cases}.$

In the last step Hellwig's synthetic indicator (d_i) was determined utilizing the following formula (Lesot, 2006):

$$d_i = 1 - \frac{C_{io}}{C_o}, \quad (i = 1, 2, \ldots, n), \tag{6}$$

where: $C_o = \overline{C_o} + 2S_o$ – the critical distance between the object and the "ideal object".

Moreover, to simplify comparisons between the development levels of cities a modification of Hellwig's synthetic indicator ($d_i^{'}$) according to the following formula was applied (Hellwig, 1968):

$$d_i = \frac{di}{di\ \max} \cdot 100\%, \tag{7}$$

where: $di\ \max$ – the maximum value of the synthetic indicator.

The transformed indicator for the most developed city, therefore, is assigned a value of 100. Hellwig's synthetic indicator (d_i) was calculated for each object (city) and a positive value from 0 to 1 was assumed. The higher the level of synthetic the indicator the more favorable the situation of the object. Next, the European cities were ordered linearly. Their classifications were determined on the basis of the mean value of the synthetic indicator $(\overline{d_i})$ and its standard deviation (S_{di}) with typological classes specified through the creation of four separate groups of similar objects (Młodak, 2006):

Group I: if the synthetic indicator is $d_i > \overline{d_i} + S_{di}$;

Group II: if the synthetic indicator is $\overline{d_i} \leq d_i < \overline{d_i} + S_{di}$;

Group III: if the synthetic indicator is $\overline{d_i} - S_{di} \leq d_i < \overline{d_i}$;

Group IV: if the synthetic indicator is $d_i \leq \overline{d_i} - S_{di}$.

3. Results and discussion

The investigation started out with 46 diagnostic variables which, after verification, were reduced to twelve representing nine areas: education (X_1, X_2), energy (X_3), fire and emergency response (X_4), health (X_5, X_6), safety (X_7), shelter (X_8), telecommunication and innovation (X_9), transportation (X_{10}, X_{11}), wastewater (X_{12}). The analysis covered fourteen European cities selected from 46 cities worldwide having an ISO 37120 certificate.

Table 3 presents statistical characteristics of diagnostic variables. Analyzed variable values of individual cities were characterized by different degrees of differentiation. Coefficient of variation values ranged from approximately 18% to nearly 374%. The greatest variance between cities was seen in the number of natural disaster related deaths per 100,000 of population. The smallest divergence was observed in the variable describing the share of students completing secondary education.

Synthetic measures of development (d_i) were defined for each city. Results of calculated synthetic measures and the order of cities in relation to the basic level of socio-economic development are summarized in Table 4. Synthetic measurements have shown great variances with values ranging from 0.293 to 0.006. The synthetic measure for the city with the highest level of development was almost a hundred times higher than the synthetic measure of the city with the lowest level of development. This means that the analyzed European cities are very different in terms of their level of socio-economic development. Values of synthetic measures of seven cities exceeded the average value. This group included Aalter, Zagreb, Zwolle, Porto, Gdynia, Barcelona and Eindhoven. Seven other cities were characterized by a level of socio–economic development which fell below the average. One Polish city (Gdynia) attained a weak position and was classified in Group IV.

Table 3. Statistical characteristics of diagnostic variables

Variables	Average ($\overline{x}$)	Standard deviation (S_X)	Coefficient of variety V [%]	Maximum	Minimum
X_1	82.6	14.5	17.6	101.6 London	51.6 Sintra
X_2	16.8	3.8	22.5	22.7 Barcelona	11.5 Zagreb
X_3	1,367.1	313.5	22.9	1,921.0 Porto	830.9 Gdynia
X_4	0.4	1.6	374.2	6.1 Heerlen	0.0 Sintra
X_5	619.6	390.5	63.0	1,641.2 Porto	0.0 Aalter
X_6	3.3	1.9	56.0	6.8 Rotterdam	0.0 Aalter
X_7	1.0	0.9	91.0	3.2 Rotterdam	0.0 Aalter
X_8	0.3	0.8	312.7	3.2 Amsterdam	0.0 Valencia
X_9	101,211	31944.0	31.6	146,892Zwolle	36,074.8 Koprivnica
X_{10}	20.4	31.1	152.2	121.1 Aalter	0.0 Koprivnica
X_{11}	236.7	200.5	84.7	625.7 Porto	0.01 Koprivnica
X_{12}	56.4	48.0	85.0	100.0 Heerlen	0.0 Gdynia

Note: author's elaboration on the basis of (World Council on City Data, 2017).

Table 4. The level of socio–economic development

Rating	Cities, country	d_i	$d_i^{'}$
1	Heerlen, Netherland	0.293188	100.00
2	Amsterdam, Netherland	0.264161	90.10
3	London, United Kingdom	0.262725	89.61
4	Porto, Portugal	0.209468	71.45
5	Zwolle, Netherland	0.186595	63.64
6	Rotterdam, Netherland	0.178828	60.99
7	Barcelona, Spain	0.176798	60.30
8	Eindhoven, Netherland	0.17596	60.02
9	Valencia, Spain	0.157182	53.61
10	Aalter, Belgium	0.117781	40.17
11	Zagreb, Croatia	0.094444	39.98
12	Koprivnica, Croatia	0.090723	30.94
13	Gdynia, Poland	0.057186	19.50
14	Sintra, Portugal	0.006007	2.05

Note: author's elaboration on the basis of (World Council on City Data, 2017).

The highest level of socio–economic development was achieved by the city of Heerlen with Sintra showing the lowest level of development. The class of cities having the highest level of development also included Amsterdam and London. Group II included five cities (Porto, Zwolle, Rotterdam, Barcelona, Eindhoven) with a relatively high level of development. Group III contained four cities (Valencia, Aalter, Zagreb, Koprivnica) characterized by low levels of development. Bringing up the rear were two cities of Group IV, presenting the lowest level of socio–economic development: Gdynia, Sintra. Table 5 shows the classification of European cities by their level of development.

Table 5. The classification of European cities by their level of development

Groups	Ranges	Cities
I	$d_i > 0.245$	Heerlen, Amsterdam, London
II	$0.163 < d_i \leq 0.245$	Porto, Zwolle, Rotterdam, Barcelona, Eindhoven
III	$0.082 < d_i \leq 0.163$	Valencia, Aalter, Zagreb, Koprivnica
IV	$d_i \leq 0.082$	Gdynia, Sintra

Note: author's elaboration on the basis of (World Council on City Data, 2017).

The characteristic of variables describing the level of socio-economic development of each group presented in Table 6. The number of in–patient hospital beds per 100,000 of population in cities from Group I is two times lower than that of cities Group II. The share of the city's wastewater receiving tertiary treatment is similar for I, II and III groups of cities. The number of homicides per 100,000 of population in cities from Group IV cities is the greatest. The length of high capacity public transport system per 100,000 of population in cities from Group III is two and half times higher than in those of Group I.

Table 6. Average values of variables describing the level of socio–economic development

Variables	Group I	Group II	Group III	Group IV
X_1	92.6	77.7	88.6	69.0
X_2	19.0	17.6	16.0	12.8
X_3	1,318.7	1,349.5	1,448.7	1,320.7
X_4	2.0	0.0	0.0	0.0
X_5	483.3	825.9	593.9	359.7
X_6	4.2	3.5	3.2	1.8
X_7	1.3	1.3	0.2	1.6
X_8	1.2	0.0	0.05	0.02
X_9	129,953.7	114,012.9	81,656.3	65,201.0
X_{10}	13.3	19.0	34.7	6.3
X_{11}	297.6	321.6	132.8	141.8
X_{12}	66.7	65.4	65.4	0.8

Note: author's elaboration on the basis of (World Council on City Data, 2017).

Conclusions

The smart city is a multidimensional concept and the use of the taxonomic method to assess its level is justified. Assessment of smartness of cities was exceptionally challenging, due both to the complexity of the phenomenon as well as in the difficulty of measuring the values of diagnostic variables. In this study the level of smartness of European cities having an ISO 37120 certificate was examined through the application of Hellwig's synthetic indicator of development. Conducted research allowed the formulation of the following conclusions. European cities with an ISO 37120 certificate vary strongly in terms of their level of smartness. The city of Heerlen is a definite leader of this ranking while the city of Sintra brings up the rear. In addition a top position in highly reputed city ranking helps to improve the image of a city.

The conducted analysis augments previously published research results on smartness and confirms the need for further analysis of differentiation and dynamics of changes in the level of European cities' development compared to other world cities as well as a continued search for reasons of these phenomena and possible ways to improve this situation. In the future, the author intends to attempt to prepare the methodology for measuring smartness of European cities. The limitation of the research was the quantity of the source material and the objectivity of the source material selection method, which contributed to the generalized nature of the results.

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APPENDIX 1. DOMAINS AND INDICATORS OF THE SMART CITY

Domains	Number of indicators	Indicators
Economy	3	City's Unemployment Rate; Assessed Value of Commercial and Industrial Properties as a percentage of Total Assessed Value of all Properties; Percentage of City Population Living in Poverty
Education	4	Percentage of Female School-aged Population Enrolled in School; Percentage of Students Completing Primary Education: Survival Rate; Percentage of Students Completing Secondary Education: Survival Rate; Primary Education Student/teacher Ratio
Energy	4	Total Residential Electrical Energy Use per Capita; Percentage of City Population with Authorized Electrical Service; Energy (Electricity) Consumption of Public Buildings per year; Percentage of Total Energy Derived from Renewable Sources, as a Share of the City's Total Energy Consumption
Environment	3	Fine Particulate Matter (PM2,5) Concentration; Particulate Matter (PM10) Concentration; Greenhouse Gas Emissions Measured in Tonnes per Capita
Finance	1	Debt Service Ratio (Debt Service Expenditure as a Percentage of a Municipality's Own–source Revenue)
Fire & Emergency Response	3	Number of Firefighters per 100000 Population; Number of Fire Related Deaths per 100000 Population; Number of Natural Disaster Related Deaths per 100000 Population
Governance	2	Volter Participation in Last Municipal Election (as a Percentage of Eligible Volters); Women as a Percentage of Total Elected to City-level Office
Health	4	Average Life Expectancy; Number of In-patient Hospital Beds per 100000 Population; Number of Physicians per 100000 Population; Under Age Five Morality per 1000 Live Births
Recreation	0	–
Safety	2	Number of police Officers per 100000 Population; Number of Homicides per 100000 Population
Shelter	1	Percentage of City Population Living in Slums
Solid Waste	3	Percentage of City Population with Regular Solid Waste collection (Residential); Total Collected Municipal Solid Waste per Capita; Percentage of the City's Solid Waste that is Recycled

Domains	Number of indicators	Indicators
Telecommunication & Innovation	2	Number of Internet Connections per 100000 Population; Number of Cell Phone Connections per 100000 Population
Transportation	4	Kilometers of High Capacity Public Transport System per 100000 Population; Kilometers of Light Passenger Public Transport System per 100000 Population; Annual Number of Public Transport Trips Per Capita; Number of Personal Automobiles per Capita
Urban Planning	1	Green Area (Hectares) per 100000 Population
Wastewater	5	Percentage of the City Population Served by Wastewater Collection; Percentage of the City's Wastewater that has Received No Treatment; Percentage of the City's Wastewater Receiving Primary Treatment; Percentage of the City's Wastewater Receiving Secondary Treatment; Percentage of the city's wastewater receiving tertiary treatment
Water and Sanitation	4	Percentage of the City Population with Potable Water Supply Service; Percentage of the City Population with Sustainable Access to an Improved Water Source; Percentage of Population with Access to Improved Sanitation; Total Domestic Water Consumption per Capita (Liters/day).

Note: author's elaboration on the basis of (World Council on City Data, 2017).