SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2020
ORGANIZATION AND MANAGEMENT SERIES NO. 149

SMART CITY RANKING WITH SUBJECTIVE INDICATORS

Adam SOJDA

Silesian University of Technology, Zabrze; adam.sojda@polsl.pl, ORCID: 0000-0002-3021-4451

Purpose: The primary purpose of the presented work is to show the impact of the residents' opinion on the formation of the city's position in the SCR ranking. Another objective was to draw attention to the problem of data shortages in publicly available databases.

Design/methodology/approach: The primary database of European countries is the Eurostat database. The research area covered cities with a population of between 200,000 and 800,000, which were not national capitals. Only one city from each country was selected. The proposed SCR covers six areas related to Smart City concept. Two types of meters for each of them are proposed – the first based on objective measures, the second on subjective measures, i.e. the opinions of residents. Each factor was standardised and transformed. The higher the value of the factor, the greater the positive effect on the index.

Findings: Cities from the database were identified. General ranking and rankings for both objective and subjective meters were created. The relationship between rankings was investigated, and the impact of subjective variables was shown to be significant**.**

Originality/value: The original method for determining the Smart City index was proposed. It is shown that subjective measures should be included in the rankings. The opinion of the residents should be taken into account when building a ranking regarding Smart City concept.

Keywords: Smart City, Eurostat, sustainable, European cities, indicators.

Category of the paper: Research paper.

1. Introduction

It is assumed that by 2030, more than 60% of the population will live in cities (United Nations 2014). Economic growth is expected to take place with their participation. It is important to ensure adequate living conditions to enable this growth. It is essential to acquire skills in the assessment of the initiatives taken by cities in this process.

The city should know its strengths and weaknesses. The Smart City concept makes it easy to assess the city. This concept is continuously being developed. Currently, we can talk about Smart City 5.0 (Svítek 2020). Its hierarchical structure facilitates the assessment of the city according to this concept. It is possible to divide it into sub-areas, factors and indicators (Ahvenniemi et al., 2017; Albino et al., 2015; Bosch et al., 2017a; Huovila et al., 2016; Stankovic et al., 2015; Lombardi, 2011; Tahir, 2016). Complexity means that there is no transparent assessment system. There are many concepts of a Smart City (Albino et al., 2015; Berrone et al., 2019; Bosch et al., 2017b.; Giffinger et al., 2007; Smart City PROFILES, 2013; Szczech-Pietkiewicz 2015; UCLG 2012).

Table 1.
Smart City Index

INDEX	Number of Categories	Number of Indicators	INFO
European Smart Cities Ranking	6	64	European ranking compiled by an international consortium chaired by the University of Technology in Vienna.
The Smart Cities Wheel	6	62	A holistic assessment system, taking into account the key elements that make up a Smart City.
Bilbao Smart Cities Study	6	49	The idea initiated at the world summit in Bilbao, giving an overview of the situation in cities of different regions of the world.
Smart City PROFILES	5	21	Smart City indicators, with particular emphasis on climate change and energy efficiency.

The categories, areas in which we perceive Smart Cities include: smart economy (ECO), intelligent population (PEO), smart management (GOV), intelligent mobility (MOB), intelligent environment (ENV), intelligent living conditions (LIV).

Many rankings have been built, and there will probably be new ones. Due to the multi-dimensional nature of the issue, every attempt to define and understand it is important. This issue matters not only from the researchers' but also from the city managers' point of view. It allows them to identify areas where development needs to be significantly improved.

The construction of the Smart City rating is labour-intensive. It requires access to a database which often requires separate research. City rating is possible compared to other cities. Solutions should be sought to make the comparison possible without requiring additional financial resources.

The most important rankings are based on objective measures. One should not forget that the city is for the people. Smart City activities to serve people are designed. Therefore, there is a concept of building an indicator using subjective meters. The use of subjective meters is undoubtedly dictated by the cost of obtaining data and quickly checking their reliability. Research often concerns economically and culturally different areas. The perception of the same question can vary considerably. This causes additional problems when interpreting the data.

The aim of the research is to create a ranking of smart cities based on reliable and open data sources. The proposed meters were used in the construction of other indicators. They are also recommended by international organisations. In this paper the author decided to use a reliable data source such as Eurostat. Eurostat is a well-founded source of data. It has extensive databases of national and regional statistics. City related data are located in the Urban Audit database (Sojda et al., 2018). The activity area, however, is associated with significant deficiencies. The most complete information we can receive concerns the age of the inhabitants. The availability of other information can be different.

2. Data and Methods

2.1. Data

The data source was the Eurostat database, from which Urban Audit was used for city section. The study found that there were 572 variables in the database. 231 variables are of an objective nature. The remaining 341 are subjective assessments of the inhabitants, they correspond to a variable expressed in the five-stage Likert scale. The number of cities or urban areas is 1,822. The cities are located in 32 countries. The data relate to the period from 1990 to 2019.

In most articles, attention is focused on large cities. Very often, work is limited to capital cities. This is usually due to the availability of data. The capital is a city with which the state identifies and transmits a lot of data about it. In this work, it was decided to depart from this principle – it covers cities from 100,000 to 500,000 inhabitants. Also, it was assumed that the city could not be the capital of a given country. These main assumptions further limited the availability of data in the Eurostat database.

Data analysis allowed to select 14 cities that matched the above criteria. It should be noted that not all cities had a full set of data. Data deficiencies had an impact on the rejection of factors. Factors with little coverage in the data were rejected.

Statistics were checked, and those variables that had little volatility were rejected. Variables with outliers are left. These values indicate an advantage over other cities. This was considered inappropriate for the construction of the ranking. It is assumed that standardisation is an effective process of levelling the playing field.

It was not possible to obtain such a set of factors which would cover the data for all the cities indicated. The data gaps were supplemented by searching the database to supplement the latest existing information. The value found replaced the lack of data. If the information could not be found, it was replaced by the worst relative value.

For data related to the perception of cities by their citizens expressed on the Likert scale, the following solution was adopted. Weights (-2; -1; 0; 1; 2) are assigned to the response: (strongly disagree, very unsatisfied; somewhat disagree, unsatisfied; do not know/no answer, somewhat agree, rather satisfied; strongly agree, very satisfied). This allowed determining a synthetic answer to the question.

Variable values have been normalised (Kukuła, 1989, 2000; Sojda et al., 2020). The following tables list the indicators assigned to the relevant areas of the ranking.

Table 2.
Indicators (INDIC) in ranking

INDIC	NAME	MD	SD
ECO O1	Activity rate	1	S
ECO O2	All companies per 1,000 inhabitants	1	S
ECO O3	Unemployment rate	0	D
ECO S1	In this city, it is easy to find a good job	0	S
ECO S2	Most important in my city: unemployment	0	D
ECO S3	You have difficulty paying your bills at the end of the month	0	D
ENV O1	Annual average concentration of NO2 (µg/m³)	0	D
ENV O2	Annual average concentration of PM10 (µg/m³)	1	D
ENV O3	Number of days particulate matter PM10 concentrations exceed 50 µg/m³	1	D
ENV S1	Most important in my city: air pollution	0	D
ENV S2	The cleanliness in the city	0	S
ENV S3	This city is committed to the fight against climate change (e.g.; reducing energy consumption in housing or promoting alternatives to transport by car)	0	S
PEO O1	Employment (jobs) in professional, scientific and technical activities; administrative and support service activities (NACE Rev. 2, M and N)	1	S
PEO O2	Median population age	1	D
PEO O3	Proportion of population aged 25-64 qualified at level 5 to 8 ISCED, from 2014 onwards	2	S
PEO S1	Foreigners who live in this city are well integrated	0	S
PEO S2	Most people in my neighbourhood can be trusted	0	S
PEO S3	Schools in the city	0	S
LIV O1	Infant mortality rate (per 1,000 live births)	0	D
LIV O2	Number of deaths per year under 65 due to diseases of the circulatory or respiratory systems per 1,000 inhabitants	1	D
LIV O3	Number of murders and violent deaths per 1,000 inhabitants	3	D
LIV S1	Health care services offered by doctors and hospitals in this city	0	S
LIV S2	Most important in my city: social services	0	D
LIV S3	You feel safe in this city	0	S
MOB O1	Cost of a combined monthly ticket (all modes of public transport) for 5-10 km in the central zone – EUR	2	D
MOB O2	Number of registered cars per 1,000 inhabitants	2	S
MOB O3	Share of journeys to work by public transport (rail, metro, bus, tram) -%	3	S
MOB S1	Means of transport primarily used to go to work/training place: public transport	0	S
MOB S2	Most important in my city: public transport	0	D
MOB S3	Public transport in the city, for example bus, tram or metro	0	S

The factors were then transformed to match the desired higher values of the indicator. Most factors are de-stimulants (D). When the character changed, they became stimulants (S).

MD indicates how many data were missing for the variable. The SD column indicates whether the factor was a stimulant (S) or a de-stimulant (D).

Table 3.
Cities in the ranking

CITY	COUNTRY	MD	POPULATION
Burgas	Bulgaria	0	202,694
Cluj-Napoca	Romania	4	324,960
Frankfurt am Main	German	0	746,878
Geneva	Switzerland	0	200,548
Graz	Austria	1	269,997
Groningen	Netherlands	4	200,908
Kosice	Slovakia	0	238,757
Krakow	Poland	3	761,873
Liege	Belgium	1	383,710
Manchester	United Kingdom	2	546,564
Ostrava	Czech Republic	2	287,968
Oviedo	Spain	1	220,020
Palermo	Italy	1	668,405
Rennes	France	0	216,268

Fundamental statistical indicators for the transformed variables were examined.

Table 4.
Statistical parameters of standardised indicators

INDIC	Range	IQR	Quartile 1	Quartile 2	Quartile 3	Skewness	Kurtosis
ECO O1	2.82	1.63	-1.00	-0.16	0.63	0.13	-1.26
ECO O2	3.74	0.70	-0.56	-0.33	0.14	2.88	9.25
ECO O3	3.61	1.40	-0.68	-0.06	0.72	-0.33	-0.03
ECO S1	3.62	1.15	-0.61	0.05	0.54	-0.25	-0.04
ECO S2	3.37	0.89	-0.35	0.17	0.54	-0.82	0.27
ECO S3	3.38	1.10	-0.70	-0.26	0.40	0.80	-0.14
ENV O1	3.18	1.67	-0.84	0.04	0.83	-0.10	-1.24
ENV O2	3.22	1.38	-0.81	0.33	0.57	-0.91	-0.52
ENV O3	3.19	1.34	-0.71	0.40	0.63	-1.29	0.20
ENV S1	3.03	1.50	-0.80	0.44	0.71	-0.97	-0.52
ENV S2	4.24	0.91	-0.27	0.13	0.64	-1.24	3.11
ENV S3	3.94	0.74	-0.21	0.09	0.54	-1.79	4.57
PEO O1	3.27	0.58	-0.76	-0.47	-0.18	2.21	4.58
PEO O2	3.43	0.64	-0.56	-0.30	0.08	0.48	-0.16
PEO O3	2.80	2.09	-1.25	-0.20	0.85	-0.09	-1.70
PEO S1	3.84	0.98	-0.66	0.23	0.32	-0.11	0.24
PEO S2	3.07	1.55	-0.83	-0.11	0.72	0.28	-1.09
PEO S3	3.35	0.95	-0.24	0.04	0.71	-1.22	1.16
LIV O1	3.43	1.16	-0.60	0.01	0.56	0.42	-0.34
LIV O2	3.72	1.19	-0.44	-0.06	0.76	-1.15	0.97
LIV O3	3.49	1.43	-0.76	0.36	0.66	-1.39	0.87
LIV S1	2.65	1.75	-0.94	0.40	0.81	-0.69	-1.29
LIV S2	3.82	1.14	-0.60	0.40	0.54	-0.79	0.66
LIV S3	3.38	1.01	-0.23	0.01	0.78	-0.44	-0.30

Cont. table 4.

MOB O1	3.18	1.84	-1.32	0.04	0.52	-0.62	-1.17
MOB O2	3.06	1.43	-0.99	-0.36	0.44	0.55	-0.80
MOB O3	3.06	0.97	-0.98	-0.55	-0.01	1.37	1.19
MOB S1	3.37	1.30	-0.61	0.15	0.69	-0.60	-0.29
MOB S2	2.91	1.15	-0.76	-0.24	0.39	0.75	-0.61
MOB S3	3.73	0.68	-0.18	0.44	0.50	-1.83	3.29

The values of the statistical parameters indicate the differentiation between variables. There is no variable that could unambiguously distort the results of the ranking. Variables can be considered as appropriately selected.

2.2. Methods

The SCIwP index is based on the relationship between the area and the measurement. Let us assume that the weights for each area are the same.

The index is the arithmetic mean of indexes for each area. In the areas, indexes are based on the arithmetic mean of the indicators depending on the area. Since index design uses measures based on subjective assessments, it was decided to take into account the weight of these factors in the shape of the index.

$$SCIwP = \frac{\sum IA_i w_i}{\sum w_i} \tag{1}$$

for the area

$$IA_i = u_o \frac{\sum IO_{ij} vo_{ij}}{\sum vo_{ij}} + u_S \frac{\sum IS_{ij} vs_{ij}}{\sum vs_{ij}} \tag{2}$$

where:

IO_{ij} – value of the j-th objective variable, a measure included in the i-th area,

IS_{ij} – value of the j-th subjective variable, a measure included in the i-th area,

vo_{ij} – weight of the j-th objective variable, the measure included in the i-th area, $\sum_j vo_{ij} = 1$,

vs_{ij} – weight of the j-th subjective variable, the measure included in the i-th area, $\sum_j vs_{ij} = 1$,

u_o – weight of u_s objective variables, weight of subjective variables, $u_o + u_s = 1$,

IA_i – index value for the i-th area,

w_i – the weight of the i-th area, $\sum_i w_i = 1$,

all weights are non-negative.

The ranking is set for values u_o that change from 0 to 100% every 10%.

3. Results and discussion

According to the methodology presented, the following ranking of cities was obtained.

Table 5.
City Ranking SCIwP

CITY	SHARE OF OBJECTIVE INDICATORS										
	100%	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**	**0%**
Geneva	1	1	1	1	1	1	1	1	1	1	3
Frankfurt am Main	2	2	3	3	3	3	3	4	8	8	8
Groningen	3	3	2	2	2	2	2	2	2	2	2
Manchester	4	4	4	4	4	4	5	5	7	7	7
Rennes	5	5	5	5	5	5	4	3	4	4	4
Oviedo	6	6	6	6	6	6	6	6	5	5	5
Burgas	7	7	7	7	7	7	7	7	6	6	6
Kosice	8	8	8	8	8	8	8	9	9	9	9
Palermo	9	12	13	14	14	14	14	14	14	14	14
Ostrava	10	9	10	10	11	11	11	11	11	11	11
Graz	11	11	12	12	13	13	13	13	13	13	13
Liege	12	13	11	11	12	12	12	12	12	12	12
Krakow	13	10	9	9	9	9	10	10	10	10	10
Cluj-Napoca	14	14	14	13	10	10	9	8	3	3	1

The results for a ranking based only on objective measures were analysed. The best city is Geneva. Second place goes to Frankfurt am Main. The fact that these cities have taken these places in the ranking is in line with expectations, with the well-known high-ranking city of Manchester is also expected. The Romanian city of Cluj-Napoca closes the ranking. One might think that the ranking of a given city depends on the economic position of the country. In this case, Krakow's position seems too low.

Changing the share of subjective measures from 0 to 70% does not result in major changes in the first five places. For a share of 20% to 50%, Groningen and Frankfurt am Main change positions. The reasons can be the location of one of the largest airports in the world which results in nuisance for residents. This results in a decrease in the city's ranking.

In the last eight places, there are the same cities. However, the changes are much more dynamic. It is shown how the position of a given city in the ranking in relation to the ranking based on subjective measures is determined.

Table 6.
Absolute differences in places in the rankings

CITY	SHARE OF OBJECTIVE INDICATORS									
	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
Geneva	0	0	0	0	0	0	0	0	0	2
Frankfurt am Main	0	1	1	1	1	1	2	6	6	6
Groningen	0	1	1	1	1	1	1	1	1	1
Manchester	0	0	0	0	0	1	1	3	3	3
Rennes	0	0	0	0	0	1	2	1	1	1
Oviedo	0	0	0	0	0	0	0	1	1	1
Burgas	0	0	0	0	0	0	0	1	1	1
Kosice	0	0	0	0	0	0	1	1	1	1
Palermo	3	4	5	5	5	5	5	5	5	5
Ostrava	1	0	0	1	1	1	1	1	1	1
Graz	0	1	1	2	2	2	2	2	2	2
Liege	1	1	1	0	0	0	0	0	0	0
Krakow	3	4	4	4	4	3	3	3	3	3
Cluj-Napoca	0	0	1	4	4	5	6	11	11	13
MAX	3	4	5	5	5	5	6	11	11	13
Average	0.57	0.86	1.00	1.29	1.29	1.43	1.71	2.57	2.57	2.86

In this group of cities, already 10% influence of subjective variables causes Palermo to fall in the ranking by three places. Krakow, on the other hand, is growing by three places. The opinion of the inhabitants about Palermo makes the city take much lower position in the ranking than the objective measures show. The biggest change is recorded in the Romanian city of Cluj-Napoca. Thanks to the opinion of the inhabitants, this city could even be in the first place in the ranking.

They looked at which areas influenced the ranking for Geneva and Cluj by comparing them with the average scores for the group of cities studied. It turned out that the most important factors for the ranking are factors related to the areas: smart economy, ECO, intelligent mobility. Residents of Cluj-Napoca believe that they have no problems with finding good work, unemployment or payment for bills. When assessing smart mobility, they also use urban transport and they have no reservations to it.

Geneva's example shows that people have a relatively poorer view of areas: smart economy ECO, intelligent mobility MOB, intelligent environment ENV, intelligent living conditions LIV. These results are close to average values. On the other hand, the area of the intelligent population PEO is strongly assessed; the results in this area are moving away from the average.

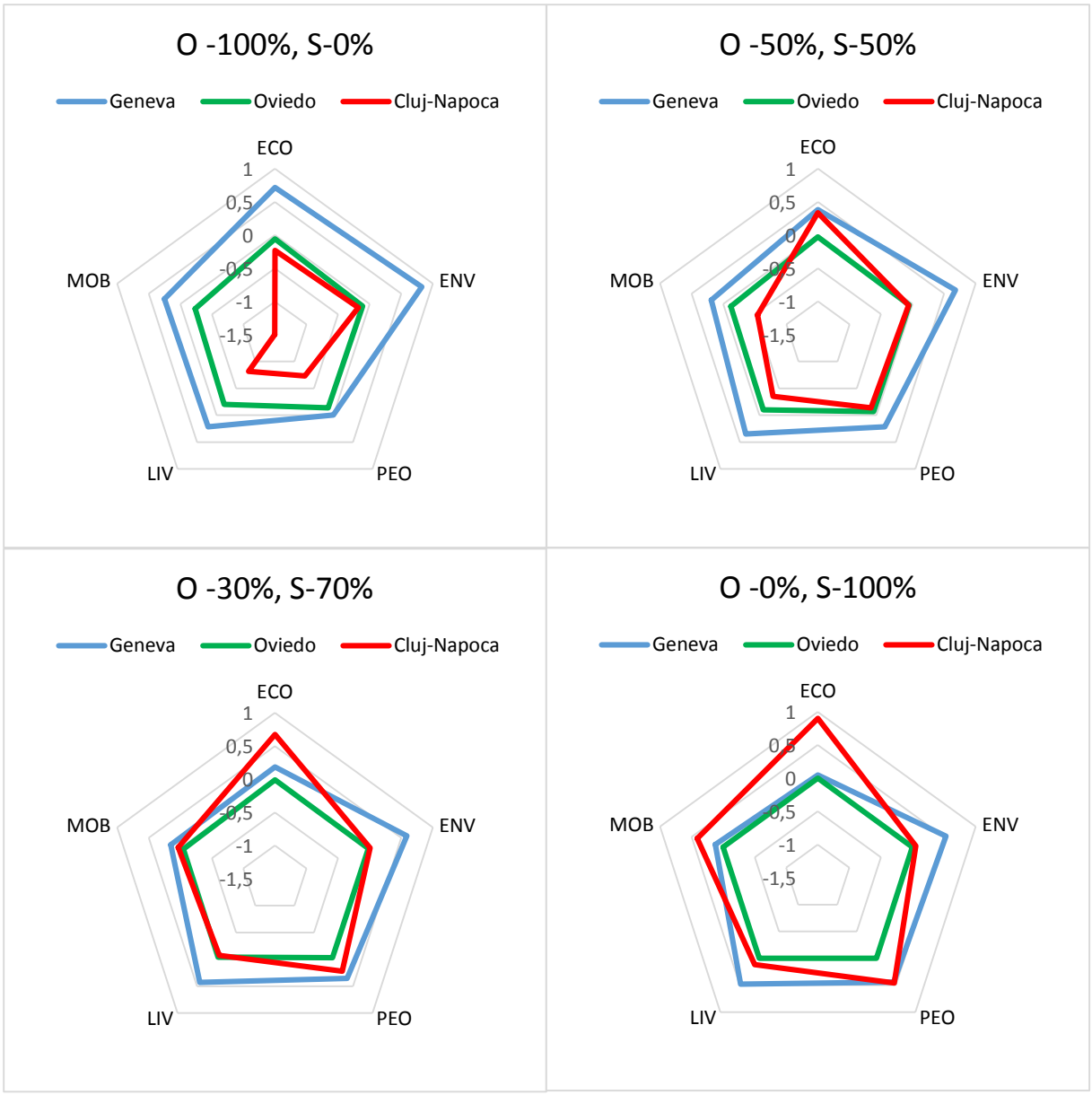

Figure 1. Comparison of areas for selected cities with different share of objective indicators.

4. Conclusion

In city rankings, it is also worth paying attention to subjective factors. The assessment of residents should be taken into account. The idea of Smart City is to be a concept of a city friendly to its inhabitants. The voice of the city's inhabitants should be included in the rankings. In the example analysed, the city of Cluj-Napoca has a better ranking than Geneva in the inhabitants ratings.

Further work on this topic should be carried out to establish a fair share of subjective assessments in constructed indexes.

References

1. Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., Airaksinen, M. (2017). What are the differences between sustainable and smart cities? *Cities, 60,* pp. 234-245.
2. Albino, V., Berardi, U., Dangelico, R.M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of Urban Technology, 22(1),* pp. 3-21.
3. Berrone P., Ricart J.E., Duch A., Carrasco C. (2019). *IESE Cities in Motion Index 2019,* IESE, ST-509-E, 05/2019 DOI: https://dx.doi.org/10.15581/018.ST-509.
4. Bosch, P., Jongeneel, S., Neumann, H.-M., Branislav, I., Huovila, A., Airaksinen, M., Pinto-Seppä, I. (2017a), *Recommendations for a Smart City index. CITYkeys – Smart city performance measurement framework.* DOI: 10.13140/RG.2.2.20190.74562, 16.04.2020.
5. Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., Huovila, A. (2017b). *CITYkeys indicators for smart city projects and smart cities. CITYkeys – Smart city performance measurement framework.* DOI: 10.13140/RG.2.2.17148.23686, 16.04.2020.
6. Giffinger, R., Fertner, C., Kramar, H., Kramar, H., Kalasek, R., Pichler-Milanovic, N., Meijers, E. (2007). *Smart Cities. Ranking of European medium-sized cities*. Centre for Regional Science, Vienna University of Technology, http://www.smart-cities.eu/download/smart_cities_final_report.pdf, 16.04.2020.
7. Huovila, A., Penttinen, T., Airaksinen, M., Pinto-Seppä, I., Piira, K., Penttinen, T. (2016, September). *Smart city performance measurement system*. Proceedings of the 41st IAHS World Congress Sustainability Innovation for the Future, Algarve, Portugal, pp. 13-16.
8. Kukuła, K. (1989). Statistical structural analysis and its application in the field of production services for agriculture. *Scientific Notebooks AE in Krakow, Special series: Monographs, 89,* p. 256.
9. Kukuła, K. (2000) *Method of zeroed unitarisation*. Warsaw: PWN.
10. Lombardi, P., Giordano, S., Caragliu, A., Del Bo, C., Deakin, M., Nijkamp, P., Kourtit, K. (2011). *An advanced triple-helix network model for smart cities performance*. Vrije Universiteit Amsterdam, Research Memorandum 2011-45, http://degree.ubvu.vu.nl /repec/vua/wpaper/pdf/20110045.pdf, 15.03.2019.
11. Smart City PROFILES (2013). *Ergebnisse*. 7.6.2013. http://www.smartcities.at/assets/03-Begleitmassnahmen/SmartCity-PDF-INTRO.pdf, 16.03.2020.
12. Sojda, A., Owczarek, T., Wolny, M. (2018). Smart city in data-oriented terms – Poland in eurostat – database. *Zeszyty Naukowe PŚl., Org. Zarz., z. 130,* p. 557-566, DOI: 10.29119/1641-3466.2018.130.46.
13. Sojda, A., Wolny, M. (2020). The impact of standardisation method on smart city ranking, *Sil. Univ. Technol. Sci. Pap., Organ. Manage., no. 142*, pp. 83-94, DOI: 10.29119/1641-3466.2020.142.6.

14. Stankovic, J., Dzunic, M., Džunić, Ž., Marinkovic, S. (2015). A multi-criteria evaluation of the European cities' smart performance: Economic, social and environmental aspects. Zbornik radova Ekonomskog fakulteta u Rijeci, časopis za ekonomsku teoriju i praksu-Proceedings of Rijeka Faculty of Economics. *Journal of Economics and Business, 35(2),* pp. 519-550.
15. Svítek, M., Skobelev, P. Kozhevnikov (2020). *Smart City 5.0 as an Urban Ecosystem of Smart Services.* 10.1007/978-3-030-27477-1_33.
16. Szczech-Pietkiewicz, E. (2015). Smart city–sample definition and measurement. *Scientific work of the University of Economics in Wroclaw. Local economy in theory and practice, 391.*
17. Tahir, Z., Malek, J.A. (2016). Main criteria in the development of smart cities determined using analytical method. *Planning Malaysia Journal, 14(5).*
18. UCLG (2012). *Smart Cities Study: International study on the situation of ICT, innovation and knowledge in cities.* Bilbao. http://www.uclg-digitalcities.org/app/uploads/2015/06/en_smartcitiesstudy.pdf, 16.04.2020.
19. United Nations (2014). *World urbanization prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352).* New York. United States of America, https://doi.org/10.4054/DemRes.2005.12.9.