Elżbieta ANTCZAK • Agnieszka RZEŃCA • Agnieszka SOBOL

"PRODUCTIVE CITIES" IN POLAND – A COMPARATIVE ANALYSIS BASED ON AN AGGREGATE MEASURE OF DEVELOPMENT

Elżbieta **Antczak** (ORCID: 0000-0002-9695-6300) – *Department of Spatial Econometrics, Faculty of Economics and Sociology, University of Lodz*

Agnieszka **Rzeńca** (ORCID: 0000-0003-1167-1363) – *Department of Regional Economics and Environment, Faculty of Economics and Sociology, University of Lodz*

Agnieszka **Sobol** (ORCID: 0000-0002-4363-8923) – *The Institute of Environmental Protection – National Research Institute*

Correspondence address:
POW Street 3/5, 90-255 Lodz, Poland
email: agnieszka.rzenca@uni.lodz.pl

ABSTRACT: The subject of the article is the "productive city", which, along with the "green city" and the "just city," is one of the main axes of the integrated development of modern cities. The main goal is to assess the degree of productivity in the development of Polish cities. The research covered 66 cities with poviat rights in 2010, 2015, 2018, and 2020. Based on previous research and available data, an aggregated measure of the productive city was proposed based on the linear ordering method. For this purpose, the average value of diagnostic variables (stimulants and destimulants) was determined using a dynamic version of the zero unitisation method. The analysis showed moderate productivity and progress in Polish cities, with an increase of approx. 2.1% over the decade 2010-2020. However, there is a decreasing differentiation in terms of the composite measure. One of the major limitations of the research was spatiotemporal data availability and continuity.

KEYWORDS: productive city, sustainable development, monitoring of the productive city development, local urban development, composite measure

Introduction

Trends in the development of cities evolve following the progress of civilisation, as well as the challenges of the present day. This is reflected in the provisions of the directional documents at all levels of city management. Linking cities' greening, justice, and productivity isa continuation of the sustainable development paradigm disseminated in theory and practice since the 1990s. In the literature on the subject, from the perspectives of economic, social, and political sciences, as well as in the United Nations Sustainable Development Goals 2030 (Ministerstwo Funduszy i Polityki Regionalnej Departament Strategii, 2021; United Nations, 2015), there is talk of:

- "Green cities" are a need to shape the balance of nature and reduce anthrop pressure in urbanised areas (Kahn, 2006; Hammer et al., 2011),
- "Just cities," in which equity, democracy, and diversity are essential considerations. Justice emphasises the importance of accessibility to basic services and resources and is related to developing a civic and inclusive city (Fainstein, 2010),
- "Productive cities", whose development is based on a diversified economy. They will provide jobs for residents and create a solid financial basis for sustainable development. In the dimension of urban productivity, complex aspects of environmental sustainability are considered in terms of resource-efficient management (European Union, 2020), urban metabolism (Lucertini & Musco, 2020), and the circular economy (European Commission, 2020; Paiho et al., 2021). The "productive city" concept is essential to the EU's development of a sustainable, low-carbon, resource-efficient, and competitive economy.

The literature on city productivity is not widely developed. Hasan (2020) shows "the absence of a theoretical framework for the spatial organisation strategies and its role in productive cities development". Therefore, the authors decided to undertake research on the productivity of cities, taking into account premises arising from the theory of green economy urban resilience, circular economy, and smart city 5.0. and others. This research is also an attempt to find a "path of urban development" under the conditions of the climate crisis since global climate change has dramatic consequences for urban dwellers in many dimensions of the local environment (Grimm et al., 2008).

These three perspectives were the premise for undertaking comprehensive research, whose results make up a series of papers on the urban subject. An important premise for undertaking the research was the update of the National Urban Policy in Poland in 2022 (Ministerstwo Funduszy i Polityki

DOI: 10.34659/eis.2023.86.3.643

Regionalnej, 2022). The papers focus on monitoring urban development from the above perspectives.

This paper assesses the productivity of the development of 66 cities with poviat rights in Poland. The starting point for the research was:

- identifying the leading theories of development, including urban economics, environmental economics, and the green economy, which provide the basis for defining the "productive city" concept,
- defining available methods and indicators for assessing and monitoring urban development that corresponds to the "productive city" concept. The analysis was based on diagnostic variables to monitor the development of the "productive city", broken down into stimulants and destimulants. A synthetic measure was built using a modified dynamic version of the zero-unitarization method,
- assessing the level of "productive city" development and creating a ranking of 66 cities with poviat rights and analysing it.

The collected data show the state and dynamics of change in the analysed citiesin 2010, 2015, 2018 and 2020. Institutional changes at the national (National Urban Policy, NPM) and EU (Green Deal, New Leipzig Charter) level are the pillars of the considerations made, which determine the temporal scope of the research. Urban policy as an area of public policy strategy has been formalised in Poland by the National Urban Policy (NPM) 2023, adopted in 2015 (Rada Ministrów, 2015), so it was crucial to determine the trajectory of changes in the degree of "productive" urban development in the perspective of years: 2010 – 2020, i.e. before the NPM 2023. That is, before the NPM 2023 (hence the development diagnosis in 2010), in the implementation phase of the NPM 2023 (2015 and 2018), the current NPM 2023 (2020) before the adoption of the new National Urban Policy 2030 (NPM, 2030) of 2022 (Ministerstwo Funduszy i Polityki Regionalnej, 2022). In addition, the availability of public statistical data and its continuity was also an important determinant of the study.

Concept and monitoring the "productive city"– an overview of the literature and initiatives

The concept of the "productive city" is a new area of research whose origins can be found in cities' transformation and adaptation to climate change, as well as the developing theories of economics, e.g., the environmental economy, the green economy, and the circular economy. The starting point of the environmental economy is productivity, the essence of which is defined by the principles formulated by Daly and Cobb (1989). It refers to reducing the amount of physically used inputs in the economy and its products and ration-

DOI: 10.34659/eis.2023.86.3.643

alising the use of non-renewable and renewable resources. Productivity characterises the level of output of services and products. Its main purpose is to incentivise greater efficiency in the use of resources and natural assets. It incorporates enhancing productivity, reducing waste production, minimizing water and energy consumption, and making resources available for their highest value use. Productivity provides knowledge on whether there is a decoupling of the interdependence of development from the increase in resource consumption and the reduction of the negative impact of the economy on the environment.

Productivity in the green economy theory is an impulse for the development of innovation and new green markets for products and services. As a result we can talk about the economical management of natural resources. The attitude is not only beneficial for the environment but also leads to lowering costs. All together, it increases efficiency and contributes to ensuring sustainable access to environmental resources (Burchard-Dziubińska et al., 2014). Productivity, therefore, builds the flexibility of systems, reduces risk and ensures the durability of development processes. It also increases the trust of stakeholders, investors and different city users thanks to greater predictability and continuity of the process. Productivity is related to production and consumption. Material consumption includes all materials directly consumed for the needs of the economy. It is the sum of resources obtained in a given country and from imports minus what is sent for export. The key to success is efficiency in the proportion of current and future consumption and maximising the utility of consumption. This should be done while respecting the quality of the environment and considering the requirements of a circular economy and consumption that has the least impact on the natural environment. Knowledge of the environment and the effects that consumption has on it has a significant impact on the creation of sustainable consumer behaviour (Saari et al., 2017; Lavuri et al., 2021). The direction of minimising resource consumption and reducing the economy's negative impact on the environment requires a departure from a linear economy in favour of a circular economy. Circularity is oriented towards resource management that prioritises the management of secondary raw materials and savings over waste management and over-scaled production and consumption. At the same time, it increases competitiveness and efficiency and improves the parameters of reducing the negative impact of human activity on the natural environment (European Union, 2019; ICLEI, 2021; European Investment Bank, 2018).

Conversely, being oriented toward productivity requires continuous and widespread innovation. Innovative solutions relate directly to products and technologies but also to business models, instruments of social impact, or methods of communication. Productivity in green economy theory is the

DOI: 10.34659/eis.2023.86.3.643

impetus for developing innovation and new "green" markets for products and services (Figure 1). The overall efficiency of the production process is increasing through improved organisation and technical progress. Proposed directions of innovation development include modern technologies and nature-based solutions. Innovation is supported by technological progress in digitisation, which accelerates development and scale. Thanks to easy access to information, good practices are popularised, and know-how is exchanged.

In addition, innovation is associated with the automation and robotisation of economic processes. In the face of climate change and the biodiversity crisis, it is significant that the direction of innovation development considers maintaining the balance of nature to improve long-term development conditions. At the same time, using knowledge about processes and phenomena that occur in nature (nature-based solutions) is an effective way to improve productivity and reduce resource consumption and the emissions generated. Innovations should be spurred by policies, including systemic and framework conditions that allow new ways to create value and address environmental problems. A high level of education and, in consequence, labour in the population is a prerequisite for a society that fosters productivity, innovation, and competitiveness (an economy based on knowledge). Additionally, greater productivity can be achieved through diversification, technological upgrading, innovation, and circularity.

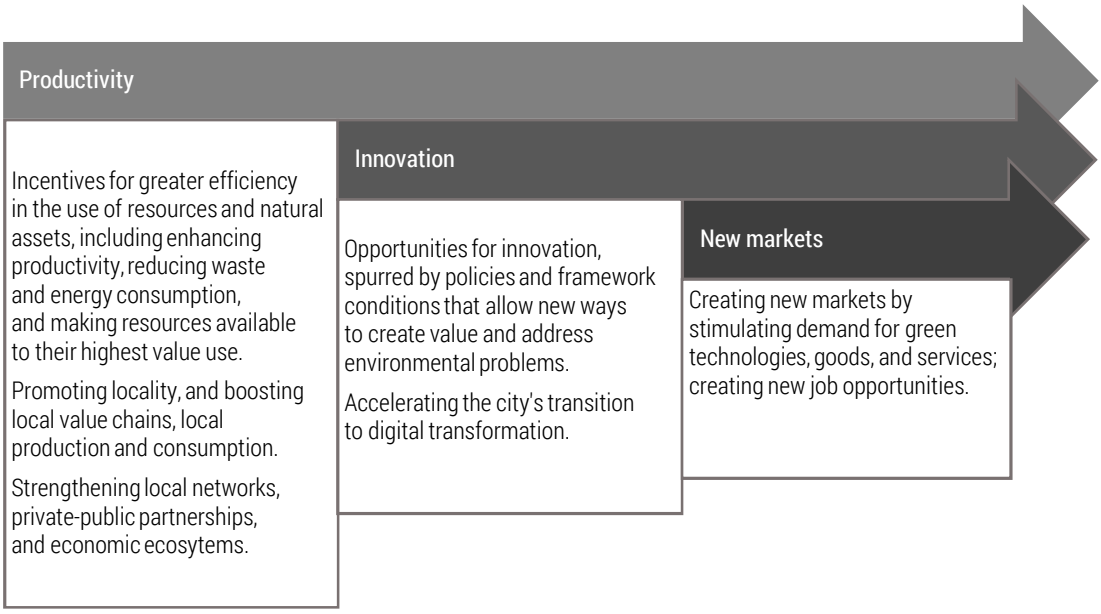


Figure 1. The essence of green economy and productivity integration

DOI: 10.34659/eis.2023.86.3.643

Productivity from the city perspective includes local production, scalability of production, and reducing the supply chain. The idea recognizes cities as proximity economy hubs that join up a city's stakeholders (Siragusa et al., 2021). This direction is important compared to spatial management and the possibility of developing space for food supply. Therefore, the productivity of contemporary cities includes promoting the locality, becoming independent from an external supplier, and using resources by using projects for small local benefits. A key aspect to achieving this is to take into account the importance of the production sectors for urban economies – from small food producers to start-up entrepreneurs in the technology industry. The issue of urban agriculture is particularly important in terms of the diversification of the city functions, the potential for adaptation to climate change and savings at every stage of agricultural production cycles (Bohn & Viliojeen, 2017). All of the above, i.e., circular value chains and the proximity economy, innovation, and local knowledge spillovers, are essential for sustainable competitiveness and local resilience (Martin & Simmie, 2008).

Innovations, especially eco-innovations, can facilitate sustainable changes in management and various sectors by increasing the efficiency of urban systems, reducing resource consumption and supporting decision-making based on monitoring and evaluation. Moreover, apart from the initiatives of the city itself, it is crucial to support the climate for developing innovation and entrepreneurship. Building innovation capacity to reduce food waste is also an important direction (Al-Obadi et al., 2022). We can also combine city productivity with the concept of smart city 5.0. (Roseman et al., 2021). Also, the link can be found with the idea of a regenerative city striving to improve city-environment relations (Schuring, 2018). Moreover, in the long term, productivity is intended to reduce the negative impact of external factors on human health and the environment (Gaffron et al., 2005).

In the literature on the subject, there is no proposal for a set of indicators specifically for operational sing the "productive city." The available proposals concern either selected aspects that fit into the concept of a productive city or are part of the monitoring of sustainable development. The choice of a specific package of indicators was dictated by the idea of capturing key aspects of the EU's Green Deal policy, which means a low-carbon and resource-efficient economy. Nevertheless, more conventional measures of monitoring productivity have also been included. In research relating to Polish cities, those concerning the economic condition or the level of economic development of cities dominate (Gwosdz et al., 2019; Czyż, 2017).

In addition, research conducted from the perspective of a particular field of science, e.g., indicators in social sciences, in particular in socio-economic geography, cover issues such as the labour market, entrepreneurship, the structure of the local economy, or the level of innovation (Gwosdz et al.,

DOI: 10.34659/eis.2023.86.3.643

2019). Śleszyński (2016, 2017, 2018) has conducted extensive research in this area regarding the condition of cities as such and the identification of "problem" cities (e.g., depopulation and indebtedness).

Table 1. An overview of the selected initiatives and research literature for monitoring a productive city

Initiative (field of monitoring development of PC – productive city or SD – sustainable urban areas)	Coordination	Categories of monitoring indicators	Example of the research literature applying the monitoring indicators
GRI – Global Reporting Initiative Standards (SD)	GRI	material management, energy sources, water management, waste management, products and services, transport and mobility	Glaser (2011) Siragusa et al. (2021)
SDG Voluntary Local Reviews (SD)	European Commission	water management, energy management, sustainable mobility, waste management, sustainable production and consumption, eco-innovation, land management	Zinkernagel et al. (2018) Nicholls et al. (2020) Siragusa et al. (2021)
Building Urban Datasets for the SDGs (SD)			
Indicators for circular economy transition in cities (PC)		sustainable production and consumption, waste management, secondary raw materials, competitiveness and innovation	Siragusa et al. (2021) Saari et al. (2017)
City Loops (PC)		local stakeholder actions, circular business models and behavioral patterns, closing material loops and reducing harmful resource use, improving human well-being and reducing environmental impacts	Czyż (2017) Papageorgiou et al. (2021)
The European Green City Index (SD)	Economist Intelligence Unit, Siemens	construction, waste management, energy sources and energy efficiency, transport and mobility, environmental management, public procurement, land management, public space	Venkatesh (2014) Brilhante and Klaas (2018) Gwosdz et al. (2019)
Ranking of Polish Sustainable Cities (SD)	Arcadis	education and labor market, land management, waste management, water management, energy management, entrepreneurship, capital market and investments, transport and mobility	Al-Obadi et al. (2022) Gierusz-Matkowska et al. (2023)
Towards Green Growth (PC)	OECD	environmental and resource productivity, economic and environmental assets, environmental quality of life, economic opportunities and policy responses, public space	Gwosdz et al. (2019), Hammer et al. (2011)
Circular Economy indicators (PC)		economy and business, environment, governance, infrastructure and technology, public space	Paiho et al. (2021), Al-Obadi et al. (2022), Hammer et al. (2011)

Source: authors' work based on OECD (2020); Arcadis (2021); Siemens (2009); GRI (2023); European Union (2019); European Commission et al. (2021); OECD (2011); European Commission (2020); European Commission (2018).

DOI: 10.34659/eis.2023.86.3.643

Since 1996, the Association of Polish Cities has been developing the Local Government Analysis System to comprehensively monitor the development of cities (European Commission, 1996).

Partial measures are a common way to examine productivity. They include labour factors, material flows, environmental resources, nutrient cycles and food production systems, spatial planning, waste management, energy efficiency, and water management. Although the set of assets may differ between cities, some will be relevant in all of them. The overview of selected initiatives and research literature to monitor the productive city presented in Table 1 below was the starting point and the basis for preparing a proprietary set of indicators.

The literature review conducted indicates a narrow view of urban productivity and focuses on mono-area issues. However, our study represents a comprehensive and universal approach to measuring and evaluating city productiveness.

Research method

The analysis was based on a structured logic research process presented in Figure 2.

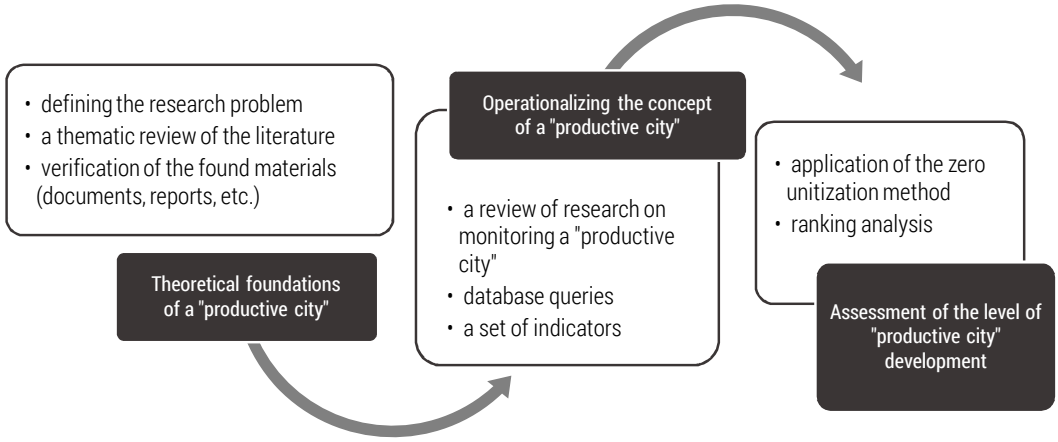


Figure 2. Framework of the research stages

To analyse and evaluate cities' productivity, we built a composite (synthetic, aggregate) measure using a dynamic version of the zero-unitization method of normalisation. This allowed us to compare the composite measures in the years studied (eq. 4). This methodology has been reviewed and

DOI: 10.34659/eis.2023.86.3.643

adopted by the Organisation for Economic Cooperation and Development (OECD, 2008). The investigation was limited to 66 cities with poviat rights, constituting a relatively homogeneous research group. We also did this due to the standardised administrative conditions, competencies, and development opportunities based on dedicated public policies. We based our assessment on the following diagnostic variables: stimulants (S) and de-stimulants (D). The collected data show the status and dynamics of changes in 2010, 2015, 2018 and 2020. Although 33 indicators were preselected to measure and monitor the development of "productive cities", only 24 of them met the statistical criteria for the aggregate measure (Table 2). The selection of indicators, in addition to the substantive justification covering a variety of areas of "productive city" in previous studies (Table 1 and Figure 1), resulted from the current main directions of urban productive development outlined in the strategic documents and international policies. In addition, as already mentioned, the availability of data in public statistics was important, their completeness and continuity allowed to observe the phenomena during the analysed period. Public databases for the assessment of "productive cities" are very limited. In addition, it was initially assumed that the set of variables would include data on, among other things, the number of entities connected to the network, units of the public administration that have already used business intelligence tools or sludge used from previously stored. Due to the lack of public data or their commercial accessibility, these characteristics were omitted.

Table 2. The suggested diagnostic variables for monitoring the development of the areas of the "productive city" by stimulants and destimulants, and the values of selected statistics (averaged for 2010, 2015, 2018, 2020)

Areas of "productive city"	Diagnostic variable	Unit	Character	Mean	SD	CV
Education, labor market and human well-being	*Unemployment rate	%	D	7.6	3.3	43.1
	Labor force participation rate	per 1,000 working-age population	S	522.8	147.0	28.1
	*Number of sickness absence days	per employee	D	11.5	1.2	10.7
	*Higher education graduates	per 10,000 population	S	181.6	170.1	93.6
Local budget	Gross Domestic Product (GDP) at current prices	PLN per capita	S	57,796.6	13,574.7	23.5
	*Share (of own revenue) in income from taxes comprising state budget revenue, personal income tax	%	S	42.2	4.9	11.6

DOI: 10.34659/eis.2023.86.3.643

Areas of "productive city"	Diagnostic variable	Unit	Character	Mean	SD	CV
Local budget	*Share (of own revenue) in income from taxes comprising state budget revenue, corporate income tax	%	S	3.1	1.4	43.4
	Cities' own revenues	PLN per capita	S	3,086.9	870.5	28.2
	*Share of expenditures on debt maintenance of total revenues	%	D	4.8	1.8	37.4
	*Share of investment expenditures in total expenditures	%	S	16.7	4.9	29.1
Construction, capital market and investments	*New residential buildings	per 1,000 population	S	1.0	0.5	51.0
	*Investment property expenditures	PLN per capita	S	70.4	58.4	83.0
	*Investment expenditures in enterprises in the industry and construction sector	PLN per capita	S	2,956.6	2,278.0	77.0
Local economy, entrepreneurship and capital market	Newly registered national economy entities	per 1,000 population	S	10.1	2.7	26.2
	*Share of funds from the EU for financing EU programs and projects in city revenues	%	S	8.7	12.2	141.1
	Accommodation places	per 1,000 population	S	15.6	34.4	220.9
	Number of catering establishments (entities engaged in food service activities)	per 1,000 population	S	3.1	1.3	42.5
	Investment expenditures in enterprises	per capita of working age	S	7,827.8	4,602.0	58.8
Governance, infrastructure and technology, competitiveness and innovation	*Share of the number of research and development (R&D) centers	% in a given city	S	1.5	3.5	233.8
	National economy entities engaged in scientific research and development	per 1,000 population	S	1.4	1.3	93.8
	*Share of newly registered creative sector entities in the number of all newly registered entities	%	S	7.2	1.3	17.8
	*Revenues to the city budget in the section of culture and national heritage protection	PLN per capita	S	25.6	33.0	129.1

DOI: 10.34659/eis.2023.86.3.643

Areas of "productive city"	Diagnostic variable	Unit	Character	Mean	SD	CV
Environmental and resource productivity, economic and environmental assets, environmental quality of life	*Share of areas of orchards, plantations and allotments in the city area	%	S	3.7	1.6	44.5
	*Markets or places on streets and squares for seasonal and permanent sales	per 10,000 population	S	3.7	13.0	351.8
	*Share of the area at risk from drought	%	D	18.1	12.0	66.2
	*Share of agricultural land in the area of the city	%	S	36.0	13.9	38.7
	*Share of degraded/industrialized areas of the city area	%	D	6.1	3.4	55.8
Municipal economy, transport and mobility	*Selectively collected waste in total waste	%	S	23.3	8.2	35.3
	*Share of uncultivated landfill area in total area	%	D	0.4	1.0	261.8
	*Municipal and county roads with hard surfaces	per 100 square kilometers	S	282.6	85.2	30.2
Sustainable production and consumption	Consumption of water in households	cubic meters per capita	D	33.7	4.4	13.2
	*Consumption of electricity in households	kilowatt-hours per capita	D	735.9	106.1	14.4
	*Share of number of organizations registered under the Eco-Management and Audit Scheme (EMAS) in the city	% of all in EMAS cites	S	1.5	2.7	176.2

Note: SD – standard deviation; module of CV – coefficient of variation, expressed as the share of the standard deviation in the mean; asterisk symbol (*) – measures that met the statistical criteria for the aggregate measure; stimulant: higher values determine a higher level of the phenomenon under study; destimulant: shows the opposite effect to stimulants (Młodak, 2006).

Source: authors' work based on CSO (2023); GUGiK (2023); MHRP (2023); MFRP (2023); ADMS (2023); GDEP (2023).

The selection of indicators for evaluating "productive cities" was based on a comprehensive approach that considered previous studies (Table 2), as well as the current main directions of urban development outlined in strategic documents and international policies (Figures 1 and 2). Moreover, the availability, completeness, and continuity of data in public statistics were vital, as they allowed us to observe the phenomena in the analysed period. Finally, the characteristics met statistical and formal criteria, thereby ensuring that the variables were of adequate informational value (Kusideł &

DOI: 10.34659/eis.2023.86.3.643

Antczak, 2014). The final set of indicators was characterised by significant spatial variation and low correlation.

The employed method in subsequent stages included:

1. Selecting and obtaining the diagnostic variables (Table 2) X_j (j = 1, 2, ..., m) for each city O_i(i= 1, 2, ..., n) in each studied period in the form of a two-dimensional matrix (1):

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

2. Conducting preliminary variability and correlation analysis to exclude factors due to their strong association with each other and low degree of variability. Pearson's coefficient was adopted to measure the strength of the association. The Student's t-test was used to examine the significance of the correlation (Senthilnathan, 2019). Variability was expressed by the CV, which is generally more than 10% (Pélabon et al., 2020).
3. Normalising the variables to maintain comparability.
   For the destimulants (2):

$$z_{ijt} = \frac{\max\{x_{ijt}\} - x_{ijt}}{\max\{x_{ijt}\} - \min\{x_{ijt}\}} \; (i = 1,2,\ldots,n);\; (j = 1,2,\ldots,m);\; (t = 1,2,\ldots,l)\; z_{ijt} \in [0,1], \tag{2}$$

and for stimulants (3):

$$z_{ijt} = \frac{x_{ijt} - \min\{x_{ijt}\}}{\max\{x_{ijt}\} - \min\{x_{ijt}\}} \; (\mathrm{i} = 1,2,\ldots,\mathrm{n});\; (\mathrm{j} = 1,2,\ldots,\mathrm{m});\; (\mathrm{t} = 1,2,\ldots,\mathrm{l})\; z_{ijt} \in [0,1], \tag{3}$$

where:
z_{ijt} – the normalised value of the jth variable for the ith city and tth period,
x_{ijt} – the value of the jth variable for the ith city and the tth period,
maxx_{ijt} – the maximum value of the jth variable for all ith cites and all tth periods,
minx_{ijt} – minimum value of the jth variable for all ith cities and all tth periods.

In the dynamic approach, the maximum and minimum values for all objects and all-time units are selected (Fura et al., 2020). The values of the normalised variables go beyond the interval [0,1].

4. Calculating the dynamic composite measure (CM_{it}) as an arithmetical mean of normalised (2)–(3) variable values (4):

$$\mathrm{CM}_{it} = \frac{1}{m}\sum_{j=1}^{m} z_{ijt} \quad . \; (i = 1, \ldots, n); (j = 1, \ldots, m); (t = 1, \ldots, l) \tag{4}$$

DOI: 10.34659/eis.2023.86.3.643

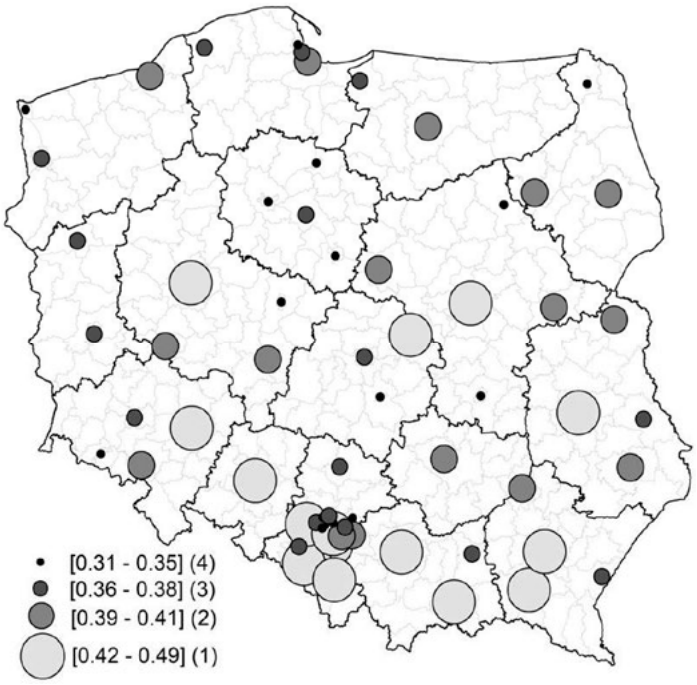
The dynamic CM obtained through formula (4) assumes values in the interval [0,1]. This method makes it possible to rank the cities with the best (close to 1) and the worst (close to 0) levels of productivity (Karmowska, 2019).

5. The classification of cities. It was carried out on the basis of quartiles, i.e., the fourth class boundaries were determined by the minimum and the first quartile, the third were determined by the first quartile and the median, the second were determined by the median and the third quartile, and finally the first were determined by the third quartile and the maximum (Kukuła & Bogocz, 2014).
6. Tabulating and visualizing the results. It plays a key role in interpreting the results of variability and understanding the development of productive cities from a spatiotemporal perspective.

Results of the research

Between 2010 and 2020, Rzeszów, Krosno, Wrocław, and Warsaw, among others, were characterised by the highest CM values. In contrast, Konin, Bytom, Ostrołęka, Suwałki, and Ruda Śląska had the lowest (Figure 3). Based on the values of selected diagnostic variables (Table 2), Rzeszów, which is a progressive city in multiple dimensions, was ahead of other cities, especially in terms of having the most higher education graduates (712.6 per 1,000 population vs. an average of 181.6), the highest rate of new residential buildings (3 per 1,000 population vs. an average of 1), an above-average rate of selectively collected waste (28.1% vs. 23.3% respectively), and no uncultivated landfill area. Warsaw, named by the Polish experts of Arcadis (2021) the most sustainable city, had the lowest unemployment rate (2.5% vs. an average of 7.6%), the highest share of R&D centers (21.4% vs. 1.5%), a high share of EMAS (8.2% vs. 1.5%), the greatest investment property expenditures (101 PLN per capita vs. 74 PLN) and share of newly registered creative sector entities (10.3% vs. 7.2%). Wrocław had one of the highest shares of orchards, plantations, and allotments areas (6.6% vs. a city average of 3.7%), an above-average number of higher education graduates (467 per 10,000 population vs. an average of 182), the most markets or places on streets and squares for seasonal and permanent sales (5.7 per 10,000 population compared to an average of 3.7) and a high share of R&D centers. Krosno had the highest revenues in the section of culture and national heritage protection (68 PLN per capita vs. an average of 25.6 PLN) and investment property expenditures (200.2 PLN per capita vs. 70.4). It also has one of the highest shares in income from corporate taxes (5.2% vs. an average of 3.1%) and an above-averages hare of investment expenditures (27.3% vs. 16.7%) (See Table 2).

DOI: 10.34659/eis.2023.86.3.643



The highest CM values for cities in different classes	
First class (1)	Fourth class (4)
Rzeszów	Świętochłowice
Krosno	Piotrków
Wrocław	Trybunalski
Warszawa	Bydgoszcz
Bielsko-Biała	Radom
Opole	Grudziądz
Lublin	Jelenia Góra
Katowice	Siemianowice
Tychy	Śląskie
Nowy Sącz	Włocławek
Skierniewice	Gdynia
Żory	Świnoujście
Poznań	Ruda Śląska
Jastrzębie-Zdrój	Suwałki
Gdańsk	Ostrołęka
Leszno	Bytom
Gliwice	Konin

Figure 3. Ranking of productive cities by the classes (2010-2020 CM average)
Source: authors' work based on data from Table 2.

Koninis a post-industrial city characterized by one of the lowest incomes from personal income taxes (35.1% vs. 42.2%), investment property expenditures (34.3 PLN per capita vs. an average of 70.4 PLN), and a lower-than-average share of funds from the EU. It also has one of the highest shares of areas at risk from drought (38.6% vs. 18.1%, respectively). In contrast, Bytom (currently on a self-reinforcing negative development path) has an unemployment rate almost twice the average (14.1%) and a similarly high share of industrialized areas in the total city area (12.3%). It also has the lowest rate of new residential buildings and one of the lowest numbers of higher education graduates (9.6 per 10,000 population vs. an average of 181.6). Suwałki and Ostrołęka have among the highest shares of areas at risk from drought and the lowest shares of areas of orchards, plantations, and allotments in the city area. Suwałki's rate of selectively collected municipal waste is less than half that of other surveyed cities. Meanwhile, Ostrołęka had one of the lowest investment property expenditures compared to the average (10.5 PLN per capita vs. an average of 70.4 PLN) and the highest share of uncultivated landfill area (5.3% vs. 0.4%). Finally, Konin, Bytom, Suwałki, and Ostrołęka lack R&D centers and organizations registered under EMAS.

DOI: 10.34659/eis.2023.86.3.643

Between 2010 and 2022, there was an annual increase in the level of development of "productive cities" by an average of 1.0%. The data also indicate an average annual decrease in the differentiation of units (by -2.4 p.p.) and faster growth of minimum values than maximum values of the measure (yCMmax=-1.1% vs. yCMmin=0.9) (see Table 3).

Table 3. Values of selected statistics of the composite measure of "productive cities" in the analyzed years

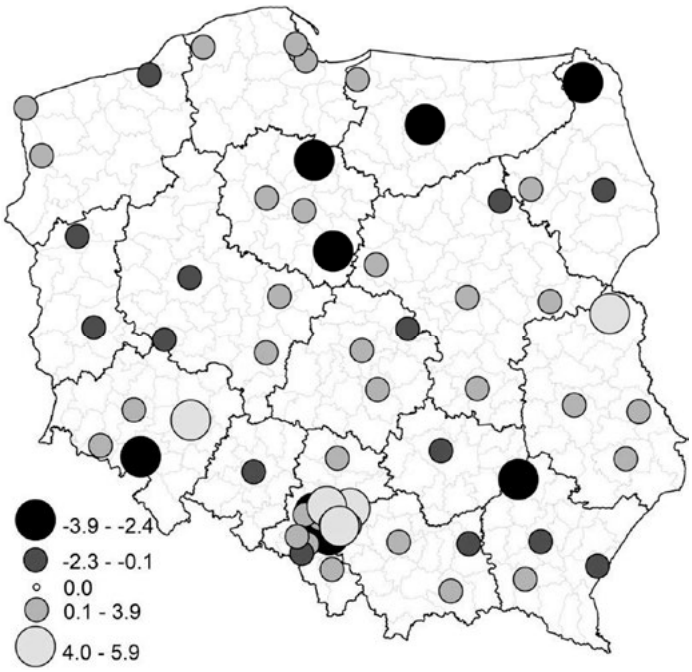
Statistics	Year				Rate of change (yCM) (2010-2020)
	2010	2015	2018	2020	
Mean	0.38	0.37	0.38	0.39	1.0%
Median	0.38	0.37	0.37	0.39	0.8%
Maximum (max)	0.49	0.49	0.49	0.47	-1.1%
Minimum (min)	0.31	0.29	0.31	0.31	0.9%
CV in %	9.9	10.0	9.4	9.3	-2.4p.p.

Note: p.p. – percentage points. The rate of change (yCM) was determined from the exponential trend function yCM = b*m^x, where the dependent yCM value is a function of independent x values. The m values are the base corresponding to the exponential values of x, and the b value is a constant. The exponent of this function (x) is approximately (when multiplied by 100%) equal to the average rate of change of the CM (Kusideł & Antczak, 2014).

As Figure 4 shows, the fastest growth in "productive city" development took place in Biała Podlaska, Wrocław, Piekary, and Siemnianowice Śląskie (the average growth was more than 5% per year). In contrast, the fastest decline, from about 6% to more than 3% per year, was recorded in Grudziądz, Wałbrzych, Tychy and Suwałki (the average decline was more than 3% per year). Wrocław, Piekary and Siemianowice Śląskie saw the fastest average annual increase in new residential buildings, while Biala Podlaska saw a significant growth in selectively collected waste rate. Along with Siemianowice Śląskie, it also recorded the highest decline in the share of expenditures on debt maintenance. Moreover, the Biała Podlaska and Siemianowice Śląśkie also have one of the highest increases in revenues to the city budget in the section of culture and national heritage protection. Wroclaw, on the other hand, recorded the fastest rate of growth in the share of EU funds and the number of R&D centers. Meanwhile, Grudziądz noted the fastest annual average increase in the number of sickness absence days per employee. Wałbrzych and Suwałki saw a significant decline of shares in income from corporate income taxes and the fastest rise in the share of degraded (industrialised) areas. Włabrzych recorded the slowest growth rate of new residential build-

DOI: 10.34659/eis.2023.86.3.643

ings. In Grudziądz and Tychy, the highest annual decrease was also observed in the share of EU funds. Additionally, the number of EMAS declined the fastest in Tychy compared to all the surveyed urban units.



The highest rate of change in CM	
Negative	**Positive**
Grudziądz	Biała Podlaska
Wałbrzych	Wrocław
Tychy	Piekary Śląskie
Suwałki	Siemianowice Śląskie
Olsztyn	Dąbrowa Górnicza
Włocławek	Mysłowice
Zabrze	Żory
Tarnobrzeg	Ruda Śląska
Gorzów Wielkopolski	Radom
Przemyśl	Bielsko-Biała

Figure 4. The average rate of change in CM of "productive cities" development [in %]

Evaluation and limitations from the research

The literature review made it possible to create a broad target list of data and indicators to describe, diagnose, and monitor the level of "productive city" development. However, verifying it based on available databases and source materials proved extremely difficult. The research revealed:

- a lack of public statistics in some areas (e.g., the number of entities connected to the fiber optic network – only paid data; public administration units that use Business Intelligence tools – data only for selected cities; waste recycling – no public data for cities; use of previously stored sewage sludge – incomplete urban bioeconomy data,
- incomplete data – gaps and deficiencies (unreliable reporting),
- a lack of continuity and regularity in data collection and sharing,
- standard (traditional) data based on the "old" view of development,
- data and indicators referred/aggregated to the voivodeship level, while the local (city, commune) perspective is key.

DOI: 10.34659/eis.2023.86.3.643

The research shows that the framework for monitoring the "productive city" is insufficient in the member states. The EU Urban Agenda (European Union, 2016) has better monitoring. The EU has identified the need to initiate a program on developing and implementing indicators at the local level (European Union, 2019; European Commission, 2022). It is stated that the conceptual framework should include overarching indicators that cover different themes and thematic indicators that can be used to make international comparisons. These sets should be regarded as mandatory for reporting. What is more, the monitoring system should introduce city-specific indicators (bottom-up) developed by particular cities to monitor their strategies. It is vital to improve statistics and develop experimental statistics that will consider new circumstances/conditions for development (energy crisis).

Conclusions

The current climate change challenges require appropriate information and comparable data to support policy analysis and track progress. Cities need to incorporate into their policies the category of productivity, which can be understood in many dimensions, to capture the need for the efficient use of economic, social, and natural capital.

Developing an optimal set of indicators is a continuous and "learning" process. Both academics and practitioners are looking for indicators that, on the one hand, will be objective and universal and, on the other hand, reflect the uniqueness and sensitivity of the conditions of an examined unit. Considering the complexity of variables while evaluating how they adjust to the dynamically changing development of modern cities remains a huge challenge. From the EU Green Deal perspective, in monitoring productivity, we need to combine conventional economic activity with environmental efficiency. It is an interdisciplinary approach that should be commonly introduced. The challenge is to increase productivity and reduce costs while easing environmental pressure. Productive cities must introduce innovations that are both efficient technologies and nature-based solutions. Such a strategy will allow them to be competitive and better prepared for the threats of climate change.

The analysis indicated the moderate progress of Polish cities in terms of their productivity, increasing by approximately 2.1% over the decade 2010-2020. More than 75% of the surveyed cities (43 out of 66 urban areas) reported an annual increase in CM values. The fastest growth in "productive city" development took place in Biała Podlaska, Wrocław, Piekary, and Siemianowice Śląskie. The fastest declines were recorded in Grudziądz, Wałbrzych, Tychy and Suwałki. However, we can also observe decreasing dif-

DOI: 10.34659/eis.2023.86.3.643

ferentiation of the surveyed units in terms of the composite measure. The outcomes indicate the possibility of convergence, i.e., cities with lower levels of productivity develop faster than those with higher levels. The faster increase in the minimum values of the composite measure compared to a decrease in the maximum allows us to conclude that the level of development is equalising and less economically stable areas are catching up with the more productive ones.

Awareness of the idea of a "productive city" and the need to monitor it should be a nexus to fill gaps in cities' reporting of data. Along with overarching, thematic, and specific indicators, cities should define indicators that represent the degree of unique factors or events that can lead to urban sustainability. Polish cities display productivity enhancement activities, and data related to productivity, at the city level, enables better planning and decision-making and drives more ambitious action. However, institutional conditions and lack of access – relatively limited or commercial (paid) access – to public data have partly blocked and determined the temporal and spatial scope of the study. Due to the growing importance of the issue of productive cities, it is important to promote the openness of data and the scope of its monitoring. This is because access to reliable databases is crucial for public administration, including local government in particular. The key is therefore to include in the public and available databases those indicators that make it possible to evaluate the development processes, taking into account the directions of the "productive city". Obtaining the aforementioned information and completing the set of variables is one of the directions for possible further research.

The final stage of the research is a paper planned to interlink all the three perspectives of the green-productive and just city. There are limitations in the research, particularly around different contexts and conditions of local development. The difficulty is certainly the dynamic process of change in cities and the need to constantly take into account new challenges in the new designed set of measures.

The contribution of the authors

Conception, E.A., A.R. and A.S.; literature review, E.A., A.R. and A.S.; acquisition of data, E.A., A.R. and A.S.; analysis and interpretation of data, E.A., A.R. and A.S.

DOI: 10.34659/eis.2023.86.3.643

References

Agricultural Drought Monitoring System, ADMS. (2023, November 15). *The threat of drought – NUTS-5 (LAU2) level*. https://susza.iung.pulawy.pl/en/wykazy/2021, 3263011/

Al-Obadi, M., Ayad, H., Pokharel, S., & Ayari, M. A. (2022). Perspectives on food waste management: Prevention and social innovations. Sustainable Production and Consumption, 31, 190-208. https://doi.org/10.1016/j.spc.2022.02.012

Arcadis. (2021, July 01). *Ranking Polskich Miast Zrównoważonych.* https://www.arcadis.com/pl-pl/aktualnosci/europe/poland/2021/7/ranking-polskich-miast (in Polish).

Bohn, K., & Viljoen, A. (2017). Food and urban design: Urban agriculture as Second Nature? In K. Lebesco & P. Naccarato (Eds.), *The Bloomsbury Handbook of Food and Popular Culture* (pp. 169-183). Bloomsbury.

Brilhante, O., & Klaas, J. (2018). Green City Concept and a Method to Measure Green City Performance over Time Applied to Fifty Cities Globally: Influence of GDP, Population Size and Energy Efficiency. Sustainability, 10(6), 2031. https://doi.org/10.3390/su10062031

Burchard-Dziubińska, M., Drzazga, D., & Rzeńca, A. (2014). *Zrównoważony rozwój-naturalny wybór.* Łódź: Wydawnictwo Uniwersytetu Łódzkiego. (in Polish).

Central Statistical Office, CSO. (2023, November 15). *Local Data Bank Center*. https://bdl.stat.gov.pl/bdl/start.

Czyż, T. (2017). Methodological problems in the design of indicators in social sciences with the focus on socio-economic geography. Studia Regionalia, 50, 49-61.

Daly, H. E., & Cobb, J. (1989). *For the Common Good. Redirecting the Economy Toward Community, the Environment, and a Sustainable Future*. Boston: Beacon Press.

European Commission, Joint Research Centre, Coll Aliaga, E., Irving, A., & Pacheco Oliveira, M. (2021). *Building urban datasets for the SDGs: Six European cities monitoring the 2030 Agenda.* Luxembourg: Publications Office of the European Union. https://data.europa.eu/doi/10.2760/510439

European Commission. (1996, March 1). *European Sustainable Cities Report.* https://edz.bib.uni-mannheim.de/www-edz/pdf/sonstige/sustcities.pdf

European Commission. (2018, May 5). *Science for Environment Policy. Indicators for sustainable cities.* https://sbe.org.gr/newsletters/eflashnews/2018_05/Sustainable-cities.pdf

European Commission. (2020, March 11). Communication from The Commission to The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions, A new Circular Economy Action Plan For a cleaner and more competitive Europe, Pub. L. No. 52020DC0098. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A98%3AFIN

European Commission. (2022, November 11). *Transition Pathway for proximity and social economy ecosystem.* https://coopseurope.coop/wp-content/uploads/2022/11/Transition-Pathway-Proximity-and-Social-Economy.pdf

European Investment Bank. (2018, December 20). *The 15 circular steps for cities*. https://www.eib.org/attachments/thematic/circular_economy_15_steps_for_cities_en.pdf

DOI: 10.34659/eis.2023.86.3.643

European Union. (2016, May 30). *Urban Agenda for the EU, Pact of Amsterdam.* https://ec.europa.eu/regional_policy/sources/policy/themes/urban-development/agenda/pact-of-amsterdam.pdf

European Union. (2019, May 03). *Indicators for circular economy (CE) transition in cities – Issues and mapping paper.* https://ec.europa.eu/futurium/en/system/files/ged/urban_agenda_partnership_on_circular_economy_-_indicators_for_ce_transition_-_issupaper_0.pdf

European Union. (2020, November 30). *The New Leipzig Charter. The transformative power of cities for the common good.* https://futurium.ec.europa.eu/sites/default/files/2021-03/new_leipzig_charter_en.pdf

Fainstein, S. S. (2010). *The Just City*. Cornell University Press.

Fura, B., Stec, M., & Miś, T. (2020). Statistical Evaluation of the Level of Development of Circular Economy in European Union Member Countries. Energies, 13(23), 6401. https://doi.org/10.3390/en13236401

Gaffron, P., Huismans, G., & Skala, F. (2005). *Ecocity. Book I. A better place to live.* http://real.mtak.hu/13865/1/Ecocity%20I.pdf

General Directorate for Environmental Protection, GDEP. (2023, November 15). *Benefits of registration in EMAS*. https://www.gov.pl/web/gdos/benefits-of-registration-in-emas

Gierusz-Matkowska, A., Wojewnik-Filipkowska, A., & Krauze-Maślankowska, P. (2023). Ranking Cities According to Their Fundamental Power: A Comparison Among Results of Different Methods of Linear Ordering. Social Indicators Research, 170, 731-763. https://doi.org/10.1007/s11205-023-03216-4

Glaeser, E. (2011). Cities, Productivity, and Quality of Life. Science, 333, 592-594. https://doi.org/10.1126/science.1209264

GRI. (2023, June 19). *The global leader for impact reporting.* https://www.globalreporting.org

Grimm, N. B., Faeth, S. H., Golubniewski, N. E, Redman, Ch. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global Change and the Ecology of Cities. Science, 319(5864), 756-760. https://doi.org/10.1126/science.1150195

Gwosdz, K., Micek, G., Sobala-Gwosdz, A., & Świgost, A. (2019). Przegląd problematyki wskaźników dotyczących kondycji ekonomicznej miast w Polsce. Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego, 33(2), 59-80. https://doi.org/10.24917/20801653.332.5 (in Polish).

Hammer, S., Kamal-Chaoui, L., Robert, A., & Plouin, M. (2011). *Cities and Green Growth: A Conceptual Framework*. https://www.oecd.org/cfe/regionaldevelopment/49330120.pdf

Hasan, N. A. (2020). The spatial organization strategies of productive cities. IOP Conference Series Materials Science and Engineering, 881(1), 012021. https://www.researchgate.net/publication/343586729

Head Office of Geodesy and Cartography, GUGiK. (2023, November 15). *Data of the Central Geodetic and Cartographic Resource*. https://www.geoportal.gov.pl/

ICLEI. (2021, October 1). *Circular city actions framework. Bringing the circular economy to every city.* https://circulars.iclei.org/wp-content/uploads/2021/10/Circular-City-Action-Framework_V2.pdf

Kahn, M. (2006). *Green cities: Urban growth and the environment*. Washington, D.C: Brookings Institution Press.

DOI: 10.34659/eis.2023.86.3.643

Karmowska, G. (2019). Economic development of European Union countries and implementation of the climate and energy package. Economics and Environment, 69(2), 18.

Kukuła, K., & Bogocz, D. (2014). Zero Unitarization Method and Its Application in Ranking Research in Agriculture. Economic and Regional Studies, 7(3), 5-13.

Kusideł, E., & Antczak, E. (2014). Wzorzec Rozwoju Mazowsza – etap II. Trendy Rozwojowe Mazowsza, 13, 1-72. (in Polish).

Lavuri, R., Jusuf, E., & Gunardi, A. (2021). Green Sustainability: Factors Fostering and Behavioural Difference between Millennial and Gen Z: Mediating Role of Green Purchase Intention. Ekonomia i Środowisko, 76(1), 8-38. https://www.ekonomia-isrodowisko.pl/journal/article/view/357

Lucertini, G., & Musco, F. (2020). Circular Urban Metabolism Framework. One Earth, 2(2), 138-142. https://doi.org/10.1016/j.oneear.2020.02.004

Martin, R., & Simmie, J. (2008, October 3). The theoretical bases of urban competitiveness: does proximity matter? Revue d'Économie Régionale & Urbaine, 3, 333-351. https://www.cairn.info/revue-d-economie-regionale-et-urbaine-2008-3-page-333.htm

Ministerstwo Funduszy i Polityki Regionalnej Departament Strategii. (2021). *Nowa Karta Lipska i Agenda Terytorialna UE 2030 przyjęte przez ministrów krajów wspólnoty europejskiej.* https://www.gov.pl/web/fundusze-regiony/nowa-karta-lipska-i-agenda-terytorialna-ue-2030-przyjete-przez-ministrow-krajow-wspolnoty-europejskiej (in Polish).

Ministerstwo Funduszy i Polityki Regionalnej. (2022, June 14). *Krajowa polityka miejska.* https://www.gov.pl/attachment/01114756-5e93-4607-a616-44d59a24e9d5 (in Polish).

Ministry of Health Republic of Poland, MHRP. (2023, November 15). *Maps of Health Needs*. https://basiw.mz.gov.pl/en/maps-of-health-needs/

Ministry of Finance Republic of Poland, MFRP. (2023, November 15). *State budget*. https://www.gov.pl/web/finance/state-budget

Młodak, A. (2006). *Analiza taksonomiczna w statystyce regionalnej*. Warszawa: Difin. (in Polish).

Nicholls, E., Ely, A., Birkin, L., Basu, P., & Goulson, D. (2020). The contribution of small-scale food production in urban areas to the sustainable development goals: a review and case study. Sustainability Science, 15, 1585-1599. https://doi.org/10.1007/s11625-020-00792-z

OECD. (2008). *Handbook on Constructing Composite Indicators: Methodology and User Guide*. Paris: OECD Publishing.

OECD. (2011, May 25). *Towards Green Growth: Monitoring Progress. OECD Indicators.* https://www.oecd.org/greengrowth/48224574.pdf

OECD. (2020, January 21). *The OECD Inventory of Circular Economy indicators.* https://www.oecd.org/cfe/cities/InventoryCircularEconomyIndicators.pdf

Paiho, S., Wessberg, N., Pippuri-Mäkeläinen, J., Mäki, E., Sokka, L., Parviainen, T., Nikinmaa, M., Siikavirta, H., Paavola, M., Antikainen, M., Heikkilä, J., Hajduk, P., & Laurikko, J. (2021). Creating a Circular City: An analysis of potential transportation, energy and food solutions in a case district. Sustainable Cities and Society, 64, 102529. https://doi.org/10.1016/j.scs.2020.102529

Papageorgiou, A., Henrysson, M., Nuur, C., Sinha, R., Sundberg, C., & Vanhuyse, F. (2021). Mapping and assessing indicator-based frameworks for monitoring cir-

cular economy development at the city-level. Sustainable Cities and Society, 75, 103378. https://doi.org/10.1016/j.scs.2021.103378

Pélabon, C., Hilde, C. H., Einum, S., & Gamelon, M. (2020). On the use of the coefficient of variation to quantify and compare trait variation. Evolution Letters, 4(3), 180-188. https://doi.org/10.1002/evl3.171

Rada Ministrów. (2015). *Krajowa Polityka Miejska 2023.* http://gamma.infor.pl/zalaczniki/mpo/2015/216/mpo.2015.216.1235.0001.pdf (in Polish).

Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088, Pub. L. No. 32020R0852, 198 OJ L (2020). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32020R0852

Rosemann, M., Becker, J., & Chasin, F. (2021). City 5.0. Business & Information Systems Engineering, 63, 71-73.

Saari, U. A., Damberg, S., Frömbling, L., & Ringle, Ch. M. (2017). Sustainable Consumption Behavior of Europeans: The Influence of Environmental Knowledge and Risk Perception on Environmental Concern and Behavioral Intention. Ecological Economic, 189, 1-14.

Schuring, S. (2018, November 21). *Regenerative cities — an urban concept whose time has come!* https://medium.com/thebeammagazine/regenerative-cities-an-urban-concept-whose-time-has-come-e08b5271ccf8

Senthilnathan, S. (2019). Usefulness of Correlation Analysis. SSRN Electronic Journal, 1-9. https://doi.org/10.2139/ssrn.3416918

Siemens. (2009, May 5). *The European Green City Index.* https://assets.new.siemens.com/siemens/assets/api/uuid:fddc99e7-5907-49aa-92c4-610c0801659e/european-green-city-index.pdf

Siragusa, A., Proietti, P., Bertozzi, C., Coll Aliaga, E., Foracchia, S., Irving, A., Monni, S., Pacheco Oliveira, M., & Sisto, R. (2021). *Building urban datasets for the SDGs. Six European cities monitoring the 2030 Agenda.* https://doi.org/10.2760/510439

Śleszyński, P. (2016). *Delimitacja miast średnich tracących funkcje społeczno-gospodarcze*. Warszawa: Polska Akademia Nauk, Instytut Geografii i Przestrzennego Zagospodarowania im. S. Leszczyckiego. (in Polish).

Śleszyński, P. (2017). Wyznaczenie i typologia miast średnich tracących funkcje społeczno-gospodarcze. Przegląd Geograficzny, 89(4), 565-593. (in Polish).

Śleszyński, P. (2018). *Polska średnich miast. Założenia i koncepcja deglomeracji w Polsce*. Warszawa: Klub Jagielloński. (in Polish).

United Nations. (2015, September 1). *The Sustainable Development Goals.* https://www.undp.org/sustainable-development-goals

Venkatesh, G. (2014). A critique of the European Green City Index. Journal of Environmental Planning and Management, 57(3), 317-328. https://doi.org/10.1080/09640568.2012.741520

Zinkernagel, R., Evans, J., & Neij, L. (2018). Applying the SDGs to Cities: Business as Usual or a New Dawn? Sustainability, 10(9), 3201. https://doi.org/10.3390/su10093201